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Lectures and Readings

Lecture 1: The political economy of early modern conquest: an economic model

Philip T. Hoffman, "Prices, the military revolution, and western Europe's comparative advantage in violence," *Economic History Review* 64, S1 (2011): 39-59

Philip T. Hoffman, "Why Was It Europeans Who Conquered the World," *Journal of Economic History* 72, 3 (2012): 601-633.

Lecture 2: The political economy of early modern conquest: can history explain what is outside the model?

Reading: same as for lecture 1.

Symposium Presentation: War, colonialism, and the industrial revolution

Lecture 3: The development of mortgage markets: the examples of France and the United States.

Philip T. Hoffman, Gilles Postel-Vinay, and Jean-Laurent Rosenthal, *Priceless Markets: The Political Economy of Credit in Paris, 1660-1870* (Chicago: University of Chicago Press, 2000), pages 1-30, 96-176

Kenneth A. Snowden, "Mortgage Rates and American Capital Market Development in the Late Nineteenth Century," *The Journal of Economic History* 47, 3 (1987): 671-691.

Why Was It Europeans Who Conquered the World?

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By the 1700s Europeans dominated the gunpowder technology, which was surprising, because it had originated in China and been used with expertise throughout Eurasia. To account for their dominance, historians have invoked competition, but it cannot explain why they pushed this technology further than anyone else. The answer lies with a simple tournament model of military competition that allows for learning by doing. Political incentives and military conditions then explain why the rest of Eurasia fell behind Europeans in developing the gunpowder technology. The consequences were huge, from colonialism to the slave trade and even the Industrial Revolution.

In the “great divergence” debate over when and why Europe forged ahead of the rest of Eurasia, one topic has been overlooked—namely, violence, or at least violence with gunpowder weapons. Here Europe possessed an undeniable comparative and absolute advantage, early on: European states were simply better at making and using artillery, firearms, fortifications, and armed ships than powers in other parts of the world and they had this advantage long before 1800. They used this gunpowder technology to wage war at home and to establish outposts abroad. The result was that by 1800 Europeans had conquered some 35 percent of the globe and were preying upon lucrative trade routes as far away as Asia. They took control of even more territory in the nineteenth century.¹ Other forces certainly worked in their favor as well, including the diseases that they introduced into vulnerable populations, and there were limits to what firearms could do.² Nonetheless, the gunpowder technology clearly played a large role in European conquest.

The Journal of Economic History, Vol. 72, No. 3 (September 2012). © The Economic History Association. All rights reserved. doi: 10.1017/S0022050712000319.

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Research for this article was supported by NSF Grants 0433358 and SES-0649062 as part of the Global Prices and Incomes Project. Numerous people have helped me by generously offering advice, criticisms, and expertise: Mary Elizabeth Berry, Dan Bogart, Philip C. Brown, John C. Brown, Warren Brown, Margaret Chen, Greg Clark, Stan Engerman, Claudia Goldin, Dave Grether, Dan Klerman, James Kung, Peter Lindert, Bozhong Li, Naomi Lamoreaux, James Lee, Guanglin Liu, Debin Ma, R. Preston McAfee, Kate Norberg, Patrick O’Brien, Sevket Pamuk, Peter Perdue, Gilles Postel-Vinay, Gary Richardson, Jean-Laurent Rosenthal, Stergios Skaperdas, Peter Temin, Harriet Zurndorfer, the late Ken Sokoloff, three anonymous referees for this JOURNAL, and its editor, Price Fishback.

¹ Headrick, *Tools and Power*; and Parker, *Military Revolution*, p. 5.

² Black, *War*.

Why then was it the Europeans who came to dominate the technology, and not the Japanese, the Ottomans, or the Indians, who all used it with expertise? Or why wasn't it the Chinese, who had invented it?

This question has attracted a number of gifted military historians, but the closest they come to a deeper explanation is the claim that military competition in Europe gave the Europeans an edge. The argument has been formulated most cogently by Paul Kennedy, who points to Europe's competitive markets and persistent military rivalries. In his view, while military rivalry created an arms race, competitive markets fostered military innovation and kept one country from establishing an empire.³

But Kennedy's story of competition is not the final answer, for it leaves far too much unexplained. To begin, 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.⁴

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

The answer lies with the peculiar form of competition in which European rulers were engaged. It was a winner-take-all tournament that spurred rulers to spend enormous sums on using the gunpowder technology in the continent's incessant wars. In the process, the technology was advanced via learning by doing. Elsewhere, however, political and military conditions were not conducive to improving the gunpowder technology. That is why the Europeans pushed the technology further than anyone else and why the rest of the world had trouble catching up.

Understanding why requires a look at the political, military, and fiscal incentives rulers faced, both in Europe and in other parts of Eurasia. We will start with Europe before 1800 and use it to motivate a simple tournament model, which will then be applied to the rest of the world. The model's predictions are borne out by quantitative and qualitative evidence; other explanations—including the argument about competition—fail such a test. The model thus gives us a deeper understanding of why Europeans came to dominate a technology that made world conquest possible.

³ Kennedy, *Rise*, pp. 16–24.

⁴ Hoffman, *Growth*.

TABLE 1
FREQUENCY OF WAR IN EUROPE

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

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

Source: Wright, *Study*, p. 1, tables 29, 45, 46; Levy, *War*, leads to similar results.

RULERS AND THEIR INCENTIVES IN EUROPE BEFORE 1800

The states that coalesced in Europe in the waning days of the Middle Ages by and large had a single purpose, at least if we judge by the reasons why they levied taxes and borrowed money. That purpose was clearly warfare. In the major powers, some 40 to 80 percent of the budget went directly to the military, to defray the costs of armies and navies that fought almost without interruption (Table 1). The fraction of the budget devoted to war climbed even higher—to 95 percent in France during the Thirty Years War—if we add sums spent subsidizing allies or paying of the debts of past wars.⁵

In early modern Europe, decisions about war typically lay in the hands of a ruler such as a king or a prince. He would of course be advised by councilors and influenced by elites, and an influential minister might sometimes be dictating most of the decisions. But the assumption that a king or prince made the decisions about war is not far from historical reality. Even in eighteenth-century Britain, where Parliament and the cabinet decided whether to commence hostilities, the choices about the conduct of the war once it had begun were ultimately up to the king.⁶

What then made European kings take up arms? That question has to be answered if we are to understand what the tournament was. In Europe's major powers, the rulers often won control of warfare in the process of assembling their states in the late Middle Ages or the sixteenth century. In modern terms, they provided the public good of defense in return for taxes. That public good was precious, as anyone

⁵ Hoffman and Rosenthal, "Political Economy"; and Tilly, *Coercion*.

⁶ Harding, *Amphibious*, pp. 28–30; Lynn, "International"; Rodger, *Command*, p. 242; Mallett *Mercenaries*, p. 88; and Pettegree, "Elizabethan."

who suffered through the horrors of the One Hundred Years War in France or the Thirty Years War in central Europe could testify. But the rulers of early modern Europe likely provided far more defense than their average subject would have wanted. They went on the offensive too, and not just to protect their kingdoms.

The reasons were not hard to understand. The kings and princes had been raised to fight one another, with toy soldiers, pikes, and firearms as children and actual training in their youth. Advisers like Machiavelli might tell them that princes “ought to have no object, thought, or profession but war.” Their own fathers would teach them that war was a path to glory, a means to “distinguish [kings] . . . and to fulfill the great expectations . . . inspired in the public,” in the words of Louis XIV’s instructions for his son. For them, fighting had gone beyond the needs of defense and become, in the words of Galileo, a “royal sport.”⁷

Glory did recede as a motive for war in the eighteenth century, when the major powers might fight simply to preserve their reputation, to gain commercial advantage, or to snatch territory from weaker neighbors. But war was still “what . . . rulers did.” It continued to appeal to them, just as it long had attracted much of the European aristocracy.⁸

For the major monarchs of early modern Europe, victory was thus a source of glory or a way to enhance their reputation. Grabbing territory from small neighbors did augment their resources and help strategically, but the thirst for glory and the drive to bolster their standing could push them to spend large sums even on small bits of terrain. Their goals may seem bizarre, but there are certainly modern analogues—the race to get a man on the moon, or, to take a nongovernmental example, college athletics. And although the kings might lose small amounts territory themselves, they faced no major downside risk to their thrones, at least in the larger states, for loss in battle in anything but a civil war never toppled a major monarch from his throne, at least in the years 1500–1790.⁹

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. The literature offers several reasons why such agreements prove unattainable, and why leaders go to war instead, despite all the

⁷ Sonnino, *Louis XIV*, p. 124; Machiavelli, *Prince*, p. 247; Hale, *War and Society*, pp. 29–32.

⁸ Lynn, “International”; and Bell, *Total War*, pp. 29–35.

⁹ Hoffman, “Politics and Economics,” Table 2. Losses in war did cost ministers their position.

devastation it causes.¹⁰ Although all of these reasons apply to early modern Europe, two of them seem to fit the continent's history like a glove.

The first was that the leaders making decisions about war—early modern Europe's kings and princes—stood to win a disproportionate share of the spoils from victory but avoided a full share of the costs. They—not their subjects—were the ones who basked in glory or who burnished their military reputations when their armies were victorious. But they bore few of the costs, which fell disproportionately on their subjects. When the leaders' incentives are that biased, it can be impossible to reach any sort of bargain to avoid war, even if the leaders trade resources to compensate one another.¹¹

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 divided up. In fact, it simply vanished if there was no fighting, making the peaceful exchange of resources potentially more expensive than fighting. The same held for reputation; it too could only be earned on the battlefield. Commercial advantage would not be easy to share either, if, as was often the case, it involved a trade monopoly. And territory posed similar problems, when it offered a strategic advantage or if sovereignty or religious differences were at stake. Then even trading other resources might not work. In negotiations to end the Great Northern War between Russia and Sweden, for example, the Tsar Peter the Great told his envoy in 1715 that he would not consider giving back Riga and Swedish Livonia 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 give him in return.¹² Religious strife could make negotiation itself impossible if it meant dealing with enemies of the faith.¹³

These obstacles to peace were not unique to early modern Europe, so they cannot be the reason why Europe came to dominate the gunpowder technology. They were at work elsewhere too, because foreign policy in other parts of Eurasia was often in the hands of kings, emperors, or warlords who could be as obsessed with glory as their European counterparts.¹⁴ But the biased incentives facing the

¹⁰ Brito and Intriligator, "Conflict"; Powell, "Guns"; Fearon, "Rationalist"; and Jackson and Morelli, "Reasons."

¹¹ Jackson and Morelli, "Political Bias."

¹² Anisimov, *Reforms*, pp. 244–45.

¹³ Mattingly, "International Diplomacy," p. 156. For the impact of past religious strife, see Fletcher and Iyigun, "Clash."

¹⁴ See, for example, Berry, *Hideyoshi*, pp. 215–16.

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.

A SIMPLE TOURNAMENT MODEL

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

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

A simple model drawn from the economic literature on conflict and tournaments provides a tractable starting point.¹⁵ 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.¹⁶

Consider two risk-neutral early modern rulers who are considering whether or not to go to war. Winning the war earns the victor a prize P , which might be glory or territory or a commercial advantage. 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.¹⁷

¹⁵ The model below is adapted from Fullerton and McAfee, "Auctioning," and Garfinkel and Skaperdas, "Economics."

¹⁶ For a review of the conflict literature, see Garfinkel and Skaperdas, "Economics." The insightful model of Jackson and Morelli, "Strategic Militarization," 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.

¹⁷ 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 $b - d$.

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.¹⁸

Resources carry an average variable cost c_i , which may be different for the two rulers; therefore, assume that $c_1 \leq c_2$. For simplicity, assume the average variable cost c_i is constant for all levels of resources z_i .¹⁹ These costs are political: they include opposition to conscription and higher taxes, and resistance by elites when tax 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

¹⁸ Garfinkel and Skaperdas, "Economics."

¹⁹ Adding constraint on the amount of resources a ruler could mobilize would not change things greatly, but it would allow the ruler of a large country to offset his opponent's lower average variable cost.

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

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

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

Inequality 2 is necessary and sufficient for there to be war in equilibrium; 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 that it will be large, which will be essential for learning by doing. To see when military spending will be big, consider the comparative statics of the equilibrium with war. In that equilibrium, ruler i will spend

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

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

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

So total military spending Z will only be large if, in addition to inequality 2, P/C is big, or, in other words, if the prize is valuable and

the rulers' political costs for mobilizing resources are low. Finally, the probability that ruler i wins the war will be

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

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

We will also suppose that the two rulers do not repeat this game. They play it once, at the outset of their reigns, and we interpret the decision to go to war as a choice not about a single conflict, but rather about being bellicose or not for their entire time on the throne. If they are bellicose (if inequality 2 holds), they will fight one another repeatedly throughout their time on the throne; if not, their reigns will be peaceful. Other rulers may play the game too, including their successors, and one might therefore worry that concern for their heirs would create a repeated game. Foreign policy, however, was dictated by short-term interests and changed enough from ruler to ruler to make this a reasonable assumption.²⁰ Furthermore, although other equilibria would in theory exist if the game were repeated, they could vanish if the prize were glory or victory over an enemy of the faith. By contrast, playing the strategy described above at each stage would always be equilibrium in the repeated game; with it there would be nothing to be gained by making the game repeated.

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

Whatever the military technology is, we will suppose that it progressed via learning by doing. Rulers fought wars and then used what worked against the enemy. That was typically how military technology advanced in the early modern world, whether it was weapons, organization, or tactics. The learning could take place during a war, or afterwards, when losers could copy winners and revise what they did. Conflicts in the late fifteenth century, for example, gave rise to lighter and more mobile artillery that could be mounted in and fired from gun carriages.

The learning extended to organization as well. French and English commanders who battled against Spain in the sixteenth century, for

²⁰ Mattingly, "International Diplomacy"; and Lynn, "International," pp. 185–86.

example, learned to appreciate the Spanish infantry's training, discipline, and small group cohesion. They urged their own countries to adopt the same organization.²¹

It is true that there were also conscious attempts to improve early modern military technology. King Philip II of Spain, for example, rewarded military inventors.²² But such efforts themselves were often triggered by successes and failures on the battlefield, such as when the French sought to make lighter and more mobile field artillery after a defeat in the Seven Years War.²³ Learning by doing dominated, until at least the eighteenth century, and while advances through research became easier after 1800, that possibility can readily be incorporated into an extended version of the model which would shed light on the nineteenth century.²⁴

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 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

²¹ La Noue, *Discours*, pp. 320–22, 352–57; Bonaparte and Favé, *Etudes*, vol. 1, pp. 65, 72; Williams, *Works*, c-civ; Hall, *Weapons*, pp. 121–22; and Parrot, *Richelieu's Army*, pp. 42–43.

²² Goodman, *Power*, pp. 123–41.

²³ Alder, *Engineering*.

²⁴ For the extended model, see Hoffman, "Why Was It Europeans," which also explains the armed peace achieved by diplomacy after 1815.

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 the first term in expression 1 above.²⁵ Winning the tournament for the best innovation will be the same as winning the war, with identical incentives, so there will be no difference, provided innovation comes from learning by doing.

So far this tournament is not repeated, but what happens if successive pairs of different rulers from the same two countries play the game over time, say once per reign? Let us assume that each pair of rulers can copy the best innovation from the previous round, which seems reasonable if they learn from experience. It also fits what happened in early modern Europe, where military innovations spread through espionage, efforts to copy what was successful, and Europe's longstanding market for weapons and military skills. 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.²⁶ It will also stop if wars are not fought. But if the technology is relatively new, then there will still be room for continued innovation, and the tournament will work like an idealized prize system that puts winning ideas into the public domain.

In that case, military innovation will be sustained and will 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 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

²⁵ Fullerton and McAfee, "Auctioning."

²⁶ Lucas, "Miracle."

($E(x)$ 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.²⁷ 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 possess the cutting edge technology. Having the winning technology, though, does not make the playing field perfectly even. Even with it, a ruler with high costs c_i will stand less of chance of winning against a low cost opponent, and if the difference in costs is big enough, he will simply avoid conflict.

Suppose now there are two technologies that are effective against different enemies. Gunpowder weapons, for example, worked well in early modern European warfare, whether on land or at sea. But until at least the seventeenth century, they were relatively ineffective against the nomads who threatened China, portions of south Asia and the Middle East, and even parts of Eastern Europe that bordered the Eurasian steppe. The mounted nomads had no cities to besiege, and they were too mobile to be targets for artillery, except when it was fired from behind the walls of fortifications. Sending the infantry chasing after them would demand too many provisions, since they could simply ride off into the steppe and live off the land. Muskets gave no advantage, because they could not easily be fired from horseback, and while pistols could, their range was limited. When fighting the nomads, the best option, at least for a long time, was simply to dispatch cavalry of mounted archers—essentially the same weapons the nomads themselves utilized. That was an ancient technology, which dated back to roughly 800 BC. In the early modern world, with fixed limits to knowledge, it could no longer be improved, although it would still be useful in war.²⁸

²⁷ Mokyr, *Gifts*.

²⁸ McNeill, *Steppe*; Esper, "Military"; Hellie, *Enserfment*; Barfield, *Fronier*; Rossabi, "Inner Asia"; Chase, *Firearms*; Gommans, *Mughal*; Agoston, *Guns*, pp. 58–59, 191; Lorge, *War*; and

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

This simple tournament model is certainly open to criticism. To begin with, the rulers are either bellicose, or they do not fight at all, either because they face no opposition or because they sit on the sidelines. The model does not generate more complex patterns of arming and fighting, as a repeated game might.²⁹ But that simple pattern does describe many rulers in the early modern world. Second, because the model pits only two rulers together at any one time, it 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 two 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.³⁰ 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.

One final problem concerns the 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 wartime. 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.

Perdue, *China*. In the nineteenth century, firearms became much more effective against nomads (Headrick, *Power*, pp. 281–84).

²⁹ See, for example, Jackson and Morelli, "Strategic Militarization."

³⁰ 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.

Tax revenues were usually the biggest component of the resources z_i that were mobilized for war; conscription and revenues from the ruler's possessions contributed much less in most cases. So if two rulers were fighting one another, the one with lower tax revenues would have a higher average variable cost c_i .³¹ And even if rulers were not fighting one another, a higher average variable cost would, from equation 3, imply lower taxes in wartime, although the lower taxes could also result from a less valuable prize or from differences in an enemy's average variable cost.

WHERE IN EARLY MODERN EURASIA 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 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 entail 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 inequality 2, is, however, only a necessary condition for sustained productivity growth with the

³¹ 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.

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 or can get the cutting-edge technology easily. 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 start with the second of the additional conditions—that the rulers use the gunpowder technology heavily. It clearly applies to Western Europe and Japan, but it fails in China, for 95 percent of the time China was engaged in war involving nomads against whom firearms long remained impotent (Table 2). In confrontations with nomads, the older technology of mounted archers was more effective. The Western Europeans, by contrast, fought no wars against nomads.

Not that China shunned the gunpowder technology altogether. It in fact gained in appeal in the early seventeenth century, when an arms race began to develop in East Asia. As the Ming dynasty, beset by rebellions and under attack by the Manchus, fell into decline, its troops fought and defended besieged cities with muskets and artillery. Their opponents replied in kind. But when the Ming dynasty collapsed and China was unified under the Qing dynasty (1644–1911), the nomads

TABLE 2
 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

Notes: 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.

Sources: Clodfelter, *Warfare*; Wright, *Study*; Stearns, *Encyclopedia*; and Kung (personal communication of the figures for China).

remained the new dynasty's major 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.³²

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 was nomadic Tatars. Firearms were of some use against them, particularly if deployed from behind fortified lines, but cavalry armed with bows and sabers was the major weapon, as in China. The Ottomans emphasized cavalry too, because much of their conflict involved frontier skirmishes and raiding. Even in the eighteenth century over 77 percent of their army was cavalry, versus under 27 percent in France. As for India, until the eighteenth century, warfare there too made heavy use of cavalry.

In addition, both the Ottomans and Russians had to funnel resources into another ancient technology with limited potential for improvement via learning by doing—galley warfare. Galleys, which dated back to classical times, were ideally suited to amphibious warfare in the light winds of the Mediterranean. They were also important for Russia 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

³² Needham, *Science*, vol. 5, part 7: pp. 398–407; Franke, "Siege"; Atwell, "T'ai-ch'ang"; Lorge *War*; and Perdue, *China*.

added without taxing the oarsmen; with little room to store water for the oarsmen, the galleys' range was severely restricted; and they were vulnerable to heavily armed sailing ships.³³

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 and Western Europe, by contrast, would be more fertile ground for innovation.

Japan, however, eventually ran afoul of inequality 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 occurred in early modern Europe, which was always torn by conflict. But that is precisely what took place in Japan when it was unified under the Tokugawa Shogunate (1603–1867).

Japan had suffered through generations of devastating civil war until three victorious warlords finally unified the fragmented country under what became the rule of the Tokugawa Shoguns. 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. Other Japanese leaders were "unenthusiastic" about the operation and "quickly" withdrew from Korea after Hideyoshi died. They seemed to realize that an invasion without adequate resources was unrealistic. They knew, in other words, that successful military competition against foreign powers entailed a large fixed cost

³³ For this and the preceding paragraph, see Agoston, *Guns*, pp. 191, 202–03; Esper, "Military"; Glete, *Navies*, pp. 114–15, 139–46, 310, 706–12; Gommans, *Mughal*; Gommans and Kolff, *Warfare*; Guilmartin, "Ideology" and *Galleons*, pp. 106–25; Hellie, *Enserfment*; Lynn, *Giant*, pp. 528–29; McNeill, *Steppe*; Parry and Yapp, *War*; Paul, "Military Revolution"; and Pryor, *Geography*.

(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.³⁴

As in Tokugawa Japan, inequality 2 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 in the eighteenth century. The Ottomans were fighting European states so they were contending for the same prize P , but their tax revenues were lower than in eighteenth-century Europe. They collected less than the median for major European powers, less than what one of their major opponents, the Austrians raised, and less than what their other chief enemy, the Russians, mobilized, at least after 1750.³⁵ It follows that the Ottomans had a higher average variable cost of mobilizing resources than in Europe and that they were unlikely to be the ones advancing the gunpowder technology. Their high cost of mobilizing resources would also imply (from expression 5) that they had little chance of defeating European rulers in the eighteenth century even if they imported the latest weapons and tactics.

As for the European rulers, their average variable costs of mobilizing resources were not only lower than in the Ottoman Empire (at least after 1700), but likely lower than in China too. The evidence comes from capita tax rates in wartime, which were much higher in Europe than in China (Table 3). Although the difference could simply reflect a less valuable prize in China or the nature of China's enemies, it is bolstered

³⁴ Smith, "Land Tax"; Reischauer, Fairbank, and Craig, *History*, vol. 1: pp. 614–15; Berry, *Hideyoshi*, pp. 207–17, "Presidential Address," and "Public Peace," pp. 207–17; Brown, *Central Authority*; Parker, *Military Revolution*, pp. 140–43; Guilmartin, *Galleons*, pp. 182–90; and Chase, *Firearms*, pp. 175–96.

³⁵ Pamuk and Karaman, "Ottoman."

TABLE 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

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 seven years out of ten in the 1770s; France fought three years of ten in the 1570s and five years of out ten in the 1770s.

Source: For France, see Hoffman and Norberg, *Fiscal Crises*, pp. 238–39; for England, see 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 website (<http://gpih.ucdavis.edu/>) and explained in Dincecco, “Fiscal Centralization,” and population figures from Wrigley and Schofield, *Population History*, table A3.1; for China, see Huang, “Ming Fiscal”; Myers and Wang, “Economic Developments”; Liu, “Nexus of Power”; and the Global Price and Income History Group website for units, silver equivalents, and prices of grain in China.

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.³⁶ Another sign that the average variable cost was low in Europe is that taxes were high relative to GDP, at least in the eighteenth century, when we can make such comparisons for France and England. By then, France was spending 5 to 10 percent of its GDP on military resources, and Great Britain even more—perhaps as much as 28 percent.³⁷ For countries that were still poor by modern standards, these figures are quite high. For comparison, at the end of the Cold War, the United States was devoting 5 percent of its GDP to the military, and the USSR perhaps 10 percent.³⁸

Like Europe, Japan before the Tokugawa Shogunate might have also faced low average variable costs. The evidence is indirect. The armies Japanese warlords raised were big relative to the population, but that would be what one would expect in wartime when *P/C* was large.³⁹

³⁶ Huang, “Military Expenditures” and “Ming Fiscal”; Sng, “Size”; and Brandt, Ma, and Rawski, “From Divergence.”

³⁷ Kennedy, *Rise*, table 2; and Mathias and O’Brien, “Taxation,” table 5. French military expenditures are assumed to range from 45 to 85 percent of tax revenues.

³⁸ Brzoska, “Military Expenditures,” table 3.

³⁹ Finer, *History*, vol. 3, p. 1088.

By the eighteenth century, the Russians too likely had a low average variable cost too and a 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, cutting the average variable costs of fielding a military force.⁴⁰ By contrast, western leaders 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 inequality 2 was satisfied, and the armies were fighting with gunpowder weapons and could easily have acquired leading innovations from one another in what was an active market for military goods and services.⁴¹ 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 for India are lacking, but it is clear that the new states that emerged on the subcontinent were struggling to gain control of resources that remained in local hands.⁴² 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.⁴³ Strife of this sort, which after the late Middle Ages was rarer in Europe, 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 shows why unending warfare and highly developed markets for military goods were not enough to obtain advances in the use of gunpowder. If they had been enough, then eighteenth-century

⁴⁰ Hellie, *Enserfment*; and Pintner, "Burden."

⁴¹ Kolff, *Naukar*; Gommans and Kolff, *Warfare*; and Gommans, *Mughal*. Although the Mughal Empire did use gunpowder weapons, it was more reliant on cavalry than the Europeans.

⁴² Barua, "Military Developments"; Stein, "State Formation"; Washbrook, "Progress"; and Alam and Subrahmanyam, "L'état moghol."

⁴³ Gommans, *Mughal*.

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 in equilibrium utilize small amounts of 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. It simply had lower average variable costs of using the military and thus was willing to mobilize more military resources in equilibrium. Not only could it draw on its own financial system to fund its military ventures, but it had also gotten control of the wealthy Ganges plain in northwestern India and won support for higher taxes there by offering elites a land market in return for higher levies. Elite cooperation and more wealth to tax would mean a lower average cost c_i and, from expression 5, a greater chance of winning wars. It would be no surprise then that the company conquered much of the subcontinent, simply by hiring away the best officers and their troops.⁴⁴

The only remaining condition is that rulers be able to acquire innovations at low cost. The barriers to doing so are clear. In the early modern world, embargos would not have been the major obstacle, since enforcement was difficult. But distance alone hampered the diffusion of the latest skills, weapons, and tactical innovations, even if mercenaries and weapons makers were willing to work for foreign masters. Technological gaps could then have increased if learning by doing persisted in one part of Eurasia and stopped in another. All rulers potentially could have advanced the gunpowder technology, but if some fell behind, catching up would have been difficult.

Some parts of the technology, after all, were just hard to transfer, which would have widened the gaps between laggards and leaders. The reason was that they 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

⁴⁴ Alavi, *Sepoys*; Gommans and Kolff, *Warfare*; Cooper, *Campaigns*; Gommans, *Mughal*; and T. Roy, "British India."

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.⁴⁵ 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 metalworking, that were scarce in the civilian economy.

Gunpowder innovations would spread most easily, we would therefore expect, when enemy powers were small and near one another and when military goods, services, and ideas could move between them with relative freedom. That was the case in India, and perhaps in Japan before the Tokugawa Shogunate as well, since the battling Japanese warlords were close enough to one another to at least copy what worked. And it was certainly the case in Western Europe.

Western Europe is also the only part of Eurasia that satisfies all the other conditions required for advancing the gunpowder technology, and it does so throughout the entire early modern period. No other Eurasian powers can meet that standard. The model would therefore predict that Western Europe would be a leader in advancing the gunpowder technology. The other Eurasian powers would have lagged behind. Could they 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.⁴⁶ 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.

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

⁴⁵ Alder, *Engineering*, pp. 39–46; and Minost, “Maritz.”

⁴⁶ Hoffman, “Prices.”

distant Asian powers, but they could now focus on fighting with gunpowder weapons and mobilize enormous resources by drafting serfs.

TESTING THE MODEL'S IMPLICATIONS IN EARLY MODERN EURASIA

We can test the model's implications for early modern Eurasia. If we begin with Western Europe, we would expect to see innovation and productivity growth in the military sector. That certainly fits the literature on the military revolution, but there is also quantitative evidence supporting this prediction too, for we can measure the rate at which the productivity of the technology was increasing. The yardsticks used underestimate the productivity growth, because they fail to capture advances in tactics or provisioning that were an integral part of the gunpowder technology. They also have trouble with naval warfare, where Western Europe's lead was perhaps greatest. The reason is that warships had a 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.⁴⁷

Yet despite all these difficulties, the evidence that military productivity was advancing in early modern Europe is clear. Suppose, for example, that we ignore the other goals navies pursued and take firepower, measure by the weight of the shot, as our sole yardstick of naval output, which we can divide by shipboard labor and capital to get an index of total factor productivity. In the English navy, this index was rising at a rate of 0.4 percent per year between 1588 and 1680, a period when firepower was gaining in importance.⁴⁸ 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 in major sectors of the economy, if it grew at all.⁴⁹

⁴⁷ Guilmartin, *Gunpowder*, pp. 253–254 and “Guns”; and Glete, *Navies*, pp. 58–61.

⁴⁸ Capital is computed from displacement, and labor from crew sizes for the English navy, using Martin and Parker, *Armada*; and Glete, *Navies*, pp. 186, 195, 205. Factor shares (0.496 for capital and 0.503 for labor) come from 1744 construction and crew labor costs in Boudriot and Berti, *Les vaisseaux*, pp. 146–52. For firepower, see Glete, *Navies*; Guilmartin, *Galleons*; and Martin and Parker, *Armada*, pp. 33–36.

⁴⁹ For examples, see Hoffman, *Growth*; and Clark, *Farewell*. One might argue 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

Nor was productivity growth limited to naval warfare. On land, the effective firing rate per French infantryman jumped by a factor of 6 or more between 1600 and 1750, as bayonets made it possible to replace pike men and matchlocks were supplanted by flintlocks with ramrods and paper cartridges. The higher firing rate translated into labor productivity growth of 1.5 percent per year, which rivals overall labor productivity growth rates in modern economies and far exceeds what one would expect for preindustrial economies.⁵⁰

Still another sign of rapid productivity growth was the falling price of weapons. The prices of cannons, muskets, and pistols tumbled relative to the price of other manufactured goods and relative to the cost of the relevant factors of production. Using the cost function dual, we can estimate productivity for weapons manufacturing in early modern France and England. 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 per year, a rapid pace even at the outset of the Industrial Revolution.⁵¹

What about the model's implications for the rest of early modern Eurasia? Although we lack similar figures for productivity, we can test the predictions against the historical record. If we begin with Japan, the model predicts improvements to the gunpowder technology until the Tokugawa Shogunate 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. With the Tokugawa, war stopped and so did that sort of innovation.⁵² And over time, tax revenues declined as fraction of agricultural output.⁵³ A cultural explanation cannot account for this sudden change, for Japanese continued to have a strong attachment to martial values. One might fear that this line of argument simply repeats the story of how the Tokugawa Shoguns banished guns. But in fact, the

in fact come from ships that were already specialized in firepower—the heavily armed flotilla that defeated the Spanish Armada.

⁵⁰ Hoffman, "Prices," Table 3.

⁵¹ Ibid. An alternative calculation yields an even higher median rate of 1.1 percent per year.

⁵² Parker, *Military Revolution*, pp. 18–19, 140–143; Chase, *Firearms*, pp. 175–196; and Berry "Presidential Address."

⁵³ Smith, "Land Tax."

shoguns did not ban firearms. Although they disarmed the population, they kept their own guns and required them for lords too.⁵⁴

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 would 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. In China, officials recognized that European weapons were superior, and they sought designs and expertise from the Portuguese or the Jesuits in both the Ming and the Qing dynasties.⁵⁵ 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, mercenary officers, and imports of weapons.⁵⁶

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

⁵⁴ For the source of the story (Noel Perrin's *Giving up the Gun*) and a review that sets the facts straight, see Totman, "Review."

⁵⁵ Josson and Willaert, *Correspondance de Verbiest*; Needham, *Science*, vol. 5, part 6; Spence, *To Change China*, pp. 15, 29; Franke, "Siege"; Vāth, *Johann Adam Schall von Bell*, pp. 111–15; Waley-Cohen, "China"; Lorge, *War*, pp. 125–28; and Li, "Late Ming Military Reform."

⁵⁶ Kolff, *Naukar*; Gommans and Kolff, *Warfare*; Gommans, *Mughal*; and K. Roy, "Hybrid Military Establishment." Even defenders of Indian military prowess admit that the advances with the gun powder technology by and large came from the West. See Subrahmanyam, "Kagemusha"; Barua, "Military Developments"; Alavi, *Sepoys*, pp. 24–25; Cooper, *Campaigns*, pp. 31–32, 42–44, 289–94; and Parthasarathi, *Why Europe*, pp. 206–13.

more likely to lose wars.⁵⁷ Russia, by contrast, joined the great powers in the eighteenth century, after importing western officers, shipwrights, cannon founders, and military architects. It increasingly began to win wars against Western European powers.⁵⁸

The divergence between Russia and the Ottoman Empire is difficult to square with the argument that wars alone led to gunpowder innovations because both were frequently engaged in conflicts. That argument also fails to explain why all the wars in war-torn eighteenth-century India failed to advance the gunpowder technology. The tournament model can. It can also account for why China lagged behind, even though it was the birthplace of the gunpowder technology, and why Japan suddenly stopped improving the gunpowder technology, a shift that cannot be reconciled with a cultural argument. And the model also fits Eurasian evidence about military victories, trends in taxation, and the flow of military goods and services.

CONCLUSION

The tournament model of Europe's wars yields a deeper understanding of why Europeans pushed the gunpowder technology of firearms, fortifications, and armed ships further than anyone else. Exogenous political and military conditions drove the rulers of Western Europe's major powers to raise taxes and to spend heavily on this technology in fighting unending wars. The result was sustained innovation via learning by doing, all before the Industrial Revolution.

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

⁵⁷ Levy, *War*; Murphey, "Ottoman Attitude"; and Agoston, *Guns*, pp. 10–12, 193–94, 201. The Ottomans lost 30 percent of 23 wars in the years 1500–1699 and 56 percent of nine wars in 1700–1799 ($p = 0.09$, one-sided).

⁵⁸ Cipolla, *Guns*; Hellie, *Enserfement*; Levy, *War*; Pintner, "Burden"; Anisimov, *Reforms*; Paul, "Military Revolution"; and Kotilaine, "Defense." 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).

to raising taxes. So did the leaders whose forces battled in unending wars in eighteenth-century India.

The implication, according to the model, is that all of these parts of Eurasia would fall behind Western Europe in developing the gunpowder technology, and that the gap would grow over time, particularly in countries far from the leaders in Western Europe, because distance would slow the transfer of innovations, particularly if packages of complementary skills were involved. Both quantitative and qualitative evidence bears out this and the other predictions the model makes and argues against alternative explanations for Europe's dominance of the gunpowder technology. The argument about competition, for example, cannot explain why all the wars in eighteenth-century India failed to make it a center of military innovation.

Europe's lead was not foreordained. Learning by doing would have been possible anywhere before the Industrial Revolution, provided that the exogenous political and military conditions were right. If the Mongols, for example, had not conquered China, then it might have remained divided, and the successors to the southern Song emperors might have had more of an incentive to funnel resources into the gunpowder technology. China, the birthplace of gunpowder, might not have fallen behind.

But Europeans ended up dominating this technology, which allowed them to wage war at a distance. They were not posting huge infantry armies abroad, at least before the nineteenth century. But they could dispatch ships armed with cannons to prey upon trade in places as far away as Southeast Asia, and for protection, ship maintenance, and essential supplies of water and fresh food, the ships could rely upon European-style fortresses, which, when built in Asia or the Americas, could be defended with a relatively small force. The fortresses thus complemented the naval forces and allowed the Europeans to hold critical trading posts and to protect what land they conquered without sending large numbers of officers and men abroad, an expensive undertaking given the high mortality rates during long voyages. And further technological innovation in the nineteenth century (which a variant of the model can explain) made it possible to extend the conquests and create colonial empires.⁵⁹

⁵⁹ Headrick, *Tools and Power*.

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Why Was It Europeans Who Conquered the World?

PHILIP T. HOFFMAN

By the 1700s Europeans dominated the gunpowder technology, which was surprising, because it had originated in China and been used with expertise throughout Eurasia. To account for their dominance, historians have invoked competition, but it cannot explain why they pushed this technology further than anyone else. The answer lies with a simple tournament model of military competition that allows for learning by doing. Political incentives and military conditions then explain why the rest of Eurasia fell behind Europeans in developing the gunpowder technology. The consequences were huge, from colonialism to the slave trade and even the Industrial Revolution.

In the “great divergence” debate over when and why Europe forged ahead of the rest of Eurasia, one topic has been overlooked—namely, violence, or at least violence with gunpowder weapons. Here Europe possessed an undeniable comparative and absolute advantage, early on: European states were simply better at making and using artillery, firearms, fortifications, and armed ships than powers in other parts of the world and they had this advantage long before 1800. They used this gunpowder technology to wage war at home and to establish outposts abroad. The result was that by 1800 Europeans had conquered some 35 percent of the globe and were preying upon lucrative trade routes as far away as Asia. They took control of even more territory in the nineteenth century.¹ Other forces certainly worked in their favor as well, including the diseases that they introduced into vulnerable populations, and there were limits to what firearms could do.² Nonetheless, the gunpowder technology clearly played a large role in European conquest.

The Journal of Economic History, Vol. 72, No. 3 (September 2012). © The Economic History Association. All rights reserved. doi: 10.1017/S0022050712000319.

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Research for this article was supported by NSF Grants 0433358 and SES-0649062 as part of the Global Prices and Incomes Project. Numerous people have helped me by generously offering advice, criticisms, and expertise: Mary Elizabeth Berry, Dan Bogart, Philip C. Brown, John C. Brown, Warren Brown, Margaret Chen, Greg Clark, Stan Engerman, Claudia Goldin, Dave Grether, Dan Klerman, James Kung, Peter Lindert, Bozhong Li, Naomi Lamoreaux, James Lee, Guanglin Liu, Debin Ma, R. Preston McAfee, Kate Norberg, Patrick O’Brien, Sevket Pamuk, Peter Perdue, Gilles Postel-Vinay, Gary Richardson, Jean-Laurent Rosenthal, Stergios Skaperdas, Peter Temin, Harriet Zurndorfer, the late Ken Sokoloff, three anonymous referees for this JOURNAL, and its editor, Price Fishback.

¹ Headrick, *Tools and Power*; and Parker, *Military Revolution*, p. 5.

² Black, *War*.

Why then was it the Europeans who came to dominate the technology, and not the Japanese, the Ottomans, or the Indians, who all used it with expertise? Or why wasn't it the Chinese, who had invented it?

This question has attracted a number of gifted military historians, but the closest they come to a deeper explanation is the claim that military competition in Europe gave the Europeans an edge. The argument has been formulated most cogently by Paul Kennedy, who points to Europe's competitive markets and persistent military rivalries. In his view, while military rivalry created an arms race, competitive markets fostered military innovation and kept one country from establishing an empire.³

But Kennedy's story of competition is not the final answer, for it leaves far too much unexplained. To begin, 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.⁴

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

The answer lies with the peculiar form of competition in which European rulers were engaged. It was a winner-take-all tournament that spurred rulers to spend enormous sums on using the gunpowder technology in the continent's incessant wars. In the process, the technology was advanced via learning by doing. Elsewhere, however, political and military conditions were not conducive to improving the gunpowder technology. That is why the Europeans pushed the technology further than anyone else and why the rest of the world had trouble catching up.

Understanding why requires a look at the political, military, and fiscal incentives rulers faced, both in Europe and in other parts of Eurasia. We will start with Europe before 1800 and use it to motivate a simple tournament model, which will then be applied to the rest of the world. The model's predictions are borne out by quantitative and qualitative evidence; other explanations—including the argument about competition—fail such a test. The model thus gives us a deeper understanding of why Europeans came to dominate a technology that made world conquest possible.

³ Kennedy, *Rise*, pp. 16–24.

⁴ Hoffman, *Growth*.

TABLE 1
FREQUENCY OF WAR IN EUROPE

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

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

Source: Wright, *Study*, p. 1, tables 29, 45, 46; Levy, *War*, leads to similar results.

RULERS AND THEIR INCENTIVES IN EUROPE BEFORE 1800

The states that coalesced in Europe in the waning days of the Middle Ages by and large had a single purpose, at least if we judge by the reasons why they levied taxes and borrowed money. That purpose was clearly warfare. In the major powers, some 40 to 80 percent of the budget went directly to the military, to defray the costs of armies and navies that fought almost without interruption (Table 1). The fraction of the budget devoted to war climbed even higher—to 95 percent in France during the Thirty Years War—if we add sums spent subsidizing allies or paying of the debts of past wars.⁵

In early modern Europe, decisions about war typically lay in the hands of a ruler such as a king or a prince. He would of course be advised by councilors and influenced by elites, and an influential minister might sometimes be dictating most of the decisions. But the assumption that a king or prince made the decisions about war is not far from historical reality. Even in eighteenth-century Britain, where Parliament and the cabinet decided whether to commence hostilities, the choices about the conduct of the war once it had begun were ultimately up to the king.⁶

What then made European kings take up arms? That question has to be answered if we are to understand what the tournament was. In Europe's major powers, the rulers often won control of warfare in the process of assembling their states in the late Middle Ages or the sixteenth century. In modern terms, they provided the public good of defense in return for taxes. That public good was precious, as anyone

⁵ Hoffman and Rosenthal, "Political Economy"; and Tilly, *Coercion*.

⁶ Harding, *Amphibious*, pp. 28–30; Lynn, "International"; Rodger, *Command*, p. 242; Mallett *Mercenaries*, p. 88; and Pettegree, "Elizabethan."

who suffered through the horrors of the One Hundred Years War in France or the Thirty Years War in central Europe could testify. But the rulers of early modern Europe likely provided far more defense than their average subject would have wanted. They went on the offensive too, and not just to protect their kingdoms.

The reasons were not hard to understand. The kings and princes had been raised to fight one another, with toy soldiers, pikes, and firearms as children and actual training in their youth. Advisers like Machiavelli might tell them that princes “ought to have no object, thought, or profession but war.” Their own fathers would teach them that war was a path to glory, a means to “distinguish [kings] . . . and to fulfill the great expectations . . . inspired in the public,” in the words of Louis XIV’s instructions for his son. For them, fighting had gone beyond the needs of defense and become, in the words of Galileo, a “royal sport.”⁷

Glory did recede as a motive for war in the eighteenth century, when the major powers might fight simply to preserve their reputation, to gain commercial advantage, or to snatch territory from weaker neighbors. But war was still “what . . . rulers did.” It continued to appeal to them, just as it long had attracted much of the European aristocracy.⁸

For the major monarchs of early modern Europe, victory was thus a source of glory or a way to enhance their reputation. Grabbing territory from small neighbors did augment their resources and help strategically, but the thirst for glory and the drive to bolster their standing could push them to spend large sums even on small bits of terrain. Their goals may seem bizarre, but there are certainly modern analogues—the race to get a man on the moon, or, to take a nongovernmental example, college athletics. And although the kings might lose small amounts territory themselves, they faced no major downside risk to their thrones, at least in the larger states, for loss in battle in anything but a civil war never toppled a major monarch from his throne, at least in the years 1500–1790.⁹

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. The literature offers several reasons why such agreements prove unattainable, and why leaders go to war instead, despite all the

⁷ Sonnino, *Louis XIV*, p. 124; Machiavelli, *Prince*, p. 247; Hale, *War and Society*, pp. 29–32.

⁸ Lynn, “International”; and Bell, *Total War*, pp. 29–35.

⁹ Hoffman, “Politics and Economics,” Table 2. Losses in war did cost ministers their position.

devastation it causes.¹⁰ Although all of these reasons apply to early modern Europe, two of them seem to fit the continent's history like a glove.

The first was that the leaders making decisions about war—early modern Europe's kings and princes—stood to win a disproportionate share of the spoils from victory but avoided a full share of the costs. They—not their subjects—were the ones who basked in glory or who burnished their military reputations when their armies were victorious. But they bore few of the costs, which fell disproportionately on their subjects. When the leaders' incentives are that biased, it can be impossible to reach any sort of bargain to avoid war, even if the leaders trade resources to compensate one another.¹¹

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 divided up. In fact, it simply vanished if there was no fighting, making the peaceful exchange of resources potentially more expensive than fighting. The same held for reputation; it too could only be earned on the battlefield. Commercial advantage would not be easy to share either, if, as was often the case, it involved a trade monopoly. And territory posed similar problems, when it offered a strategic advantage or if sovereignty or religious differences were at stake. Then even trading other resources might not work. In negotiations to end the Great Northern War between Russia and Sweden, for example, the Tsar Peter the Great told his envoy in 1715 that he would not consider giving back Riga and Swedish Livonia 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 give him in return.¹² Religious strife could make negotiation itself impossible if it meant dealing with enemies of the faith.¹³

These obstacles to peace were not unique to early modern Europe, so they cannot be the reason why Europe came to dominate the gunpowder technology. They were at work elsewhere too, because foreign policy in other parts of Eurasia was often in the hands of kings, emperors, or warlords who could be as obsessed with glory as their European counterparts.¹⁴ But the biased incentives facing the

¹⁰ Brito and Intriligator, "Conflict"; Powell, "Guns"; Fearon, "Rationalist"; and Jackson and Morelli, "Reasons."

¹¹ Jackson and Morelli, "Political Bias."

¹² Anisimov, *Reforms*, pp. 244–45.

¹³ Mattingly, "International Diplomacy," p. 156. For the impact of past religious strife, see Fletcher and Iyigun, "Clash."

¹⁴ See, for example, Berry, *Hideyoshi*, pp. 215–16.

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.

A SIMPLE TOURNAMENT MODEL

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

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

A simple model drawn from the economic literature on conflict and tournaments provides a tractable starting point.¹⁵ 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.¹⁶

Consider two risk-neutral early modern rulers who are considering whether or not to go to war. Winning the war earns the victor a prize P , which might be glory or territory or a commercial advantage. 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.¹⁷

¹⁵ The model below is adapted from Fullerton and McAfee, "Auctioning," and Garfinkel and Skaperdas, "Economics."

¹⁶ For a review of the conflict literature, see Garfinkel and Skaperdas, "Economics." The insightful model of Jackson and Morelli, "Strategic Militarization," 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.

¹⁷ 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 $b - d$.

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.¹⁸

Resources carry an average variable cost c_i , which may be different for the two rulers; therefore, assume that $c_1 \leq c_2$. For simplicity, assume the average variable cost c_i is constant for all levels of resources z_i .¹⁹ These costs are political: they include opposition to conscription and higher taxes, and resistance by elites when tax 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

¹⁸ Garfinkel and Skaperdas, "Economics."

¹⁹ Adding constraint on the amount of resources a ruler could mobilize would not change things greatly, but it would allow the ruler of a large country to offset his opponent's lower average variable cost.

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

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

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

Inequality 2 is necessary and sufficient for there to be war in equilibrium; 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 that it will be large, which will be essential for learning by doing. To see when military spending will be big, consider the comparative statics of the equilibrium with war. In that equilibrium, ruler i will spend

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

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

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

So total military spending Z will only be large if, in addition to inequality 2, P/C is big, or, in other words, if the prize is valuable and

the rulers' political costs for mobilizing resources are low. Finally, the probability that ruler i wins the war will be

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

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

We will also suppose that the two rulers do not repeat this game. They play it once, at the outset of their reigns, and we interpret the decision to go to war as a choice not about a single conflict, but rather about being bellicose or not for their entire time on the throne. If they are bellicose (if inequality 2 holds), they will fight one another repeatedly throughout their time on the throne; if not, their reigns will be peaceful. Other rulers may play the game too, including their successors, and one might therefore worry that concern for their heirs would create a repeated game. Foreign policy, however, was dictated by short-term interests and changed enough from ruler to ruler to make this a reasonable assumption.²⁰ Furthermore, although other equilibria would in theory exist if the game were repeated, they could vanish if the prize were glory or victory over an enemy of the faith. By contrast, playing the strategy described above at each stage would always be equilibrium in the repeated game; with it there would be nothing to be gained by making the game repeated.

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

Whatever the military technology is, we will suppose that it progressed via learning by doing. Rulers fought wars and then used what worked against the enemy. That was typically how military technology advanced in the early modern world, whether it was weapons, organization, or tactics. The learning could take place during a war, or afterwards, when losers could copy winners and revise what they did. Conflicts in the late fifteenth century, for example, gave rise to lighter and more mobile artillery that could be mounted in and fired from gun carriages.

The learning extended to organization as well. French and English commanders who battled against Spain in the sixteenth century, for

²⁰ Mattingly, "International Diplomacy"; and Lynn, "International," pp. 185–86.

example, learned to appreciate the Spanish infantry's training, discipline, and small group cohesion. They urged their own countries to adopt the same organization.²¹

It is true that there were also conscious attempts to improve early modern military technology. King Philip II of Spain, for example, rewarded military inventors.²² But such efforts themselves were often triggered by successes and failures on the battlefield, such as when the French sought to make lighter and more mobile field artillery after a defeat in the Seven Years War.²³ Learning by doing dominated, until at least the eighteenth century, and while advances through research became easier after 1800, that possibility can readily be incorporated into an extended version of the model which would shed light on the nineteenth century.²⁴

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 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

²¹ La Noue, *Discours*, pp. 320–22, 352–57; Bonaparte and Favé, *Etudes*, vol. 1, pp. 65, 72; Williams, *Works*, c-civ; Hall, *Weapons*, pp. 121–22; and Parrot, *Richelieu's Army*, pp. 42–43.

²² Goodman, *Power*, pp. 123–41.

²³ Alder, *Engineering*.

²⁴ For the extended model, see Hoffman, “Why Was It Europeans,” which also explains the armed peace achieved by diplomacy after 1815.

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 the first term in expression 1 above.²⁵ Winning the tournament for the best innovation will be the same as winning the war, with identical incentives, so there will be no difference, provided innovation comes from learning by doing.

So far this tournament is not repeated, but what happens if successive pairs of different rulers from the same two countries play the game over time, say once per reign? Let us assume that each pair of rulers can copy the best innovation from the previous round, which seems reasonable if they learn from experience. It also fits what happened in early modern Europe, where military innovations spread through espionage, efforts to copy what was successful, and Europe's longstanding market for weapons and military skills. 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.²⁶ It will also stop if wars are not fought. But if the technology is relatively new, then there will still be room for continued innovation, and the tournament will work like an idealized prize system that puts winning ideas into the public domain.

In that case, military innovation will be sustained and will 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 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

²⁵ Fullerton and McAfee, "Auctioning."

²⁶ Lucas, "Miracle."

($E(x)$ 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.²⁷ 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 possess the cutting edge technology. Having the winning technology, though, does not make the playing field perfectly even. Even with it, a ruler with high costs c_i will stand less of chance of winning against a low cost opponent, and if the difference in costs is big enough, he will simply avoid conflict.

Suppose now there are two technologies that are effective against different enemies. Gunpowder weapons, for example, worked well in early modern European warfare, whether on land or at sea. But until at least the seventeenth century, they were relatively ineffective against the nomads who threatened China, portions of south Asia and the Middle East, and even parts of Eastern Europe that bordered the Eurasian steppe. The mounted nomads had no cities to besiege, and they were too mobile to be targets for artillery, except when it was fired from behind the walls of fortifications. Sending the infantry chasing after them would demand too many provisions, since they could simply ride off into the steppe and live off the land. Muskets gave no advantage, because they could not easily be fired from horseback, and while pistols could, their range was limited. When fighting the nomads, the best option, at least for a long time, was simply to dispatch cavalry of mounted archers—essentially the same weapons the nomads themselves utilized. That was an ancient technology, which dated back to roughly 800 BC. In the early modern world, with fixed limits to knowledge, it could no longer be improved, although it would still be useful in war.²⁸

²⁷ Mokyr, *Gifts*.

²⁸ McNeill, *Steppe*; Esper, "Military"; Hellie, *Enserfment*; Barfield, *Fronier*; Rossabi, "Inner Asia"; Chase, *Firearms*; Gommans, *Mughal*; Agoston, *Guns*, pp. 58–59, 191; Lorge, *War*; and

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

This simple tournament model is certainly open to criticism. To begin with, the rulers are either bellicose, or they do not fight at all, either because they face no opposition or because they sit on the sidelines. The model does not generate more complex patterns of arming and fighting, as a repeated game might.²⁹ But that simple pattern does describe many rulers in the early modern world. Second, because the model pits only two rulers together at any one time, it 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 two 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.³⁰ 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.

One final problem concerns the 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 wartime. 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.

Perdue, *China*. In the nineteenth century, firearms became much more effective against nomads (Headrick, *Power*, pp. 281–84).

²⁹ See, for example, Jackson and Morelli, “Strategic Militarization.”

³⁰ 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.

Tax revenues were usually the biggest component of the resources z_i that were mobilized for war; conscription and revenues from the ruler's possessions contributed much less in most cases. So if two rulers were fighting one another, the one with lower tax revenues would have a higher average variable cost c_i .³¹ And even if rulers were not fighting one another, a higher average variable cost would, from equation 3, imply lower taxes in wartime, although the lower taxes could also result from a less valuable prize or from differences in an enemy's average variable cost.

WHERE IN EARLY MODERN EURASIA 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 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 entail 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 inequality 2, is, however, only a necessary condition for sustained productivity growth with the

³¹ 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.

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 or can get the cutting-edge technology easily. 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 start with the second of the additional conditions—that the rulers use the gunpowder technology heavily. It clearly applies to Western Europe and Japan, but it fails in China, for 95 percent of the time China was engaged in war involving nomads against whom firearms long remained impotent (Table 2). In confrontations with nomads, the older technology of mounted archers was more effective. The Western Europeans, by contrast, fought no wars against nomads.

Not that China shunned the gunpowder technology altogether. It in fact gained in appeal in the early seventeenth century, when an arms race began to develop in East Asia. As the Ming dynasty, beset by rebellions and under attack by the Manchus, fell into decline, its troops fought and defended besieged cities with muskets and artillery. Their opponents replied in kind. But when the Ming dynasty collapsed and China was unified under the Qing dynasty (1644–1911), the nomads

TABLE 2
 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

Notes: 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.

Sources: Clodfelter, *Warfare*; Wright, *Study*; Stearns, *Encyclopedia*; and Kung (personal communication of the figures for China).

remained the new dynasty's major 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.³²

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 was nomadic Tatars. Firearms were of some use against them, particularly if deployed from behind fortified lines, but cavalry armed with bows and sabers was the major weapon, as in China. The Ottomans emphasized cavalry too, because much of their conflict involved frontier skirmishes and raiding. Even in the eighteenth century over 77 percent of their army was cavalry, versus under 27 percent in France. As for India, until the eighteenth century, warfare there too made heavy use of cavalry.

In addition, both the Ottomans and Russians had to funnel resources into another ancient technology with limited potential for improvement via learning by doing—galley warfare. Galleys, which dated back to classical times, were ideally suited to amphibious warfare in the light winds of the Mediterranean. They were also important for Russia 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

³² Needham, *Science*, vol. 5, part 7: pp. 398–407; Franke, "Siege"; Atwell, "T'ai-ch'ang"; Lorge *War*; and Perdue, *China*.

added without taxing the oarsmen; with little room to store water for the oarsmen, the galleys' range was severely restricted; and they were vulnerable to heavily armed sailing ships.³³

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 and Western Europe, by contrast, would be more fertile ground for innovation.

Japan, however, eventually ran afoul of inequality 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 occurred in early modern Europe, which was always torn by conflict. But that is precisely what took place in Japan when it was unified under the Tokugawa Shogunate (1603–1867).

Japan had suffered through generations of devastating civil war until three victorious warlords finally unified the fragmented country under what became the rule of the Tokugawa Shoguns. 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. Other Japanese leaders were "unenthusiastic" about the operation and "quickly" withdrew from Korea after Hideyoshi died. They seemed to realize that an invasion without adequate resources was unrealistic. They knew, in other words, that successful military competition against foreign powers entailed a large fixed cost

³³ For this and the preceding paragraph, see Agoston, *Guns*, pp. 191, 202–03; Esper, "Military"; Glete, *Navies*, pp. 114–15, 139–46, 310, 706–12; Gommans, *Mughal*; Gommans and Kolff, *Warfare*; Guilmartin, "Ideology" and *Galleons*, pp. 106–25; Hellie, *Enserfment*; Lynn, *Giant*, pp. 528–29; McNeill, *Steppe*; Parry and Yapp, *War*; Paul, "Military Revolution"; and Pryor, *Geography*.

(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.³⁴

As in Tokugawa Japan, inequality 2 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 in the eighteenth century. The Ottomans were fighting European states so they were contending for the same prize P , but their tax revenues were lower than in eighteenth-century Europe. They collected less than the median for major European powers, less than what one of their major opponents, the Austrians raised, and less than what their other chief enemy, the Russians, mobilized, at least after 1750.³⁵ It follows that the Ottomans had a higher average variable cost of mobilizing resources than in Europe and that they were unlikely to be the ones advancing the gunpowder technology. Their high cost of mobilizing resources would also imply (from expression 5) that they had little chance of defeating European rulers in the eighteenth century even if they imported the latest weapons and tactics.

As for the European rulers, their average variable costs of mobilizing resources were not only lower than in the Ottoman Empire (at least after 1700), but likely lower than in China too. The evidence comes from capita tax rates in wartime, which were much higher in Europe than in China (Table 3). Although the difference could simply reflect a less valuable prize in China or the nature of China's enemies, it is bolstered

³⁴ Smith, "Land Tax"; Reischauer, Fairbank, and Craig, *History*, vol. 1: pp. 614–15; Berry, *Hideyoshi*, pp. 207–17, "Presidential Address," and "Public Peace," pp. 207–17; Brown, *Central Authority*; Parker, *Military Revolution*, pp. 140–43; Guilmartin, *Galleons*, pp. 182–90; and Chase, *Firearms*, pp. 175–96.

³⁵ Pamuk and Karaman, "Ottoman."

TABLE 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

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 seven years out of ten in the 1770s; France fought three years of ten in the 1570s and five years of out ten in the 1770s.

Source: For France, see Hoffman and Norberg, *Fiscal Crises*, pp. 238–39; for England, see 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 website (<http://gpih.ucdavis.edu/>) and explained in Dincecco, “Fiscal Centralization,” and population figures from Wrigley and Schofield, *Population History*, table A3.1; for China, see Huang, “Ming Fiscal”; Myers and Wang, “Economic Developments”; Liu, “Nexus of Power”; and the Global Price and Income History Group website for units, silver equivalents, and prices of grain in China.

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.³⁶ Another sign that the average variable cost was low in Europe is that taxes were high relative to GDP, at least in the eighteenth century, when we can make such comparisons for France and England. By then, France was spending 5 to 10 percent of its GDP on military resources, and Great Britain even more—perhaps as much as 28 percent.³⁷ For countries that were still poor by modern standards, these figures are quite high. For comparison, at the end of the Cold War, the United States was devoting 5 percent of its GDP to the military, and the USSR perhaps 10 percent.³⁸

Like Europe, Japan before the Tokugawa Shogunate might have also faced low average variable costs. The evidence is indirect. The armies Japanese warlords raised were big relative to the population, but that would be what one would expect in wartime when *P/C* was large.³⁹

³⁶ Huang, “Military Expenditures” and “Ming Fiscal”; Sng, “Size”; and Brandt, Ma, and Rawski, “From Divergence.”

³⁷ Kennedy, *Rise*, table 2; and Mathias and O’Brien, “Taxation,” table 5. French military expenditures are assumed to range from 45 to 85 percent of tax revenues.

³⁸ Brzoska, “Military Expenditures,” table 3.

³⁹ Finer, *History*, vol. 3, p. 1088.

By the eighteenth century, the Russians too likely had a low average variable cost too and a 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, cutting the average variable costs of fielding a military force.⁴⁰ By contrast, western leaders 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 inequality 2 was satisfied, and the armies were fighting with gunpowder weapons and could easily have acquired leading innovations from one another in what was an active market for military goods and services.⁴¹ 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 for India are lacking, but it is clear that the new states that emerged on the subcontinent were struggling to gain control of resources that remained in local hands.⁴² 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.⁴³ Strife of this sort, which after the late Middle Ages was rarer in Europe, 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 shows why unending warfare and highly developed markets for military goods were not enough to obtain advances in the use of gunpowder. If they had been enough, then eighteenth-century

⁴⁰ Hellie, *Enserfment*; and Pintner, "Burden."

⁴¹ Kolff, *Naukar*; Gommans and Kolff, *Warfare*; and Gommans, *Mughal*. Although the Mughal Empire did use gunpowder weapons, it was more reliant on cavalry than the Europeans.

⁴² Barua, "Military Developments"; Stein, "State Formation"; Washbrook, "Progress"; and Alam and Subrahmanyam, "L'état moghol."

⁴³ Gommans, *Mughal*.

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 in equilibrium utilize small amounts of 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. It simply had lower average variable costs of using the military and thus was willing to mobilize more military resources in equilibrium. Not only could it draw on its own financial system to fund its military ventures, but it had also gotten control of the wealthy Ganges plain in northwestern India and won support for higher taxes there by offering elites a land market in return for higher levies. Elite cooperation and more wealth to tax would mean a lower average cost c_i and, from expression 5, a greater chance of winning wars. It would be no surprise then that the company conquered much of the subcontinent, simply by hiring away the best officers and their troops.⁴⁴

The only remaining condition is that rulers be able to acquire innovations at low cost. The barriers to doing so are clear. In the early modern world, embargos would not have been the major obstacle, since enforcement was difficult. But distance alone hampered the diffusion of the latest skills, weapons, and tactical innovations, even if mercenaries and weapons makers were willing to work for foreign masters. Technological gaps could then have increased if learning by doing persisted in one part of Eurasia and stopped in another. All rulers potentially could have advanced the gunpowder technology, but if some fell behind, catching up would have been difficult.

Some parts of the technology, after all, were just hard to transfer, which would have widened the gaps between laggards and leaders. The reason was that they 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

⁴⁴ Alavi, *Sepoys*; Gommans and Kolff, *Warfare*; Cooper, *Campaigns*; Gommans, *Mughal*; and T. Roy, "British India."

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.⁴⁵ 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 metalworking, that were scarce in the civilian economy.

Gunpowder innovations would spread most easily, we would therefore expect, when enemy powers were small and near one another and when military goods, services, and ideas could move between them with relative freedom. That was the case in India, and perhaps in Japan before the Tokugawa Shogunate as well, since the battling Japanese warlords were close enough to one another to at least copy what worked. And it was certainly the case in Western Europe.

Western Europe is also the only part of Eurasia that satisfies all the other conditions required for advancing the gunpowder technology, and it does so throughout the entire early modern period. No other Eurasian powers can meet that standard. The model would therefore predict that Western Europe would be a leader in advancing the gunpowder technology. The other Eurasian powers would have lagged behind. Could they 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.⁴⁶ 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.

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

⁴⁵ Alder, *Engineering*, pp. 39–46; and Minost, “Maritz.”

⁴⁶ Hoffman, “Prices.”

distant Asian powers, but they could now focus on fighting with gunpowder weapons and mobilize enormous resources by drafting serfs.

TESTING THE MODEL'S IMPLICATIONS IN EARLY MODERN EURASIA

We can test the model's implications for early modern Eurasia. If we begin with Western Europe, we would expect to see innovation and productivity growth in the military sector. That certainly fits the literature on the military revolution, but there is also quantitative evidence supporting this prediction too, for we can measure the rate at which the productivity of the technology was increasing. The yardsticks used underestimate the productivity growth, because they fail to capture advances in tactics or provisioning that were an integral part of the gunpowder technology. They also have trouble with naval warfare, where Western Europe's lead was perhaps greatest. The reason is that warships had a 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.⁴⁷

Yet despite all these difficulties, the evidence that military productivity was advancing in early modern Europe is clear. Suppose, for example, that we ignore the other goals navies pursued and take firepower, measure by the weight of the shot, as our sole yardstick of naval output, which we can divide by shipboard labor and capital to get an index of total factor productivity. In the English navy, this index was rising at a rate of 0.4 percent per year between 1588 and 1680, a period when firepower was gaining in importance.⁴⁸ 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 in major sectors of the economy, if it grew at all.⁴⁹

⁴⁷ Guilmartin, *Gunpowder*, pp. 253–254 and “Guns”; and Glete, *Navies*, pp. 58–61.

⁴⁸ Capital is computed from displacement, and labor from crew sizes for the English navy, using Martin and Parker, *Armada*; and Glete, *Navies*, pp. 186, 195, 205. Factor shares (0.496 for capital and 0.503 for labor) come from 1744 construction and crew labor costs in Boudriot and Berti, *Les vaisseaux*, pp. 146–52. For firepower, see Glete, *Navies*; Guilmartin, *Galleons*; and Martin and Parker, *Armada*, pp. 33–36.

⁴⁹ For examples, see Hoffman, *Growth*; and Clark, *Farewell*. One might argue 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

Nor was productivity growth limited to naval warfare. On land, the effective firing rate per French infantryman jumped by a factor of 6 or more between 1600 and 1750, as bayonets made it possible to replace pike men and matchlocks were supplanted by flintlocks with ramrods and paper cartridges. The higher firing rate translated into labor productivity growth of 1.5 percent per year, which rivals overall labor productivity growth rates in modern economies and far exceeds what one would expect for preindustrial economies.⁵⁰

Still another sign of rapid productivity growth was the falling price of weapons. The prices of cannons, muskets, and pistols tumbled relative to the price of other manufactured goods and relative to the cost of the relevant factors of production. Using the cost function dual, we can estimate productivity for weapons manufacturing in early modern France and England. 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 per year, a rapid pace even at the outset of the Industrial Revolution.⁵¹

What about the model's implications for the rest of early modern Eurasia? Although we lack similar figures for productivity, we can test the predictions against the historical record. If we begin with Japan, the model predicts improvements to the gunpowder technology until the Tokugawa Shogunate 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. With the Tokugawa, war stopped and so did that sort of innovation.⁵² And over time, tax revenues declined as fraction of agricultural output.⁵³ A cultural explanation cannot account for this sudden change, for Japanese continued to have a strong attachment to martial values. One might fear that this line of argument simply repeats the story of how the Tokugawa Shoguns banished guns. But in fact, the

in fact come from ships that were already specialized in firepower—the heavily armed flotilla that defeated the Spanish Armada.

⁵⁰ Hoffman, "Prices," Table 3.

⁵¹ Ibid. An alternative calculation yields an even higher median rate of 1.1 percent per year.

⁵² Parker, *Military Revolution*, pp. 18–19, 140–143; Chase, *Firearms*, pp. 175–196; and Berry "Presidential Address."

⁵³ Smith, "Land Tax."

shoguns did not ban firearms. Although they disarmed the population, they kept their own guns and required them for lords too.⁵⁴

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 would 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. In China, officials recognized that European weapons were superior, and they sought designs and expertise from the Portuguese or the Jesuits in both the Ming and the Qing dynasties.⁵⁵ 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, mercenary officers, and imports of weapons.⁵⁶

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

⁵⁴ For the source of the story (Noel Perrin's *Giving up the Gun*) and a review that sets the facts straight, see Totman, "Review."

⁵⁵ Josson and Willaert, *Correspondance de Verbiest*; Needham, *Science*, vol. 5, part 6; Spence, *To Change China*, pp. 15, 29; Franke, "Siege"; Vāth, *Johann Adam Schall von Bell*, pp. 111–15; Waley-Cohen, "China"; Lorge, *War*, pp. 125–28; and Li, "Late Ming Military Reform."

⁵⁶ Kolff, *Naukar*; Gommans and Kolff, *Warfare*; Gommans, *Mughal*; and K. Roy, "Hybrid Military Establishment." Even defenders of Indian military prowess admit that the advances with the gun powder technology by and large came from the West. See Subrahmanyam, "Kagemusha"; Barua, "Military Developments"; Alavi, *Sepoys*, pp. 24–25; Cooper, *Campaigns*, pp. 31–32, 42–44, 289–94; and Parthasarathi, *Why Europe*, pp. 206–13.

more likely to lose wars.⁵⁷ Russia, by contrast, joined the great powers in the eighteenth century, after importing western officers, shipwrights, cannon founders, and military architects. It increasingly began to win wars against Western European powers.⁵⁸

The divergence between Russia and the Ottoman Empire is difficult to square with the argument that wars alone led to gunpowder innovations because both were frequently engaged in conflicts. That argument also fails to explain why all the wars in war-torn eighteenth-century India failed to advance the gunpowder technology. The tournament model can. It can also account for why China lagged behind, even though it was the birthplace of the gunpowder technology, and why Japan suddenly stopped improving the gunpowder technology, a shift that cannot be reconciled with a cultural argument. And the model also fits Eurasian evidence about military victories, trends in taxation, and the flow of military goods and services.

CONCLUSION

The tournament model of Europe's wars yields a deeper understanding of why Europeans pushed the gunpowder technology of firearms, fortifications, and armed ships further than anyone else. Exogenous political and military conditions drove the rulers of Western Europe's major powers to raise taxes and to spend heavily on this technology in fighting unending wars. The result was sustained innovation via learning by doing, all before the Industrial Revolution.

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

⁵⁷ Levy, *War*; Murphey, "Ottoman Attitude"; and Agoston, *Guns*, pp. 10–12, 193–94, 201. The Ottomans lost 30 percent of 23 wars in the years 1500–1699 and 56 percent of nine wars in 1700–1799 ($p = 0.09$, one-sided).

⁵⁸ Cipolla, *Guns*; Hellie, *Enserfement*; Levy, *War*; Pintner, "Burden"; Anisimov, *Reforms*; Paul, "Military Revolution"; and Kotilaine, "Defense." 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).

to raising taxes. So did the leaders whose forces battled in unending wars in eighteenth-century India.

The implication, according to the model, is that all of these parts of Eurasia would fall behind Western Europe in developing the gunpowder technology, and that the gap would grow over time, particularly in countries far from the leaders in Western Europe, because distance would slow the transfer of innovations, particularly if packages of complementary skills were involved. Both quantitative and qualitative evidence bears out this and the other predictions the model makes and argues against alternative explanations for Europe's dominance of the gunpowder technology. The argument about competition, for example, cannot explain why all the wars in eighteenth-century India failed to make it a center of military innovation.

Europe's lead was not foreordained. Learning by doing would have been possible anywhere before the Industrial Revolution, provided that the exogenous political and military conditions were right. If the Mongols, for example, had not conquered China, then it might have remained divided, and the successors to the southern Song emperors might have had more of an incentive to funnel resources into the gunpowder technology. China, the birthplace of gunpowder, might not have fallen behind.

But Europeans ended up dominating this technology, which allowed them to wage war at a distance. They were not posting huge infantry armies abroad, at least before the nineteenth century. But they could dispatch ships armed with cannons to prey upon trade in places as far away as Southeast Asia, and for protection, ship maintenance, and essential supplies of water and fresh food, the ships could rely upon European-style fortresses, which, when built in Asia or the Americas, could be defended with a relatively small force. The fortresses thus complemented the naval forces and allowed the Europeans to hold critical trading posts and to protect what land they conquered without sending large numbers of officers and men abroad, an expensive undertaking given the high mortality rates during long voyages. And further technological innovation in the nineteenth century (which a variant of the model can explain) made it possible to extend the conquests and create colonial empires.⁵⁹

⁵⁹ Headrick, *Tools and Power*.

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Economic History Association

Mortgage Rates and American Capital Market Development in the Late Nineteenth Century

Author(s): Kenneth A. Snowden

Source: *The Journal of Economic History*, Vol. 47, No. 3 (Sep., 1987), pp. 671-691

Published by: [Cambridge University Press](#) on behalf of the [Economic History Association](#)

Stable URL: <http://www.jstor.org/stable/2121335>

Accessed: 23/04/2014 01:57

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Mortgage Rates and American Capital Market Development in the Late Nineteenth Century

KENNETH A. SNOWDEN

Substantial regional differentials in mortgage rates persisted throughout the postbellum period. I find that these differentials reflected not only variations in lending risk, but also the costs incurred in transferring funds between markets and unexplained regional premia. The results are consistent with the traditional interpretation that capital markets were at least partially segmented throughout the late nineteenth century. The effects on home and farm mortgage rates in the South and West were substantial and suggest that market segmentation could have had a substantial impact on the regional pattern of urbanization as well as agricultural development.

During the late nineteenth century mortgage rates were on average two to four percentage points higher in the western and southern regions of the United States than in the Northeast. Borrowers in high-interest regions, and especially farmers, complained bitterly that usurious interest charges were being extracted from them by eastern monopolists.¹ Lenders countered that higher interest rates in the West and South were fair compensation for additional lending costs and risks. The distributional implications of the mortgage-rate controversy fueled an intense political debate. By 1890 thirty-three states had adopted usury laws, and in the same year a coalition of Populists, Single Taxers, Farmers' Alliances, and labor groups called for the federal government to conduct an extensive examination of the burdens which mortgage indebtedness and interest payments placed on borrowers throughout the country.²

Beyond its political repercussions, the mortgage-rate controversy has profound implications for the assessment of late nineteenth-century

Journal of Economic History, Vol. XLVII, No. 3 (Sept. 1987). © The Economic History Association. All rights reserved. ISSN 0022-0507.

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The author is indebted to Barry Eichengreen, Zvi Griliches, Barry Hirsch, John James, Terry Seaks, İnsan Tunali, Jeffrey Williamson, and the participants of the Economic History Workshops at Harvard University and the Research Triangle for helpful comments concerning this research in its earlier stages. Claudia Goldin, George Boyer, and an anonymous referee provided valuable editorial criticism. The able research assistance of Caroline Gramley and Nancy Robbins is gratefully acknowledged.

¹Two excellent treatments of the farmers complaints are: John Hicks, *The Populist Revolt* (Minneapolis, 1931), chap. 3; and Fred Shannon, *The Farmer's Last Frontier* (New York, 1961), chap. 13.

²U.S. Census Office, "The Report on Home Proprietorship and Indebtedness" (Washington, D.C., 1895), vol. 13, p. 3-4, 113.

capital market performance. Lance Davis argues that barriers to investment-fund mobility between the savings-rich Northeast and the capital-starved South and West resulted in regional differentials in long and short-term loan rates, and reflected an underlying misallocation of capital.³ From this perspective the debate between mortgage borrowers and lenders was moot; differentials that resulted from either monopoly power or transactions costs associated with interregional transfers would have led to a regional allocation of mortgage funds that was not characteristic of a frictionless and fully integrated national mortgage market.⁴ Davis concludes that institutional innovations, primarily life insurance companies and mortgage banks, gradually improved the allocative efficiency of the mortgage market before 1914. He emphasizes, however, that regional segmentation in the mortgage market was overcome more slowly than in the short-term market. Davis's conjectures have fostered an extensive literature examining the commercial banking system, but his observations concerning the mortgage market have received much less attention.

Barry Eichengreen recently examined the complaints of western farmers about monopoly power in the mortgage market.⁵ Using state-level data, Eichengreen found that farm mortgage rates, when adjusted for the risk of foreclosure, displayed no statistically significant regional variation in 1890.⁶ In one important sense his result is not surprising. Farmers' allegations concerning freight rates, farm prices, and incomes all appear to have been either groundless or exaggerated.⁷ Eichengreen's results suggest that farmers also mistook large risk premia as evidence of monopoly power. In fact, Eichengreen presents evidence that usury laws in the East may have actually reduced mortgage rates to below their competitive levels in the western regions.

A more startling inference, which Eichengreen does not emphasize, is

³ Lance Davis, "The Investment Market, 1870–1914: The Evolution of a National Market," this JOURNAL, 25 (Sept. 1965), pp. 355–93. For the mortgage market see pp. 373–87.

⁴ In an allocatively efficient national capital market the rates of return on the marginal investment projects for each region would have been equalized after adjustment for the lending risk intrinsic to the loan and the normal costs associated with making and administering the loan. Departures from this benchmark could have occurred for a variety of reasons: extraordinary costs and risks (beyond loan default) incurred when transferring funds between regions, regional differences in lending costs due to the uneven diffusion of cost effective financial intermediation, or variations in monopoly power. All these institutional and structural characteristics of the market were external to the underlying return on the financed project, and are considered here to be sources of inefficiency. The presence of any of these factors will be referred to throughout as market segmentation.

⁵ Barry Eichengreen, "Mortgage Rates in the Populist Era," *American Economic Review*, 74 (Dec. 1984), pp. 995–1015.

⁶ Eichengreen's risk-adjusted rates showed substantial variation across states. The important point here is that the variation in the risk-adjusted rates showed no distinct regional pattern.

⁷ For the more modern and less sympathetic view of the farmers' complaints see: Robert Higgs, *The Transformation of the American Economy, 1865–1914* (New York, 1971); and Susan Previat Lee and Peter Passell, *A New Economic View of American History* (New York, 1979), pp. 292–301.

that the farm mortgage market was perfectly integrated by 1890. Millions of investment dollars had flowed into the western and southern markets from the Northeast by that date. If the regional structure of farm mortgage rates reflected only variations in the risk of foreclosure and if lenders behaved rationally, then transfers must have been subject to negligible transactions costs. Moreover, Eichengreen's risk premia appear to explain the regional mortgage-rate gradient without taking into account the uneven diffusion of financial innovation and intermediation that characterized the market. If warranted, these conclusions would represent a serious challenge to the observations of Davis, as well as participants and observers of the market in 1890, that barriers to fund mobility persisted until that date. Furthermore, if the mortgage market was perfectly integrated, then a widely held view—that distortions in the capital market had a profound effect on the regional and sectoral structure, if not the growth, of the late nineteenth-century American economy—would be seriously undermined.⁸

I argue here that such a revision is premature. I use a previously unexamined sample of mortgage conditions in 102 counties to identify the determinants of mortgage rates in 1890. I analyze both farm and home mortgages. The examination of the residential market represents an important extension of the literature because the urban mortgage market was much larger and was expanding more rapidly than the farm market during the 1880s.⁹ Default risk was higher outside the Northeast for mortgages in these samples, but the estimated risk premia do not explain all of the regional variation in mortgage rates. Instead, factors consistent with the segmented-market hypothesis, such as the cost of out-of-state funds and regional location (after controlling for default risk), appear to have played an important role. The evidence does not support the farmers' allegations concerning monopoly power, but it does suggest that borrowers in the West and South paid substantially higher rates than they would have in a perfectly integrated and institutionally mature market. Surprisingly, I find that the most severe effects of the segmentation were felt in the home, and not the farm, mortgage market.

I. THE TWO CENSUS REPORTS

The sample I analyze here is drawn from two of the 1890 census reports. The "Report on Home Proprietorship and Indebtedness"

⁸ Davis, "The Investment Market," pp. 355–56, discusses the importance of capital market imperfections to economic growth. Richard Sylla, *The American Capital Market, 1846–1914* (New York, 1975), pp. 219–32; and Jeffrey G. Williamson, *Late Nineteenth Century American Development* (Cambridge, Mass., 1974), pp. 119–45 also discuss the issue.

⁹ The economy-wide share of mortgage debt made on acres (relative to lots) decreased from 45 percent during the period 1880 to 1884 to 37 percent between 1885 and 1889. This pattern was pervasive throughout the national market except for the South Central region. See U.S. Census Office, "Report of Real Estate Mortgages in the United States" (Washington, D.C., 1895), vol. 12, p. 29.

(Volume 13 of the U.S. Eleventh Census) was specifically designed to investigate the claim that “the present economic condition of society tends toward the concentration of wealth in the hands of the few . . . by compelling the majority of the people to become and remain debtors . . .”¹⁰ Congress authorized the Census Office to use the standard enumeration, mail surveys, and interviews to determine the volume of mortgage encumbrance and mortgage rates for owner-occupied homes and owner-operated farms in all counties in the country.¹¹ The “Report of Real Estate Mortgages in the United States” (Volume 12 of the U.S. Eleventh Census) was conducted independently of the regular census. For each mortgage made in the country between 1880 and 1889, the Census Office determined the amount of indebtedness and the effective interest rate. The results of this remarkable enumeration reveal the central importance of the mortgage market to the expansion of the economy. During the decade examined the volume of mortgage debt in the United States increased twice as fast as the nation’s wealth, three times faster than the value of taxed real estate, and six times faster than population.¹²

Included in Volume 12 are the results of a special investigation of 102 counties, including the duration of mortgages, the residence of mortgagees, and the purposes for which the mortgages in force had been made.¹³ This information would have been prohibitively expensive to collect for the entire country, so the Census Office chose a sample of counties to represent the national market.¹⁴ The counties were primarily agricultural, although several contained or were contiguous to large urban centers, or had local economies dominated by mining or manufacturing activities.¹⁵

The Census Office reports provide a wealth of detail concerning mortgage market conditions throughout the country at the state and county level. In this article I examine the structure of rates for mortgages made on owner-occupied homes and owner-operated farms in the 102 counties that were the subject of the special investigation.¹⁶

¹⁰ U.S. Census Office, “Report on Home Proprietorship and Indebtedness” (Washington, D.C., 1895), p. 4.

¹¹ *Ibid.*, pp. 5–11. The Census Office reported that the enumeration covered 82 percent of the farm and 74 percent of the home families in the country.

¹² U.S. Census Office, “Report of Real Estate Mortgages,” p. 309.

¹³ The description and summary of the special investigation appears in *ibid.*, pp. 269–95. The basic data for each county appears in *ibid.*, Table 110, pp. 836–95. For a complete enumeration of the sample counties see Appendix Table 6.

¹⁴ The counties were selected from 35 states representing the five census regions (the Northeast, South Atlantic, North Central, South Central, and West). The North Central region (which contained 49 of the counties) has been subdivided into the East and West North Central regions here.

¹⁵ A description of the sample counties can be found in *ibid.*, pp. 273–77.

¹⁶ By restricting the analysis to owner-operated farms and owner-occupied homes, mortgages on rental and business property have been excluded. This homogeneity in the sample is a desirable

TABLE 1
AVERAGE MORTGAGE CHARACTERISTICS FOR THE 102 COUNTIES BY REGION

Region ^a	Effective Interest Rate	Size of Mortgage (000)	Encumbrance to Property Value Ratio	Average Life of Mortgage	Number of Counties
Farms					
Northeast	5.56%	\$2.033	.41	6.62	14
South Atlantic	7.45	1.672	.44	4.58	12
East North Central	7.07	1.243	.32	4.87	19
South Central	8.23	0.819	.43	2.72	17
West North Central	8.55	0.928	.35	3.79	30
West	9.11	2.313	.37	2.81	10
Homes					
Northeast	5.63	1.255	.40	5.99	14
South Atlantic	7.36	0.847	.45	3.32	10 ^b
East North Central	7.25	0.629	.33	3.42	19
South Central	8.25	1.436	.48	1.92	17
West North Central	8.75	0.655	.37	2.87	30
West	9.11	1.248	.36	2.08	10

^a Regions are defined in Table 6 in the Appendix.

^b There was no information on home mortgages for two counties in Georgia.

Sources: Effective interest rates, mortgage size, and encumbrance to property value ratio from U.S. Census Office, "Report on the Proprietorship and Home Indebtedness of the People of the United States," vol. 13 (Washington, D.C., 1895), table 103, pp. 382–420 and table 108, pp. 430–436. Average life of the mortgages ("on acres" and "on lots") from U.S. Census Office, "Report of Real Estate Mortgages in the United States," vol. 12 (Washington, D.C., 1895), table 44, pp. 110–11.

The average size of the loans, the average market value of the property encumbered, and the average effective interest rate (including commissions) were drawn for each of the counties from Volume 13.¹⁷ These contractual features of the mortgages are summarized by region in Table 1 for the farm and home markets. Both samples display the familiar regional rate structure, with the lowest rates in the Northeast and the gradient increasing to the South and West. Mortgage size also varied considerably among counties with the largest loans generally prevailing in the Northeast and the West. The encumbrance to property value ratio was highest for the counties in the Northeast and South, and lowest in the North Central region. Finally, there are marked differences in the average life of mortgages among regions. Throughout the country the duration of mortgages was short relative to modern standards, but they were particularly short-lived in the West and South Central region.¹⁸

feature because the hedonic interest rate equation used here requires mortgages to be identical in as many unobservable characteristics as possible.

¹⁷ U.S. Census Office, "Report on the Proprietorship," table 103, pp. 382–420 and table 108, pp. 430–66. Two counties in Georgia reported no information for home mortgages. It was a common practice in the South and West for the borrower to pay an initial commission on the loan in addition to the stipulated interest payments. The Census Office included these commissions when calculating the effective interest rate.

¹⁸ The average life of the mortgages reported in Table 1 represent the duration of all mortgages

II. A HEDONIC MODEL TO EXPLAIN REGIONAL VARIATION IN MORTGAGE RATES

The detailed information contained in the Census Office reports permits the estimation of an empirical model similar to those used for modern mortgage markets.¹⁹ I include in the specification contractual characteristics and market conditions which lenders regularly took into account when setting rates during the postbellum period. Other variables are included that would have affected rates only if the national market was not fully integrated. By testing the significance of each of these groups of variables in a common model I am able to determine the degree to which the mortgage markets were segmented.²⁰

In a perfect mortgage market the effective interest rate charged to each borrower would have exceeded the one-year, risk-free rate of return by a term premium, a transactions cost premium, and a risk premium. The duration of the loan is an important feature because the nominal effective rate was fixed until the loan was either repaid or renegotiated. Borrowers and lenders were aware that changes in the real effective rate could occur over the life of the mortgage, and thus the term premium adjusted the nominal rate. The transactions cost premium paid by each borrower would have compensated lenders for the normal costs incurred in making and administering a loan. If these dollar costs were fixed, the effective interest rate would have been inversely related to the size of the loan in a competitive market. Lenders in both the urban and rural mortgage markets appear to have followed such rules.²¹

The risk premium paid by each borrower represents compensation for the expected costs associated with default.²² Default or foreclosure rates are not available for the sample counties, or for any geographically diverse sample of mortgage markets in 1890. In the specification I control for default risk by including information which lenders regularly employed in assessing loan quality. Of particular importance is the ratio

in force on acres and lots rather than only for those farm and home mortgages reported in Volume 13.

¹⁹ For the modern market see: A. H. Schaff, "Regional Differences in Mortgage Financing Costs," *Journal of Finance*, 21 (Mar. 1966), pp. 85-94; James R. Ostay, "Regional Differences in Mortgage Financing Costs: A Reexamination," *Journal of Finance*, 32 (Dec. 1977), pp. 1774-78.

²⁰ Eichengreen does not include explicit measures of market segmentation in his reduced form equation. He examines the estimated risk-adjusted rates for regional differences. Eichengreen, "Mortgage Rates," p. 1012.

²¹ Allan Bogue, *Money at Interest* (Ithaca, 1955) p. 120; and Harold Williamson and Orange Smalley, *Northwestern Mutual Life* (Evanston, 1957), p. 119, document this practice.

²² I will refer here to the costs of default rather than foreclosure. When a borrower defaulted on interest payments additional costs would be incurred even if foreclosure did not follow. These might have included foregone interest (unless the contract stipulated a penalty), or additional monitoring costs. Of course, expected foreclosure costs would have been included in default costs as well, and were likely to have been quite large.

of the encumbrance to the market value of the property encumbered.²³ Default was more likely as the leverage of the borrower increased, as well as the probability that the principal and foregone interest would not be fully recovered in the event of foreclosure. The purpose of the loan also entered into the determination of lending risk. A borrower who encumbered his property to pay current expenses (referred to here as a calamitous mortgage) was more likely to default than one who had made a mortgage for the purpose of acquiring or improving property. Finally, the creditworthiness of a loan applicant was based on the length of tenure in the local community. Recent settlers were more likely to default for several reasons: inexperience in local agricultural practices, shorter tenure in nonagricultural employment, and a weaker attachment to locale and property in the event of financial distress.²⁴ Although other factors were sometimes taken into account, it appears that the security and purpose of the loan, and the reputation and tenure of the loan applicant were the primary considerations lenders used to assess loan quality.

In a fully integrated mortgage market the considerations outlined above would explain all systematic variation in effective rates which individual borrowers paid throughout the country. The empirical analysis presented here must rely on the county averages that the Census Office reported. The implied model is:²⁵

$$I_i = r + \beta_1(AVLIFE_i) + \beta_2(1/SIZE_i) + \beta_3(L_i) + \beta_4(PERCAL_i) + \beta_5(TEN_i) + \beta_6(PER85_i) + \mu_i \quad (1)$$

The variables are defined in Table 2. The measure of the age distribution of the mortgages (*PER85*) was required because the Census Office reported all home and farm mortgages that were in force in 1890, regardless of when they were made.²⁶ In Table 3 the regional means of the measures of calamitous lending and borrower stability are presented

²³ Bogue, *Money at Interest*, chap. 6 discusses the process of evaluating mortgage loans in detail for the Watkins Land Company.

²⁴ *Ibid.*, p. 146, documents that J. B. Watkins complained of just this behavior by borrowers in western Kansas.

²⁵ The reduced-form equation for the county averages can be derived from a similar structural equation for individual mortgage contracts which treats the calamitous loan, borrower stability, and mortgage age effects as dummy variables. The specification is preserved for the averaged data under the assumptions that the home and farm mortgages in the sample were randomly selected from the total county population for these three characteristics. The (*1/SIZE_i*) variable is not strictly preserved by averaging. The error term in equation 1 is heteroskedastic because the effective loan rates (and hence the errors) were averaged across the number of borrowers in each market.

²⁶ The general level of mortgage rates were subject to both cyclical and long-term variations. Identical mortgages of different vintage would, therefore, have different effective rates simply because of differences in market conditions when they were made. The measure used here discriminates between mortgages that were made during the depression years before 1885 and those made during the lending boom later in the decade.

TABLE 2
DEFINITION OF VARIABLES IN THE MORTGAGE RATE EQUATION

I_i	= the average effective mortgage rate in the i^{th} county.
r	= the one-year risk-free rate of return.
$AVLIFE_i$	= the average life of mortgages in the i^{th} county.
$SIZE_i$	= the average size of the mortgage (\$000) in the i^{th} county.
L_i	= the average encumbrance to property value ratio in the i^{th} county.
$PERCAL_i$	= the percentage of mortgages in the i^{th} county that had been made for "calamitous" purposes.
TEN_i	= a measure of the average tenure of the borrowers in the i^{th} county. For farm borrowers: the percentage growth in the number of farms in the county between 1880 and 1889. For home borrowers: the percentage growth in the population of the county between 1880 and 1889.
$PER85_i$	= the percentage of mortgages in force in the i^{th} county that had been made between 1885 and 1889.
OOS_i	= the percentage of mortgage funds in the i^{th} county that had been lent by out of state investors.

Sources: See text.

for the sample counties.²⁷ The extent of financial distress in the South and the large numbers of recent arrivals in the West were clearly important considerations in assessing the risk of lending in those regions.

In a fully integrated mortgage market funds would have been costlessly transferred among regions to arbitrage any differentials that persisted after differences in normal administrative costs, term premia, and expected default costs had been taken into account. The qualitative evidence suggests, however, that such transfers involved additional costs and risks which prevented funds from moving so freely. Eastern investors, both institutional and individual, relied heavily on loan agents to select prospective borrowers and to administer loans. Supervision of these agents entailed additional expenses and risks that would not have been incurred by a local investor.²⁸ In particular, agency costs would have arisen because agents were generally paid out of initial commission charges. These contractual arrangements gave the agent the incentive to extend loans lower in quality than those desired by the ultimate investor. In addition, loan companies that operated in the West and then resold mortgages to eastern investors faced an additional layer of costs associated with transferring the mortgage contract or issuing bonds on the mortgage collateral. These costs, if substantial, would have been

²⁷ For both population and farm growth figures data in 1880 are unavailable for three counties that had yet to be organized—Brown and Kimball in Nebraska, and Dickey in North Dakota. For these counties the measures were calculated for the smallest area that contained these counties for which data was available in both 1880 and 1890.

²⁸ Bogue, *Money at Interest*, documents the problems that both the Davenport family of Bath, New York, and the Watkins Land Company had in hiring and retaining reliable loan agents.

TABLE 3
MARKET CHARACTERISTICS OF THE SAMPLE COUNTIES, BY REGION

Region	Percent of Mortgage Funds Lent for Calamitous Purposes	Index of Farm Growth	Index of Population Growth	Percent of Mortgage Funds Lent by Out-of- State Investors
Northeast	3.69%	-4.58%	11.95%	7.00%
South Atlantic	17.47	12.88	7.27	42.74
East North Central	5.79	3.97	13.67	38.64
South Central	10.19	12.15	21.18	32.09
West North Central	3.86	37.01	39.49	66.96
West	2.81	40.10	45.03	43.19

Sources: Calamitous mortgages and percent of out-of-state funds from "The Report of Real Estate Mortgages in the United States", table 89, pp. 286-89 and table 91, pp. 291-92. Number of farms for 1880 and 1890 from "Report on the Statistics of Agriculture in the United States," vol. 3 of the U.S. Tenth Census and vol. 5 of the U.S. Eleventh Census. Population for 1880 and 1890 taken from the *Compendium of the Eleventh Census: 1890. Part I: Population* (Washington, D.C., 1892), pp. 7-47.

reflected in the equilibrium structure of mortgage rates in a competitive market. To control for these potential costs I include in the specification the percentage of mortgage funds in each county that had been lent by out-of-state investors.²⁹ The regional means of this variable, shown in Table 3, reveal the importance of intermarket transfers to borrowers in all regions outside the Northeast, but especially for those in the West North Central region.³⁰

The measure of out-of-state investor participation is a remarkable feature of the sample and allows me to get to the heart of the market integration controversy. However, other factors besides the direct costs of interregional lending could have distorted the mortgage rate structure. These include variations in monopoly power, in the extent of financial intermediation, and in the legal protection afforded to investors in the event of foreclosure. To capture these effects regional dummies are also included in the specification.³¹

²⁹ Out-of-state funds would have lowered actual rates in the receiving market relative to their counterfactual levels had the mortgage market been perfectly segmented. However, once those funds were mobile, arbitrage would have ensured that the participation of out-of-state investors would have had either no effect on mortgage rates in the receiving market (if the transfers had been costless) or a positive effect (as compensation for the costs incurred).

³⁰ In Volume 12 all nonresident mortgagees of record, as well as mortgage and land banks, and railroads were considered to be out-of-state lenders.

³¹ The specification does not account for the potential effects of usury ceilings. The level of usury ceilings are available for the samples, but belong in the specification only if they are binding. Nonbinding ceilings would introduce endogeneity problems because the same forces that led to relatively high rates in the West would have led legislators to adopt a relatively high maximum customary rate in a usury law. An attempt to identify potentially binding usury ceilings for the sample was unsatisfactory, and I conclude that any such categorization would have been arbitrary.

TABLE 4
DETERMINANTS OF MORTGAGE RATES, 1890

Variable ^a	Farm Mortgages	Home Mortgages
r	4.030** (0.908)	2.970** (0.780)
L_i	2.800* (1.130)	2.351* (1.010)
$PERCAL_i$	0.043* (0.020)	0.028 (0.018)
TEN_i	0.013** (0.003)	0.004 (0.003)
$(1/SIZE_i)$	0.321** (0.104)	0.415** (0.137)
$AVLIFE_i$	-0.043 (0.071)	0.042 (0.057)
$PER85_i$	0.356 (0.737)	1.372* (0.502)
OOS_i	0.015** (0.003)	0.010** (0.003)
Regional Dummies		
South Atlantic	0.534 (0.392)	0.321 (0.238)
East North Central	0.910** (0.214)	0.916** (0.173)
South Central	1.110* (0.407)	2.273** (0.297)
West North Central	1.318** (0.286)	1.896** (0.218)
West	2.335** (0.349)	2.565** (0.230)
Weighted residuals ^b		
Standard error of the regression	0.500	0.374
Adjusted R^2	0.862	0.922
Unweighted residuals		
Standard error of the regression	0.774	0.833
Adjusted R^2	0.715	0.653
$F(5, n - 13)$	9.080**	32.830**
Sample size	102	100

* Significantly different from zero at the 5 percent level.

** Significantly different from zero at the 1 percent level.

^a The variables are defined in Table 2.

^b The weights used in the regression were the square roots of the number of mortgages in each county.

^c The F -ratio tests the null hypothesis that the regional dummies are all zero. The Northeast is the omitted regional dummy.

Note: Standard errors are reported in parentheses.

Sources: See text.

The results of the estimation, shown in Table 4, are broadly similar for the farm and home mortgage markets.³² The constant terms measure the riskless one-year rate of return available to lenders plus the fixed regional effect of the Northeast region. Although the estimated intercept term in the home mortgage market is lower than in the farm market equation, both lie within one standard deviation of the range of the long-term, risk-free rate in 1890 (3.65 to 4.4 percent).³³ In addition, the term effect is insignificant in both markets. Taken together the estimated

Eichengreen concludes that usury ceilings had a weak effect on rates in the Northeast, but also did not incorporate usury ceilings in his interest rate equation.

³² The error term is found to be heteroskedastic and the equations are estimated by Generalized Least Squares. The observations are weighted by the square root of the number of mortgages in each county.

³³ Eichengreen, "Mortgage Interest Rates," p. 1009, argues that this is the reasonable range for the long-term risk-free rate in 1890, based on the yields of government and railroad bonds.

constants and term effects indicate that lenders in the Northeast earned rates of return similar to those available on comparable assets after default risk and lending costs had been taken into account.

The coefficients on the encumbrance to property value ratios are positive and significant in both markets and are about equal in magnitude. The prevalence of calamitous lending and new arrivals also increased interest rates in both markets, although the effect was more pronounced in the farm market. The coefficients on the loan size variables are significant at the 1 percent level for both markets. Moreover, the magnitudes of the coefficients suggest an adjustment to mortgage rates to compensate lenders for administrative costs consistent with actual practice.³⁴ These results indicate that normal transactions costs and default risk, as measured by this specification, had significant impacts on farm and home mortgage rates throughout the country. In this important sense the mortgage market functioned efficiently.

The vintage effect (measured by *PER85*) is much stronger in the home than the farm market. The positive coefficient in each market indicates that rates were higher on mortgages made in the late 1880s than on those made earlier in the decade. Although other nominal long-term interest rates (such as on railroad bonds) drifted slowly downward during the entire decade, the rapid expansion of mortgage debt after 1885 apparently put substantial upward pressure on mortgage rates throughout the country. This pronounced short-term cyclical effect suggests that the mortgage market was to some extent isolated from other long-term loan markets. Moreover, the differential impact of the vintage effect on home rates indicates that the impact of the urban mortgage lending boom late in the decade was not fully transmitted to the farm market.

The variables included to detect market segmentation provide compelling evidence that the farm and home markets were not perfectly integrated. The coefficients on the percentage of out-of-state funds were significant in both markets. Rates would have been 1.5 percent higher in the farm market and 1 percent higher for home mortgages in a county which had imported all funds from out of state than in a county that was self-sufficient in mortgage funds. Although not reported in Table 4, a regional interaction term on the out-of-state variable was included to ascertain if out-of-state lenders in the South Central, West North Central, and West regions required additional compensation. The coefficients were insignificant in both markets.³⁵

The coefficients on the regional dummies are positive in all regions for

³⁴ Bogue, *Money at Interest*, p. 120, reported that The Watkins Land Company (in 1881) charged an effective rate of interest that was 0.5 percent lower for a \$1500 mortgage than for a \$500 mortgage. The coefficients reported here imply a reduction in rates of 0.44 percent and 0.55 percent for the farm and home markets respectively over the same range.

³⁵ The results including the interaction term are available upon request.

the home and farm markets, and significantly different from zero in all regions except the South Atlantic. The magnitudes of the coefficients suggest a pattern of segmentation that followed the expected geographic configuration. The relatively small and insignificant coefficients on the South Atlantic dummies imply that the eastern seaboard market was nearly completely integrated after the cost of importing out-of-state funds is taken into account. On the other hand, farm and home mortgage borrowers in the Far West paid the highest regional premia in the country. Significantly positive but smaller regional premia were paid by all borrowers in the central regions of the country.

III. THE SOURCES AND COSTS OF MORTGAGE MARKET SEGMENTATION

Even in a fully integrated market regional mortgage-rate differentials would have existed, although they would have been modest. In the second line of the first two panels in Table 5 the predicted effects of default risk, loan size and term, and the vintage of mortgages have been added to the estimated intercept terms from Table 4. In the hypothetical case assumed in this calculation each borrower would have paid compensation to lenders only for those default risks and costs intrinsic to the loan as measured in the specification.

Borrowers in the South would have paid the highest effective rates in a fully integrated market. Average southern farm mortgage rates would have been more than a percentage point higher than in the Northeast, and home mortgage rates 0.8 percent higher. Effective rates in the North Central and West regions would have fallen between these extremes. These differentials would have been attributable in part to the higher default risk of southern loans (resulting from the prevalence of calamitous mortgages) and of farm loans in the West North Central region (due primarily to the borrower stability effect). Higher effective rates in some of the central regions of the country would have resulted from small loan size. Finally, the pronounced vintage effect in the home market, due to the urban lending boom of the late 1880s, would have raised mortgage rates in all regions above those in the Northeast, where the long duration of loans muted this effect in the county aggregates. In fact, the vintage effect is the sole reason that home mortgage rates in the West would have been higher than those in the Northeast if the market had been fully integrated.

In the second part of each panel in Table 5 the estimated costs of market segmentation are presented. The extra costs of borrowing out-of-state funds weighed particularly heavily on borrowers in the West North Central region. The total costs of market segmentation (including the regional premia) were highest for home and farm borrowers in the West region. For the other regions an interesting contrast between the farm and home markets appears. For the two regions

contiguous to the Northeast, the South Atlantic and East North Central, the total burden of segmentation fell more heavily on farm than home borrowers. The reverse pattern characterized the South Central and West North Central regions.

In the last panel of Table 5 the actual farm mortgage rates and Eichengreen's estimated risk premia and risk adjusted rates are presented by region for the thirty-five states that contained the sample counties.³⁶ The reasons for his sanguine appraisal of mortgage market performance are readily apparent. His estimated risk premia were larger and showed greater regional variation than those calculated for the sample counties. As a result, Eichengreen's average regional mortgage rates adjusted for the risk of default ranged only between 3.63 and 4.53 percent, and were nearly identical for the Northeast and Central regions of the country. In such a market there is little room for the substantial market segmentation that I have identified.

These two contrasting views are unlikely to have resulted from differences in the samples. Eichengreen's state-level data offer much broader coverage than the county samples examined here.³⁷ The regional means of the actual effective mortgage rates are, nonetheless, strikingly similar for both samples. The 102 counties were specifically chosen by the Census Office to represent the national market, so it is not surprising that they accurately reflected the interest rate gradient for the nation. It is probable that the different results are attributable to the empirical specifications employed. Unfortunately, a straightforward comparison of the specifications on a common sample is not possible. The extensive information on the encumbrance to property value ratios, purposes of the mortgages, and participation of out-of-state lenders is not available for the state-level data which Eichengreen employed. On the other hand, the agricultural data Eichengreen uses are available for only very few farms in many of the sample counties and were not collected in any county for only the owner-operated farms examined here.

The differences in the magnitudes of the estimated risk premia are striking. Because foreclosure rates are not available for either sample, Eichengreen and I measure lenders' appraisals of the probability of default indirectly. I use a hedonic specification which incorporates borrower-specific and market-wide characteristics actually used by lenders to assess loan quality, while Eichengreen employs an implicitly derived measure of farm income variability. The central issue for assessing market performance is whether Eichengreen's risk premia are

³⁶ Eichengreen, "Mortgage Interest," pp. 1010–11. I have reported the *ALT2* risk adjusted rates and the *PREM2* risk premia.

³⁷ Besides the more complete geographic coverage, Eichengreen's sample includes all mortgages made on acres, some of which were not agricultural.

TABLE 5
SOURCES OF MORTGAGE RATE DIFFERENTIALS BY REGION

	Farms					
	Northeast	South Atlantic	East North Central	South Central	West North Central	West
I. Actual effective rate	5.56	7.45	7.07	8.23	8.55	9.11
II. Predicted effective rate, hypothetical fully integrated market	5.40	6.57	5.69	6.53	6.21	5.89
Due to						
Risk premia	1.26	2.14	1.21	1.81	1.62	1.45
Size and term effects	-0.08	0.15	0.20	0.40	0.26	0.09
Vintage effects	0.20	0.24	0.25	0.29	0.29	0.33
III. Predicted effective rate, full model	5.51	7.74	7.17	8.12	8.52	8.87
Due to						
Cost of imported funds	0.10	0.64	0.58	0.48	1.00	0.64
Regional effect		0.53	0.91	1.11	1.32	2.34
IV. Total estimated costs of segmentation	0.10	1.17	1.49	1.59	2.32	2.98

Homes						
I. Actual effective rate	5.63	7.36	7.25	8.25	8.75	9.11
II. Predicted effective rate, hypothetical fully integrated market	5.50	6.25	5.98	6.30	6.09	5.87
Due to						
Risk premia	1.10	1.47	0.99	1.50	1.14	1.12
Size and term effects	0.61	0.72	0.94	0.59	0.81	0.46
Vintage effects	0.82	1.10	1.09	1.23	1.17	1.32
III. Predicted effective rate, full model	5.57	6.96	7.30	8.90	8.68	8.88
Due to						
Cost of imported funds	0.07	0.39	0.40	0.33	0.70	0.45
Region effect		0.32	0.92	2.27	1.90	2.57
IV. Total estimated costs of segmentation	0.07	0.71	1.32	2.60	2.60	3.02
Mortgages Made on Acres ^a						
I. Actual effective rate	5.77	7.03	6.75	8.05	8.33	9.13
II. Risk premia	1.79	3.40	2.68	4.20	4.36	4.60
III. Risk adjusted rate	3.98	3.63	4.07	3.85	3.97	4.53

^a State level data taken from Barry Eichengreen, "Mortgage Rates in the Populist Era" *American Economic Review*, 74 (Dec. 1984), pp. 1010-11. Sources: See text.

inflated and incorporate factors attributable to segmentation, or whether the variables I use to measure segmentation are actually measuring the risks of default. Not surprisingly, I maintain that the former alternative is more likely.

To recover an implicit measure of the variability of farm income, and hence foreclosure risk, Eichengreen assumes that an acre of farm land was like any risky asset—the price increased with the expected income that could be produced on the land, and decreased with the variability of that income. In estimating this relationship Eichengreen uses physical yields as a proxy for expected income per acre. Although lower land prices for a given level of nominal income would indicate greater income variability, lower land prices for a given level of physical yields could reflect higher transportation costs as well as greater variability. The problem is particularly troublesome because transportation costs were surely highest in the same regions where interest rates, and Eichengreen's estimated risk premia, were the highest. Because Eichengreen's specification does not control for variations in transportation costs across regions, it is likely to have overstated the role risk played. In addition, Eichengreen assumes that the encumbrance ratio was constant across states, although I show here that lower ratios in the North Central and West regions reduced the risk of default and risk premia modestly in these regions.³⁸

Skeptical readers will be concerned that the hedonic specification I employ arbitrarily assigns labels such as administrative costs and default risks to the included variables.³⁹ In fact, the size variables included to measure normal transactions costs (within markets) imply an adjustment to effective rates that is almost identical to those made by actual lenders. It is particularly important that the specification of default risk fully capture the assessments made by lenders. The adequacy of the encumbrance ratio as a measure of lending risk is underscored by the fact that it has been used as the sole measure of lending risk (in the absence of foreclosure rates) in studies of the modern home mortgage market.⁴⁰ Indeed, I found the encumbrance ratio to be a significant determinant not only of the home mortgage rates for the

³⁸ Eichengreen examines the encumbrance ratios for his sample and finds that they are stable across regions. Because his sample includes all mortgages made on acres, and not only those made on farm land, the average encumbrance per acre and average price of a farm acre that he examined are not strictly comparable. The regional variations in encumbrance ratios for homes and farms in the sample counties are roughly the same as those reported for all counties in the country. U.S. Census Office, "Report on Proprietorship," p. 82.

³⁹ An additional assumption of the hedonic specification is that all characteristics are priced linearly. In the case of the borrower risk measure (the encumbrance to property ratio) the true specification may well be nonlinear for individual loans. This potential misspecification should be mitigated to some extent by the use of county averaged data. In any case, the low risk premia in the North Central regions (relative to Eichengreen's) could not be explained by such a misspecification because borrowers in these regions had the lowest encumbrance ratios in the country.

⁴⁰ See for example: Ostas, "Regional Differences."

postbellum period, but also of farm rates. On the other hand, the other risk factors employed here had a substantially larger impact on farm than on home rates. This result suggests that special factors influenced lenders' assessments of risk in the farm mortgage market, factors that appear to have been captured in the hedonic specification.

What of the variables that I have interpreted as measures of market segmentation? In Table 5 I show that borrowers in the West and South paid on average one to three percentage points more for loans than they would have in a fully integrated market. Differentials of this magnitude suggest that market segmentation could have resulted in a substantial misallocation of mortgage funds and mortgage-financed capital. It is imperative, therefore, that the causes of these differentials be adequately explained.

I interpret the positive effect on average rates associated with the use of out-of-state funds as a measure of the costs involved in interregional fund transfer. The magnitude of these premia (which averaged between 0.4 and 1.0 percent across regions) is consistent with lenders' claims that significant additional costs were incurred when lending in a distant market.⁴¹ Although these costs were a tangible burden on borrowers, they do not confirm the western farmers' allegations concerning eastern monopoly power. Farmers in the West North Central region, the hotbed of agrarian unrest, paid the highest premia for out-of-state funds only because these transfers were relied on so heavily, and not because eastern lenders charged them more per dollar.⁴² In fact, the only beneficiaries of segmentation costs were local lenders who operated in markets which relied heavily on out-of-state funds. They appear to have charged the same effective rates as eastern lenders, although the latter were being compensated in part for the real costs of fund transfer.⁴³ Nonetheless, the bitterest invective was heaped upon the eastern investor.

The regional dummies included in the specification provide evidence of additional, and substantial, unexplained regional variation. Mortgage rates in the West and South were up to 2.5 percentage points higher after adjustment for all lending costs and risks than rates in the Northeast. These fixed regional effects are open to a variety of interpretations, but their magnitudes and patterns appear to reflect the central institutional factor associated with the segmentation hypothesis—the modest and regionally unbalanced role of financial intermediaries. National banks

⁴¹ In addition to the complaints of lenders noted by Bogue, Morton Keller, *The Life Insurance Enterprise* (Cambridge, Mass., 1963), p. 135 documents that some large New York insurance companies were reluctant to invest in the West where rates were much higher because of the costs and expenses involved.

⁴² Recall that the regional interaction term on the out-of-state variable is statistically insignificant and not reported.

⁴³ Bogue, *Money at Interest*, pp. 230–31, found that contractual rates paid to local investors in Nebraska were higher than those paid to nonresidents. He concludes that the agent's commission in the latter case would have brought to effective rates to near equality.

were prohibited from holding mortgages, and state banks appear to have been hardly more involved in the market.⁴⁴ Much has been made of the rapid growth of the mortgage banking sector that peaked in the early 1890s. A more sobering judgment made by D. M. Frederiksen in 1894 claimed that the mortgage banking sector in the United States was small, served a relatively narrow geographic area, and was institutionally immature, especially relative to the mortgage banking sectors in several European countries.⁴⁵ Frederiksen estimated that financial intermediaries were the source of only 27 percent of all mortgage funds in 1890.⁴⁶

Financial intermediaries reduce the costs and risks of mortgage lending in two ways. Institutional investors take advantage of economies of scale in their lending operations which reduce the average costs of gathering information and processing loans. In addition, the large size of institutional portfolios provide an opportunity to diversify risk more effectively both within and between local and regional markets.⁴⁷ In a perfectly integrated market the benefits of intermediation would have reduced the costs of lending to borrowers throughout the country. Instead, it appears that these benefits were distributed unevenly during the postbellum period.

The farm market reveals the pattern dramatically. The fixed regional effects for farm loans in the South Central and West North Central regions were only modestly higher than for borrowers in the East North Central states. Moreover, these regional premia were substantially lower than those on home loans in the same areas. It was precisely in these areas that intermediaries, such as mortgage banks and life insurance companies, aggressively entered the farm mortgage market. As Eichengreen points out, farmers in these regions were benefiting from the activities of the same eastern lenders they so vehemently condemned. However, these innovations do not appear to have been extensive enough to have fully integrated the farm market.⁴⁸

The home mortgage market was, if anything, more severely affected

⁴⁴ Margaret Myers, *The New York Money Market* (New York, 1931), vol. 1, p. 294.

⁴⁵ D. M. Frederiksen, "Mortgage Banking," *Journal of Political Economy*, 2 (Mar. 1894), pp. 229–31. Frederiksen notes that both the French and German mortgage banking sectors controlled substantial portions of those country's banking capital, while in the United States the mortgage banks controlled only 2 percent of total bank capital at their peak in 1890. In addition, the bonds of American mortgage banks were rarely listed and traded on the formal securities market, again in contrast to their European counterparts.

⁴⁶ *Ibid.*, pp. 208–9. Raymond Goldsmith, *Financial Intermediaries in the American Economy Since 1900* (Princeton, 1958), reports that intermediaries supplied 50 percent of home mortgage and 14 percent of farm mortgage funds in 1900. These estimates appear to be consistent with Frederiksen's.

⁴⁷ Neither Eichengreen's specification nor the one employed here allows for the potential effects of risk diversification by mortgage lenders. Instead, it is assumed that the risk of the mortgage loan to the lender is a function of the characteristics of the loan itself and not its covariance with the returns of other loans or assets the investor might have held.

⁴⁸ Davis, "The Investment Market," pp. 384–85 reaches the same conclusion using the mortgage earnings of life insurance companies.

by market segmentation and the absence of intermediation than was the farm mortgage market. The fixed regional effect in the South Central region was more than a percentage point higher for home borrowers than for farmers, and one-half percentage point higher in the West North Central region. The transactions cost premia on small home loans were also greater than the premia on small farm loans. Finally, the vintage effect in the home market reveals substantial upward pressure on rates during the late 1880s that was not present in the farm market. All of these factors suggest that small home borrowers in the western half of the country were the group most affected by market segmentation.

This generalization about the home mortgage market has not been previously noted. Nonetheless, it is consistent with the institutional history of the market. Western farm mortgages were aggressively marketed in the East through a variety of channels, but no similar activity has been documented for the home mortgage market. Life insurance companies that invested in the West were increasingly drawn to the urban market during the 1880s. Their lending activities, however, were concentrated in the largest urban areas, not the smaller towns and cities heavily represented in this sample.⁴⁹ The most important institutional lenders in the residential market, mutual savings banks and building associations, were prevalent only in the Northeast and East North Central regions and restricted their activities to their local markets. In short, there was no institutional channel through which eastern funds could be easily transferred to finance land acquisition and improvement in the smaller cities and towns of the South and West. Frederiksen commented precisely on this problem:

[T]hese [mortgage] companies have been unable advantageously to take up the business of the cities and towns,—a business which is entirely in the hands of local agents who negotiate the loans, and sell the loans chiefly to local investors. The varying rate of interest on lots throughout the country shows also that—even for city loans, and especially in the matter of smaller loans—capital flows from place to place with great difficulty.⁵⁰

It appears that the mortgage rate controversy was not exclusively a farmers' problem or issue. Furthermore, the magnitude of the segmentation which I identify suggests that the pace of urbanization in the South and West, as well as agricultural development, may have been

⁴⁹ Keller, *The Life Insurance Enterprise*, p. 135, reports that the investments of the large New York companies were heavily weighted to the metropolitan area. The Connecticut companies, the most active interregional lenders in the market, concentrated on urban properties in the Midwest, see Lester Zartman, *The Investments of Life Insurance Companies* (New York, 1906), pp. 29–30. The Northwestern, a Milwaukee-based company, allocated 80 percent of its mortgage portfolio to urban loans (primarily in Chicago) between 1880 and 1900, Williamson and Smalley, *Northwestern Mutual*, pp. 57–58.

⁵⁰ Frederiksen, "Mortgage Banking," p. 221.

seriously affected by distortions in the mortgage market. This is a topic worthy of further examination.

IV. CONCLUSION

Mortgage lending was associated with some of the most important components of capital formation in the decades after the Civil War. During the postbellum period rates of economy-wide accumulation reached a historic plateau and were driven by investment in durable capital, especially construction.⁵¹ Three sectors dependent upon mortgage lending for external long-term financing, residential housing, agriculture, and unincorporated business, accounted for over 70 percent of new construction in the 1870s and over 60 percent in the subsequent decade.⁵² Although it has been largely neglected in the financial history of the postbellum period, the mortgage market stood at the center of the processes of regional expansion and urbanization. For these reasons alone its performance is of great importance to understanding late nineteenth-century American growth.

Americans directly involved in the market understood the problem in a more immediate sense. Mortgage rates were substantially higher for borrowers in the West and South and represented a tangible financial burden. The results presented here confirm that these borrowers had reason to complain. Effective rates of interest on both home and farm mortgages were 2 to 3 percent higher in many of the western regions than identical loans would have been in the Northeast. Borrowers in these regions do not, however, appear to have been the victims of eastern monopoly power. Instead, I conclude that home as well as farm borrowers paid high rates in the West and South because of the direct costs of moving funds between regions and the uneven diffusion of financial innovation. The resulting mortgage rate differentials were large enough to imply that the pace of development, both on the farm and in the city, may have been retarded in the affected areas.

In a broader sense my results confirm the traditional view that capital market segmentation was an important part of the landscape of the late nineteenth-century American economy. With few exceptions this literature has been dominated by analyses of the institutional determinants of the performance of the commercial banking system. The conclusions drawn here suggest that much can be gained by similar analyses of the market for both urban and farm mortgages.

Editors' Note: A reply to this article, written by Barry Eichengreen follows on page 757.

⁵¹ The share of new construction in net capital formation increased from 45 percent in the 1870s to over 70 percent by the 1890s. These shares were calculated from data in Simon Kuznets, *Capital in the American Economy* (Princeton, 1961), p. 524.

⁵² Raymond Goldsmith, *A Study of Savings in the United States* (Princeton, 1956), vol. 1, p. 619.

APPENDIX TABLE 6
REGIONAL CLASSIFICATION OF SAMPLE COUNTIES

Northeast (14 counties)

Maine: York
Massachusetts: Franklin, Hampden
New Jersey: Burlington
New York: Albany, Allegany, Dutchess, Fulton, Livingston, Richmond
Pennsylvania: Chester, Lackawanna, Lebanon, Washington

South Atlantic (12 counties)

Georgia: Bartow, Houston (no home mortgages), Twiggs (no home mortgages)
Maryland: Washington
North Carolina: Forsyth, Halifax
South Carolina: Anderson, Colleton, Laurens
Virginia: Augusta, Louisa
West Virginia: Kanawha

East North Central (19 counties)

Illinois: Bureau, Iroquois, Jasper, Morgan
Indiana: Crawford, Hendricks, Lagrange
Michigan: Hillsdale, Ionia, Marquette, Sanilac
Ohio: Athens, Madison, Montgomery, Union
Wisconsin: Brown, Douglas, St. Croix, Waukesha

South Central (17 counties)

Alabama: Greene, Jefferson
Arkansas: Lee, Pulaski, St. Francis
Kentucky: Anderson, Clark, Daviess, McCracken
Louisiana: Caddo, East Baton Rouge
Mississippi: Yazoo
Tennessee: McNairy, Maury
Texas: Bell, Harrison, Tarrant

West North Central (30 counties)

Iowa: Cass, Crawford, Delaware, Johnson
Kansas: Decatur, Jefferson, Lincoln, Lyon, Pawnee
Minnesota: Clay, Goodhue, Polk, Stearns
Missouri: Adair, Bollinger, Cass, Mercer
Nebraska: Brown, Gage, Hayes, Kimball, Thayer, Washington
North Dakota: Burleigh, Dickey, Grand Forks, Ramsey
South Dakota: Beadle, Hughes, Yankton

West (10 counties)

California: Santa Clara, Sonoma, Yolo
Colorado: El Paso, Weld
Montana: Custer, Lewis and Clarke
Oregon: Umatilla, Union
Washington: King
