

Institutionally Constrained Technology Adoption: Resolving the Longbow Puzzle

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Abstract

For over a century the longbow reigned as undisputed king of medieval European missile weapons. Yet only England used the longbow as a mainstay in its military arsenal; France and Scotland clung to the technologically inferior crossbow. This longbow puzzle has perplexed historians for decades. We resolve it by developing a theory of institutionally constrained technology adoption. Unlike the crossbow, the longbow was cheap and easy to make and required rulers who adopted the weapon to train large numbers of citizens in its use. These features enabled usurping nobles whose rulers adopted the longbow to potentially organize effective rebellions against them. Rulers choosing between missile technologies thus confronted a trade-off with respect to internal and external security. England alone in late medieval Europe was sufficiently politically stable to allow its rulers the first-best technology option. In France and Scotland political instability prevailed, constraining rulers in these nations to the crossbow.

The most important thing in the world, for battles, is the archers.
(Philippe de Commines, late medieval chronicler [quoted in Rogers 1993, p. 249])

1. Introduction

On July 19, 1333, amid the Second War of Scottish Independence, Scotland's Sir Archibald Douglas led a massive force of some 15,000 men up Halidon Hill to face England's King Edward III and his army of only 8,000. It was a slaughter—not of the English, but of the Scots.

Edward had spread his men-at-arms in three divisions across the hilltop, flanked by archers armed with longbows. As the Scots proceeded to the hill's bottom to begin their ascent, English longbow arrows rained down “as thickly as the rays in sunlight, hitting the Scots in such a way that they struck them down”

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in hordes, and thinning them to the point of defeat (Rogers 1999, p. 38).¹ As the Scots retreated, mounted English knights hunted down the remainder until nightfall. Scotland's casualties numbered thousands. England's numbered but 14 (Strickland and Hardy 2011, p. 188).

The Battle of Halidon Hill was not the first conflict in which England displayed the longbow's military potency, nor would it be the last. Between 1332 and 1428, in battle after battle the longbow enabled vastly outnumbered English armies to defeat the Scots, the French, and anyone else who dared engage them, garnering the English and their longbow a reputation of near invincibility.²

And therein lies the puzzle. Over the past thousand years, military technology has improved constantly: from heavy horses to armored infantry, pikes and bills, guns and cannons, the *trace italienne*, gun ports, rifles, tanks, and nuclear missiles.³ In each case military innovation led to a temporary advantage for the first adopter, but others quickly followed, and the advantage was eliminated.⁴ Not the longbow. "Discovered" by the English in Wales in the late 13th century, the longbow was adopted by England as its centerpiece missile weapon in the early 14th century and remained so until the middle of the 15th century. Over this 150-year period, other countries in Europe never used the longbow in a major way—despite repeatedly suffering defeats by it.

Historians have long puzzled over why this missile weapon—clearly superior to its alternative, the crossbow—was monopolized by the English for so long (see, for instance, Featherstone 1967; Strickland and Hardy 2011; Sumption 1990). Popular explanations are easily rejected. For example, it is often noted that proficient use of the longbow took years to learn and required continuous practice (Prestwich 1996). And this is true. But if it was worth the effort for the English, who had no comparative advantage in physical size or aptitude in training, surely it was worth the effort for the French and the Scots.

Another possibility is that the French and the Scots believed their repeated defeats were not the result of the longbow but instead were due to other English tactics. Yet the Hundred Years War (1337–1453) lasted longer than a hundred years—plenty of time for England's enemies to learn that their defeats were heavily influenced, if not caused, by the longbow. And learn they clearly did (Sump-

¹ In fact, "[f]ew [Scots] ever reached the English main 'battles.' They were simply shot down by the [English] archers" (Hardy 2012, p. 52).

² The longbow had been used before 1332, in the late 13th century, by Edward I and was used after the end of the Hundred Years War. During the period 1332–1428, however, the longbow was the central missile weapon of English armies.

³ Alongside this technological improvement, military organization has evolved from feudal to modern. Lynn (1996, p. 514) famously divides organizational styles into seven stages: feudal (800–1100), medieval stipendiary (1100–1450), aggregate contract (1450–1650), state commission (1650–1800), popular conscript (1789–1860), mass reserve (1860–present), and volunteer technical (1970–present). See also Allen (2012) for a discussion of the institutional evolution of the English army and navy over the premodern period.

⁴ Lynn (1996, p. 508) argues that in the West, military competition within the context of similar "political, social, economic, and cultural characteristics" has always led to armies that were minor variations of a single military style for a given time period. See also Strickland and Hardy (2011, p. 219).

tion 1990, p. 288; Strickland and Hardy 2011, p. 219). Historical documents show that both France and Scotland were keenly aware of the longbow's effectiveness, and in fact each experimented with archers in their armies to a limited extent. France even contemplated adopting the longbow as a major missile weapon at one point, so as to level the playing field with England—only to cling resolutely to the crossbow after all.

A third possibility is that the longbow, while technologically superior to other medieval missile weapons, was more expensive than technologically inferior substitutes. Yet throughout the age of longbow supremacy, the price of a large crossbow was roughly six times that of a longbow (Hardy 2012, p. 44). The longbow was not only the better weapon, it was cheaper.

Economists may be inclined to think that factor endowments determined military technology adoption: the Welsh relied on forest hunting with the longbow, and this gave them an endowment that inclined them toward longbow use. However, at the height of its use, the archers of England were mostly English, not Welsh. There was no dramatic difference in economic activities between southern England and Normandy or Northumberland and the Scottish lowlands. Yet there was a binary difference in longbow adoption.

Alternatively, economists might consider rent seeking on the part of knights as an explanation for the longbow puzzle. If vast numbers of French knights were a strong political force, they may have thwarted the introduction of archers who would have otherwise encroached on knights' honor and glory. Over a short time period, this hypothesis seems plausible. But after a hundred years of slaughter (many of the victims knights) and losses of vast tracts of territory and tribute, it does not.

Our theory resolves the longbow puzzle by recognizing that military technology adoption is often constrained by institutional context. We argue that, unlike the crossbow, the longbow had three critical features that, in combination, constrained its widespread adoption. First, the longbow required large numbers of archers to be effective, and the number of individuals privately willing to develop longbow skills was never sufficient to meet this demand. Second, as a result, a ruler who wanted to adopt the longbow had to create and enforce a culture of archery through tournaments, financial incentives, and laws supporting longbow use to ensure sufficient numbers of archers. Third, the longbow was cheap and easy to make—in fact, many archers made their own bows—and because of this, where there was a large number of citizens who had been trained in proficient use of the bow, there was a potential army of archers.⁵ A ruler who adopted the longbow by creating a culture of archery thus effectively armed a large segment of his population, which in turn created an opportunity that a usurping noble with an eye on the Crown could exploit. Such a noble could organize effective rebellion against his ruler by utilizing the large number of citizens with the human capital required for proficient use of the cheap and easy-to-produce weapon. A

⁵ Note, however, that a supply of bows in itself was not sufficient to make an army of archers.

ruler therefore had to be confident in his political security to be willing to adopt the bow.

Medieval rulers choosing between missile technologies thus confronted a trade-off with respect to internal and external security. England alone, for a 150-year window in late medieval Europe, was politically stable enough to render the longbow its rulers' optimal technology choice. In contrast, in France and Scotland political instability prevailed, rendering the crossbow the optimal technology choice for rulers in these nations. The obstacle to widespread longbow adoption was not the time it took to train effective archers, a failure to appreciate the weapon's military superiority, the longbow's expense, differences in factor endowments, or rent seeking. Rather, England's enemies chose to adopt the inferior missile weapon over the superior one as a second-best strategy. To test our theory we examine historical evidence on political stability, missile-weapon reliance, and relative wealth across countries and over time. The evidence supports our theory.

2. The Longbow

2.1. *The War Bow*

A longbow is just that: a long bow, around 6 feet in length. A variety of bows have existed since prehistory. Most were made of wood, but they could be strengthened through the addition of horn, sinew, or other materials, creating a composite bow with greater power and range. The medieval longbow, which contemporaries referred to as a "war bow," differed from other composite bows in its specific construction (Hardy 2012, p. 38).

A war bow was best made from yew. Although yew was available in England, it was not as abundant there as in other parts of Europe, and what supply could be found was often of inferior quality compared to yew grown elsewhere. England therefore relied on yew imports to produce many of its bows. Yew importation, typically into London, began in the mid-13th century but became truly substantial in the mid-14th century when Edward III (r. 1327–77) increased England's reliance on the longbow significantly and English demand for yew began to seriously outstrip domestic supply. "The centre of attention" for these imports "was the Alpine regions with their extensive mixed forests, but large numbers of yew staves also came from the far off Carpathian Mountains in Eastern Europe and the Mediterranean forests in Spain, Italy, and Albania" (Hageneder 2013, at 1288).

Figure 1 illustrates a yew trunk cross section and how a longbow stave was carved out of the tree to incorporate both its sapwood and heartwood components. The former was used on the bow's back, which faced away from the archer, taking advantage of the fact that flexible sapwood performs well under tension. The latter was used on the bow's belly, which faced the archer, taking advantage of the fact that hard heartwood performs well under compression. Together the two types of wood created a natural composite bow that, when made from a long and thick stave, was remarkably powerful. Military historians and technicians are

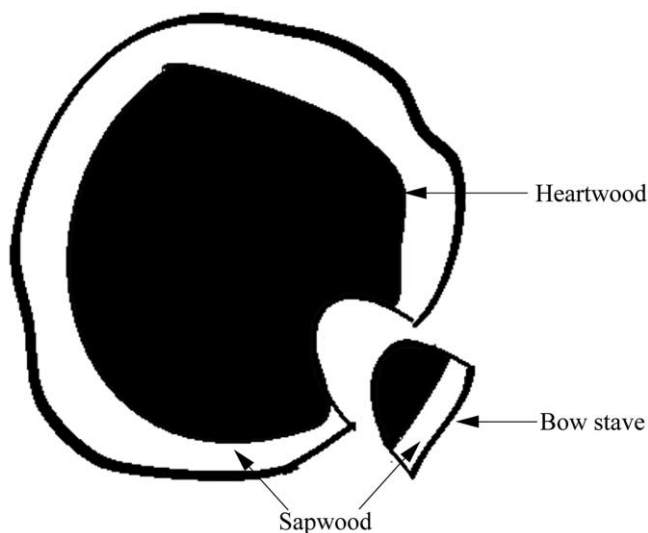


Figure 1. Cross section of yew trunk and bow stave

uncertain about the precise power of late medieval longbows, but it seems likely that draw weights in excess of 120 pounds were common.⁶

England's Edward I (r. 1272–1307), often called the Father of the Longbow, came upon the weapon during his conquest of Wales (Hardy 2012, p. 41). Initially Edward I developed a small force of English and Welsh archers to complement his infantry and mounted knights, but he soon had thousands of archers in his army (Hardy 2012, p. 46). His first major use of archers was in the Battle of Falkirk (1298) against the Scots, led by William Wallace. The Scots formed tight squares armed with long spears to defend against cavalry. Ironically, some of these squares had unprotected archers stationed outside them. Edward I overran the latter with his cavalry and then used his bowmen to decimate the Scottish squares until his forces could penetrate.⁷

Between the Battle of Falkirk and the Battle of Neville's Cross (1346), the English fought nine battles against the Scots (and one internally between Edward II and Thomas of Lancaster).⁸ The longbow was used in various ways and degrees during these battles, but by the time of Edward III and the first part of the Hundred Years War (the Edwardian phase) the English had perfected the longbow

⁶ See Hardy (2012, pp. 213–36) and Strickland and Hardy (2011, pp. 408–14) on various power tests done on the bows recovered from the *Mary Rose*, a naval ship of Henry VIII's that sank off Portsmouth in 1545 and contained 250 longbows and 6,000 arrows. Tests of these bows reveal draw weights ranging from 110 to 185 pounds.

⁷ As effective as the longbow was, it had to be used in conjunction with men-at-arms and other forms of protection. The longbow by itself was never sufficient for victory.

⁸ These battles were Falkirk (1298), Methven (1306), Loudoun Hill (1307), Bannockburn (1314), Myton (1319), Stanhope Park (1327), Dupplin Moor (1332), Halidon Hill (1333), and Neville's Cross (1346).

tactical form. This form involved smaller armies of dismounted knights and men-at-arms holding a defensive position on high ground, flanked by large numbers of archers (Strickland and Hardy 2011, p. 36).⁹ As the enemy army approached, the archers would attack with a thick storm of arrows. The thinned-out enemy was then engaged by the men-at-arms.¹⁰

2.2. *Crown Support for the Longbow*

The thick storm of arrows required for the longbow's successful military use required a large number of archers proficient in its use. The longbow took years of continuous training to master. Not only was there the matter of the physical strength necessary to draw 120-plus pounds with one arm over and over again, but because the longbow arrow was drawn to the ear, aim was largely a matter of intuition rather than sight. Thus, if war erupted, it was not possible to recruit a company of men untrained on the longbow and train them to use the weapon quickly. A stock of proficient archers had to already be in place, prepared to serve.

Private incentives to develop the human capital necessary for proficient use of the longbow were weak for most English citizens. Apart from hunting, longbow skills deployed in conjunction with large numbers of archers had little value outside military application. Ensuring a stock of proficient archers therefore required substantial effort and support from the English Crown aimed at creating a culture of archery among its citizens (Featherstone 1967, p. 46). Among the most significant manifestations of this effort were the laws and decrees that English kings enacted encouraging, and often compelling, longbow usage.

The first such law was the Assize of Arms of 1242, which made bow ownership compulsory for men who owned land worth more than 40 shillings, a status that encompassed the yeoman class (Loades 2013, pp. 34–35). In 1363 Edward III went much further. He made universal, weekly archery practice compulsory and made alternative sporting activities, which might compete with time spent practicing the bow, illegal (Loades 2013, p. 26): “[E]very able bodied man on feast days [including Sundays] when he has leisure shall in his sports use bows and arrows . . . and shall learn and practise the art of shooting, forbidding all and singular on pain of imprisonment to attend or meddle with hurling of stones, loggats, or quoits, handball, football, club ball, cambuc, cock fighting or other vain games of no value.” Similar legislation was repeated throughout Edward III's reign, then by Richard II (r. 1377–99), by Henry IV (r. 1399–1413), and again under Edward IV (r. 1461–70, 1471–83) (Green 2014, p. 135; Pickering 1762, 2:302, 2:408–9, 2:444–46, 2:481–82).

To ensure that bows were abundantly available to his citizens and that archers were abundantly available to him, beginning in 1357 Edward III enacted laws prohibiting the export of finished bow staves, and beginning in 1365 he forbade

⁹ Archers wore minimal armor—often no more than padded leather garments. They therefore required protection in the form of sharp stakes pounded into the ground, ditches, and men-at-arms.

¹⁰ At this point in battles, the archers (now out of arrows) often engaged in hand-to-hand fighting with swords, bills, axes, and similar weapons.

archers from leaving England without royal license (Green 2014, p. 135; Loades 2013, p. 14). In 1472 Edward IV introduced import regulations supporting the longbow, which required merchants to import a minimum number of bow staves with every shipment of other cargo they carried to England, as did Richard III (r. 1483–85) in 1483 (Pickering 1762, 3:408–9; 1763, 4:18). Edward IV also regulated the price of the weapon (Pickering 1762, 3:460–61).

While outside our period of interest encompassing the Hundred Years War, the longbow legislation of England's Tudor kings also evidences the critical importance of a centralized effort to support the culture of archery required for effective longbow use. Henry VII (r. 1485–1509), for example, passed laws banning crossbow shooting and established longbow price ceilings (Pickering 1763, 4:27, 4:84). And Henry VIII (r. 1509–47) repeated his pre-Tudor predecessors' laws compelling longbow ownership, mandating longbow practice (at a minimum distance, no less), banning crossbow ownership and shooting, and prohibiting other activities that competed with longbow practice (Pickering 1763, 4:111, 4:118, 4:134, 4:141, 4:181; Davis 1988, p. 296).

English kings' efforts to support longbow usage among their citizens were not limited to legislation supporting the bow. To further encourage a culture of archery, Edward III held contests and festivals for the art of shooting on feast days. He also introduced indentures to lords to raise their own troops, who would have a right to share in prizes captured in battle. These semiprivate companies were the early beginnings of the military purchase system and effectively made archers (and men-at-arms) residual claimants on battle, which financially incentivized longbow proficiency by creating opportunity for archers to amass riches (Featherstone 1967, p. 62; Prestwich 1996, p. 92).

2.3. *Technological Superiority*

Table 1 presents information about England's major battles with its late medieval enemies, Scotland and France, between 1298 and 1453. These data include 25 battles for the century and a half spanning the reigns of Edward I to Henry VI—the era of longbow supremacy. In varying degrees, these battles pitted English armies with longbows against French and Scottish armies with crossbows.

The data in Table 1 furnish striking evidence of the longbow's technological superiority over the crossbow on the battlefield. On average, England's armies were outnumbered by their enemies by a factor of 1.56 to 1. Despite this, England was victorious nearly two-thirds of the time. These victories reflect battles in which England often faced daunting odds—sometimes absurdly so. They include the Battle of La Roche-Derrien, where the French outnumbered the English by 6.29 to 1, the Battle of Dupplin Moore, where the Scots outnumbered the English by 5 to 1, and the Battle of Agincourt, where the French outnumbered the English by more than 4 to 1.¹¹ Given such victories, it is easy to understand the longbow's ominous contemporary reputation.

¹¹ The battle of Dupplin Moor was actually between two contestants for the Scottish Crown. Since Edward Balliol was backed and supplied by the English king, we count this as an English victory.

Table I
Major Battles between England and Its Enemies in the Era of Longbow Supremacy

Battle	Year	Enemy	Victor	Forces			English Archers	Source
				English	Enemy	Enemy/English		
Edward I (r. 1272–1307):								
Falkirk	1298	Scots	English	28,700	9,000	.31	1,000	Fisher (2009) Strickland and Hardy (2011)
Methve	1306	Scots	English					
Edward II (r. 1307–27):								
Loudoun Hill	1307	Scots	Scots	3,000	600	.20	1,000	Oliver (2009)
Bannockburn	1314	Scots	Scots	13,000	5,500	.20	1,000	Mackenzie (1989)
Myton	1319	Scots	Scots	15,000	12,500	.83	1,000	Strickland and Hardy (2011)
Boroughbridge	1322	Lancaster	English	4,000	700	.18	1,000	Strickland and Hardy (2011)
Stanhope Park	1327	Scots	Scots					Strickland and Hardy (2011)
Edward III (r. 1327–77):								
Dupplin Moor	1332	Scots	English	2,000	10,000	5.00	1,000	Strickland and Hardy (2011)
Halidon Hill	1333	Scots	English	9,000	14,700	1.63	1,000	Strickland and Hardy (2011)
Morlaix	1342	French	French	2,400	4,500	2.00	1,200	Strickland and Hardy (2011)
Neville's Cross	1346	Scots	English	6,000	12,000	2.00	5,000	Tate (1866); Rollason and Prestwich (1998)
Saint-Pol-de-Léon	1346	French	English	200	500	2.50	120	Strickland and Hardy (2011)
Crécy	1346	French	English	14,000	30,000	2.14	11,000	Ayton (2005); Sumption (1990)
La Roche-Derrien	1347	French	English	700	4,400	6.29	400	Strickland and Hardy (2011)
Poitiers	1356	French	English	6,000	11,000	1.83	2,000	Perrett (1992)
Richard II (r. 1377–99):								
Otterburn	1388	Scots	Scots					Froissart (1903)
Henry IV (r. 1399–1413):								
Homildon Hill	1402	Scots	English	17,000	10,000	.59	7,000	Strickland and Hardy (2011)
Shrewsbury	1403	Percy	English	14,000	7,000	.50	2,500	Strickland and Hardy (2011)
Henry V (r. 1413–22):								
Agincourt	1415	French	English	5,900	25,000	4.24	5,000	Curry (2000)
Henry VI (r. 1422–61, 1470–71):								
Cravant	1423	French	English	4,000	8,000	2.00	2,000	Smith and DeVries (2005)
Verneuil	1424	French	English	9,000	15,000	1.67	4,000	Strickland and Hardy (2011)
Rouvray	1428	French	English	1,700	3,500	2.06	1,000	Strickland and Hardy (2011)
Sark	1448	Scots	Scots	6,000	4,000	.67	2,000	Rose (2002)
Formigny	1450	French	French	4,300	3,000	.70	2,080	Strickland and Hardy (2011)
Castillon	1453	French	French	6,000	8,500	1.42	2,000	Wagner (2006)

Note. At the battle of Dupplin Moor, the Scottish Edward Balliol was supported by England.

The data in Table 1 testify impressively to the longbow's superiority over the crossbow. Nevertheless, they manage to underestimate that superiority significantly.¹² Looking only at English battles that actually occurred neglects the one-sided nature of warfare during the era. It ignores battles that did not occur because England's enemies, fearful of being routed by the bow, refused to take part. Because of the longbow's battlefield dominance, the typical military strategy of the French and the Scots was to not engage in battle with the English. Major battles in which the English took up position and then were attacked by the enemy were exceptions to the rule of the enemy retreating inside castle walls when confronted with English hostility.¹³ Edward III's infamous *chevauchée* tactic of pillaging and looting the French countryside, for example, was designed not so much to enrich the English but to force the French to come forth and fight.¹⁴

The longbow's potency reflects the significantly superior rate of fire it enjoyed, which was achieved at minimal expense in terms of relevant power.¹⁵ The reloading time of the longbow was such that archers were able to fire an estimated five to 15 arrows per minute.¹⁶ The crossbow, in contrast, took three to four times longer to reload, resulting in three to four times fewer rounds fired per minute (Sumption 1990, p. 326).

The crossbow's slowness was a consequence of the different way in which it was fired. Whereas the longbow was drawn with the unaided hand, to span even a small handheld crossbow required the use of one's feet.¹⁷ Before the 15th century, at least, the much faster firing longbow may have rivaled or even exceeded the crossbow in terms of range and penetration power. However, the much larger crossbows of the 15th century—the largest of which were frame mounted—had extraordinary draw weights and thus were more powerful than longbows. The crossbow's already significant speed disadvantage was more severe still in these larger, more powerful incarnations. To span such crossbows required the as-

¹² The longbow was also highly effective in naval battles. In the naval battle of Sluys (1340), for example, "the longbow once again proved to be greatly superior to the crossbow . . . the arrows falling down on the French crews 'like hail in winter'" (Sumption 1990, p. 326). In that battle the French lost 190 of their 213 ships, and between 16,000 and 18,000 French were killed.

¹³ These tactics are similar to English and French naval tactics in the age of fighting sail (c. 1500–1830), when the French avoided battle with the English unless they had overwhelming superiority in numbers (see Allen 2012).

¹⁴ Between 1369 and 1389 there was near-constant fighting between England and France that covered more territory than during any other period of the war. This fighting mostly involved English marches through France without any decisive victory. As Palmer (1972, p. 6) puts it, "The English leaders knew that any army they chose to put into the field could march through France with near impunity." In the end, however, this strategy proved successful for the French, who would simply retake territory the English left behind with only small forces to hold it.

¹⁵ The longbow was also flexible in tactics. It could be used offensively in cavalry and missile attacks (for example, at Falkirk) or defensively with pike and shot (for example, at Agincourt) (Rogers 1993, p. 251).

¹⁶ In the historical literature, there is considerable variation in the longbow's estimated rate of fire. Most historians, however, would agree on an average rate of fire of 12 arrows per minute. When combined with a large number of archers, the firepower produced was remarkable. At Agincourt, for instance, 1,000 arrows flew every second.

¹⁷ The drawing of crossbows was assisted, eventually, by an ancillary mechanical device, such as the belt and hook or windlass.

sistence of cumbersome mechanical devices, such as the spanning wheel or the cranequin.

More powerful but slower-firing crossbows were developed in response to advancements in body armor that improved its resistance to missile penetration and became widespread in the late 14th century. While longbows' draw weights were necessarily limited by human strength, crossbows—which could be spanned by mechanical devices, and by the late 14th century were often constructed of steel rather than wood—did not face this limitation.¹⁸ Still, for most of the era of longbow supremacy, trading speed for power, as the crossbow did, was a poor bargain.

Plate armor that could be penetrated by large crossbows, but was impenetrable by longbows, was uncommon in Europe until about 1380—the better part of a century after the era of longbow supremacy had begun and well into the Hundred Years War. Instead, “[f]rom the early Middle Ages to at least the mid-14th century the basic form of defence for the well-armed warrior was the hauberk or mail shirt” (Strickland and Hardy 2011, p. 267). When used with the small metal bodkin arrowhead, a longbow with a draw weight of 160 pounds was capable of penetrating mail. Moreover, what plate armor could be found before 1380 was typically made of wrought iron, not the more penetration-resistant steel from which successor plate armor was made, and the longbow was powerful enough to penetrate this armor too (Strickland and Hardy 2011, p. 274). Because of this, prior to the late 14th century, in practice the crossbow's potential draw-weight advantage was often moot.

Nor did the longbow trade substantial range for its substantial speed advantage. Both longbows and crossbows of the late medieval period could fire missiles an impressive distance. A longbow with a draw weight of 160 pounds had a range of up to 300 yards. The average 15th-century crossbow, by comparison, had a maximum range of perhaps 375 yards (Strickland and Hardy 2011, p. 122).

While there was certainly a place for both types of missile weapons in any late-medieval arsenal, it is equally certain that, for the purposes of winning conflicts on the open battlefield, the longbow's technological superiority warranted it a major place, if not the central one. As Rogers (1998, p. 42), a military historian, puts it, the longbow was a “killing machine.” English military success in this era “cannot be satisfactorily explained without reference to the development of the longbow” (Rogers 2011, p. 341).¹⁹ Indeed, remarkably, it was not until the introduction of the Gatling gun in the mid-19th century that a missile technology rivaling the medieval longbow in terms of speed and accuracy was invented (Churchill 1956, p. 332).²⁰

¹⁸ While more powerful than their wooden counterparts, steel crossbows had several drawbacks. Steel crossbows could lose strength if poorly tempered and often had difficulty firing in cold temperatures (Strickland and Hardy 2011, pp. 121–22).

¹⁹ Fearful of falling into “technological determinism” with the longbow, DeVries (1997, pp. 462–64) argues that despite its effectiveness, it was not an “invincible killing machine.” Rogers disagrees.

²⁰ Benjamin Franklin argued in 1776 that the Americans should adopt the longbow because of its ease of use and rate of fire, the better visibility afforded by the lack of gun smoke, the visual terror

England's victories against its late medieval enemies, such as at the Battle of Crécy in 1346, where the French outnumbered the English by more than 2 to 1, evidenced "the technical superiority of the longbow over the crossbow" in a manner that "was never more convincingly demonstrated" (Sumption 1990, p. 531). Still, England's enemies refused to put themselves on an even playing field with their foe by adopting the longbow as a major missile weapon. Although they "were consistently defeated in most of the major engagements" with England, they clung steadfastly to the technologically inferior crossbow and thus "had not, in tactical terms, succeeded in either restoring the military equilibrium or tilting it in their favour" (Strickland and Hardy 2011, p. 240).

3. An Institutional Theory of Military Technology Adoption

In the neoclassical model, a production function embodies the best available technology, and, given a set of prices, producers arrive at a cost function that achieves a given level of output at minimum cost. Producers who do not use technologically superior production methods do not minimize cost and experience losses that eventually drive them from their industries. In the case of military technology, such cost-minimizing pressures are typically felt quickly, leading to widespread and rapid adoption of superior technology. Because of this, military innovations seldom offer more than a short-term advantage to their initial adopters (Lynn 1996).²¹ The longbow presents a puzzling exception to this rule. As described above, in open-field confrontations the bow was clearly the most efficient weapon, and to devastating effect. Yet its adoption was limited to England.

The key to resolving this puzzle is recognizing that technology adoption may be constrained in such a way that first-best technology is second-best inferior. The presence of network externalities, for example, may create a path dependency whereby a better technology remains unused (Katz and Shapiro 1986). Alternatively, governments may create barriers that hinder technology adoption, such as when they seek to protect politically valuable private interests that would be damaged by greater reliance on superior, competing technology (Tullock 1989).

Our concern is with a still-different potential constraint on first-best technology adoption, which is of special importance in the context of military weaponry: the effect that adoption may have on a ruler's political security.²² A military technology that dominates in battle with foreign enemies but undermines a ruler's domestic position of power is unlikely to be adopted by a ruler who seeks to retain his position.

The longbow was a military technology that posed such a dilemma. Its military

produced by a hail of arrows, the incapacitation of an enemy by a lodged arrow, and the smaller expense of longbows as compared with muskets (Esper 1965, p. 382).

²¹ Aside from the longbow, an exception to this rule is the French navy's failure to adopt the weather "gage" in the age of fighting sail, at great loss to the French (see Allen 2002).

²² This institutional constraint has been ignored by economists, but "for the broader questions of history, institutional development is simply more important than technical innovation" (Lynn 1996, p. 507).

superiority depended on its use by a large number of archers, which required an interested ruler to train a sizable population of citizens on the bow and to encourage its continual practice. A handful of archers could not produce the thick storm of arrows needed to thin an advancing enemy, and an unpracticed archer could not draw a bow's 120-pound-plus draw weight, let alone do so quickly, repeatedly, and with accuracy. The longbow was also cheap and could be easily produced by almost anyone.

These features of longbow technology had two important implications for those interested in adopting it. First, centralized efforts were necessary to create a culture of archery. As shown above, these efforts in England consisted of laws supporting bow ownership and practice, restrictions on competing leisure activities, subsidies for bows, and festivals and tournaments focused on archery skills. Because of this, the longbow could be adopted only by, or with the permission and support of, a nation's ruler, who alone wielded the authority and resources required to undertake such efforts. Indeed, given the nature of longbow technology, to have even attempted to adopt the longbow without his ruler's permission, a noble, for example, would have needed to successfully hide the fact that he was continuously training large numbers of archers for years—a highly improbable proposition.

Second, conditional on a nation's ruler adopting longbow technology, a usurper noble with an eye on the Crown, or a prince interested in independence for his territory, could lead an effective rebellion against his ruler by supplying the inexpensive weapon to large numbers of citizens, whose ruler-sponsored training and practice with the bow had made them proficient archers.²³ Thus, to be willing to develop longbow use in his country, a ruler had to be confident that his efforts would not be turned against him.

With the crossbow things were different. In addition to being inferior in battle, the crossbow was expensive to purchase, often operated by professional mercenaries, and, because of its complex mechanical firing mechanism, infeasible for all but specialists to make. Such features rendered the crossbow an exceptionally difficult weapon for a noble with an eye on the crown to supply to citizens for the purposes of rebellion en masse (Strickland and Hardy 2011, p. 115). Because of this, while adopting the crossbow meant probable defeat in battles with foreign enemies, it posed little threat to a ruler in terms of creating the conditions required for a domestic rebellion that would depose him from power.²⁴

²³ At the battle of Courtrai, for instance, the small principality of Flanders was able to muster an army of archers larger than the army of the entire kingdom of France, which consisted of knights and men-at-arms (Rogers 1993, p. 252). In this sense, a weapon like the longbow allows for the military enfranchisement of commoners, which institutionally constrains the ruler.

²⁴ A longbow-equipped rebellion against a longbow-equipped king would likely end in the latter's defeat. The probable victor would depend strongly on which side had the larger number of archers, and given the longbow's cheapness, rebel archers could outnumber the king's. Hence, a king would adopt the longbow only if he were politically secure. In contrast, given the expense of crossbows, a crossbow-equipped rebellion against a crossbow-equipped king was very unlikely. Hence, a politically insecure king could adopt the crossbow.

3.1. Model

To explore this trade-off in military technology adoption explicitly, we develop a model of rulers' technology choice. Our model's simplified features render it only illustrative of the more complex set of choices that nations' rulers actually confronted. For example, we treat rulers' technology choices as binary, whereas a more realistic rendering would treat them as continuous. However, our model permits a clearer and more intuitive picture of the central dilemma that rulers faced and provides testable implications for their decisions about the adoption of military technology.

Consider two countries governed by two rulers, F and E, with wealth $W_F > 0$ and $W_E > 0$, respectively. Each ruler lives under one of two exogenous states of the world, $\omega = \{\text{Stable}, \text{Unstable}\}$. In a stable state, a ruler's subjects never rebel against him.²⁵ In an unstable state, a ruler's subjects rebel against him with certainty if military technology is available to them—ousting him from power and appropriating his entire wealth—and do not rebel against him with certainty if such technology is unavailable to them. Let $\omega = \text{Stable}$ denote the former state and $\omega = \text{Unstable}$ denote the latter, where ω is publicly observable.

Rulers confront the specter of war with one another. There are two military technologies available to them for engaging such wars: T^L and T^C , where T^L is technologically superior to T^C for warring.²⁶ A ruler adopts a military technology by training a large population of his citizens in its use.²⁷ Let p be the probability of victory for a ruler for a given distribution of military technology. If one ruler adopts the superior technology and the other adopts the inferior one, the former ruler is victorious in war with probability $p > .5$. If both rulers adopt the same military technology, whether T^L or T^C , each wins a war with probability .5.

War occurs when either ruler attacks the other. If rulers war and F is victorious, F earns $\tau W_E + W_F$ and E earns $(1 - \tau)W_E$, where $\tau \in (0, 1]$ is some fraction of the loser's wealth that the victor secures in ransom.²⁸ Likewise, if rulers war but instead E is victorious, E earns $\tau W_F + W_E$ and F earns $(1 - \tau)W_F$. If neither ruler attacks the other, each keeps his initial wealth.

The technology T^C is expensive and so, if adopted, does not become available to subjects. The technology T^L is cheap and so, if adopted, becomes available to subjects, which leads to rebellion when $\omega = \text{Unstable}$. A ruler in an unstable state

²⁵ We do not have in mind a peasant revolt but rather a revolt led by nobles who may use commoners for this purpose.

²⁶ Consider T^L longbow technology and T^C crossbow technology.

²⁷ For the late medieval period, this is a reasonable assumption. The king led armies, dressed for battle, and sometimes fought. The king was personally involved with the finances, tactics, and logistics of the army.

²⁸ In the late Middle Ages, defeat in battle with a foreign nation never led to dethroning—even when a king was captured. It led to ransom instead. For example, King David II of Scotland was captured at the battle of Neville's Cross (1346) and ransomed 11 years later; King John II of France was captured at the battle of Poitiers (1354) and was ransomed in 1360 (Prestwich 1996, pp. 100–104). On the economics of ransoming, see Frey and Buhofer (1988) and Leeson and Nowrasteh (2011). In contrast, defeat in a civil war could lead to death or imprisonment and dethroning, as was the case with Henry VI (imprisoned) and Richard III (killed in battle).

of the world who chooses the superior technology therefore earns nothing. Such a ruler, who loses power and all his wealth, can neither attack nor be attacked by the other ruler. Thus, if a ruler in an unstable state of the world chooses the superior technology, the game ends.

Rulers F and E play a two-stage game of complete and perfect information. In the first stage rulers make their arms decisions: each chooses a military technology to adopt. In the second stage rulers make their attack decisions: each chooses whether to militarily assault or abstain from assaulting the other ruler.

3.2. Arms Decision

Finding rulers' equilibrium decisions regarding arms is straightforward. First consider a ruler's decision when he occupies an unstable state of the world. There are four possible combinations of military technologies that may result from the ruler's and his adversary's choices of such technologies: both rulers adopt the superior technology, E adopts the superior technology and F adopts the inferior technology, E adopts the inferior technology and F adopts the superior technology, and both rulers adopt the inferior technology. Each possible combination is associated with an expected payoff of war or peace for each ruler, which depends on the state of the world each ruler inhabits. Table 2 presents F's payoffs under each possible combination of military technologies when F occupies an unstable state of the world.

Inspecting Table 2 reveals that F's dominant strategy is to adopt T^C . Regardless of the state of the world E occupies or the military technology E adopts, when $\omega_F = \text{Unstable}$, F maximizes his (expected) payoff by adopting T^C . The payoffs in this game are symmetric, so this is also true for E when $\omega_E = \text{Unstable}$. A ruler who occupies an unstable state of the world, therefore, always chooses the inferior military technology.

Next consider a ruler's arms decision when he occupies a stable state of the world. There are again four possible combinations of military technologies that may result from the ruler's and his adversary's choices of such technologies. And again, each possible combination is associated with an expected payoff of war and peace for each ruler, which depends on the state of the world each ruler inhabits. Table 3 presents F's payoffs under each possible combination of military technologies when F occupies a stable state of the world.

Inspecting Table 3 reveals that F's (weakly) dominant strategy is to adopt T^L . Regardless of the state of the world E occupies or the technology E adopts, when $\omega_F = \text{Stable}$, F maximizes his (expected) payoff by adopting T^L . This is also true for E when $\omega_E = \text{Stable}$. A ruler who occupies a stable state of the world, therefore, always chooses the superior military technology.

3.3. Decision to Attack

Because a ruler adopts T^L only if he occupies a stable state of the world and adopts T^C only if he occupies an unstable state, determining when he will attack

Table 2
Ruler F's Arms-Decision Payoffs When $\omega_F = \text{Unstable}$

ω_E, T_E	T_F	War	Peace
Unstable, T^L	T^L	0	0
Unstable, T^L	T^C	W_F	W_F
Unstable, T^C	T^L	0	0
Unstable, T^C	T^C	$.5(\tau W_E + W_F) + .5(1 - \tau)W_F$	W_F
Stable, T^L	T^L	0	0
Stable, T^L	T^C	$(1 - p)(\tau W_E + W_F) + p(1 - \tau)W_F$	W_F
Stable, T^C	T^L	0	0
Stable, T^C	T^C	$.5(\tau W_E + W_F) + .5(1 - \tau)W_F$	W_F

Table 3
Ruler F's Arms-Decision Payoffs When $\omega_F = \text{Stable}$

ω_E, T_E	T_F	War	Peace
Unstable, T^L	T^L	W_F	W_F
Unstable, T^L	T^C	W_F	W_F
Unstable, T^C	T^L	$p(\tau W_E + W_F) + (1 - p)(1 - \tau)W_F$	W_F
Unstable, T^C	T^C	$.5(\tau W_E + W_F) + .5(1 - \tau)W_F$	W_F
Stable, T^L	T^L	$.5(\tau W_E + W_F) + .5(1 - \tau)W_F$	W_F
Stable, T^L	T^C	$(1 - p)(\tau W_E + W_F) + p(1 - \tau)W_F$	W_F
Stable, T^C	T^L	$p(\tau W_E + W_F) + (1 - p)(1 - \tau)W_F$	W_F
Stable, T^C	T^C	$.5(\tau W_E + W_F) + .5(1 - \tau)W_F$	W_F

his adversary (and when his adversary will attack him) is straightforward. In arms-decision equilibrium there are four possible combinations of states of the world rulers may confront, each of which corresponds to a unique combination of military technologies:

1. $\omega_E = \text{Stable}, \omega_F = \text{Stable}$, which means $T_E = T^L, T_F = T^L$;
2. $\omega_E = \text{Stable}, \omega_F = \text{Unstable}$, which means $T_E = T^L, T_F = T^C$;
3. $\omega_E = \text{Unstable}, \omega_F = \text{Stable}$, which means $T_E = T^C, T_F = T^L$; and
4. $\omega_E = \text{Unstable}, \omega_F = \text{Unstable}$, which means $T_E = T^C, T_F = T^C$.

To find the attack-decision equilibrium, all that is necessary is to find the conditions under which rulers attack their adversary, which is accomplished by comparing rulers' expected payoffs of war with their payoffs of peace in combinations 1–4. Each of these (expected) payoffs can be found by identifying the appropriate combination of state and technology for each ruler in Tables 2 and 3.

In combination 1, F attacks E when $.5(\tau W_E + W_F) + .5(1 - \tau)W_F > W_F$. Algebraic manipulation reveals that this is when $W_E > W_F$. The symmetric result holds for E. That is, E attacks F in combination 1 when $W_E < W_F$. A ruler who adopts superior technology and whose adversary also adopts that technology therefore attacks his adversary only if his adversary is wealthier than he. This re-

sult is intuitive. When the odds of victory in war are even, it is sensible to attack your adversary only if he has more than you.²⁹

In combination 4, the situation is the same. Here rulers adopt the inferior technology, but because both do so, the expected payoffs are identical to those in combination 1. Thus, a ruler who shares military technology with his adversary—be it superior or inferior—attacks his adversary as long as his adversary is wealthier than he.

In combination 2, F attacks E when $(1 - p)(\tau W_E + W_F) + p(1 - \tau)W_F > W_F$. Algebraic manipulation reveals that this is when $p/(1 - p) < W_E/W_F$. A ruler who adopts inferior technology and whose adversary adopts superior technology therefore attacks his adversary only if the superior technology's advantage over the inferior technology is less than the ratio of his adversary's wealth to his own. This result is also intuitive. The more heavily the odds of victory in war are stacked against a ruler, the greater must be the prospective spoils of war in the event of victory relative to the prospective losses in the event of defeat to render war profitable.

The symmetric result again obtains for E. That is, E attacks F in combination 2 when $p/(1 - p) > W_E/W_F$. A ruler who adopts superior technology and whose adversary adopts inferior technology therefore attacks his adversary only if the superior technology's advantage over the inferior technology is greater than the ratio of his wealth to his adversary's. The more a ruler stands to lose in war in the event of defeat relative to what he stands to gain in the event of victory, the better his odds of victory must be for war to make sense.

In combination 3, the situation is the mirror image of that in combination 2, as the roles of F and E here are simply reversed. Thus, F attacks E when $p/(1 - p) > W_F/W_E$, and E attacks F when $p/(1 - p) < W_F/W_E$. The intuition is the same as above.

3.4. Equilibria

The foregoing two-stage game has four possible equilibria—one for each possible combination of states of the world. These equilibria are characterized in Table 4. As we discuss below, the equilibria in the second and fourth rows of Table 4 are historically relevant for the longbow puzzle and thus for testing our resolution of that puzzle grounded in our theory of institutionally constrained technology adoption.

4. Predictions and Evidence

4.1. Political Stability

According to our theory, a ruler rejects superior military technology and chooses to adopt inferior technology if his domestic position is politically unsta-

²⁹ This is the case provided that wealth has no influence on the probability of victory, as is assumed in our model.

Table 4
Equilibria

ω	T	Attack or Do Not Attack	War or Peace
$\omega_F = \text{Stable}, \omega_E = \text{Stable}$	T_F^L, T_E^L	F attacks if $W_E > W_F$; E attacks if $W_E < W_F$	War if $W_E \neq W_F$
$\omega_F = \text{Unstable}, \omega_E = \text{Unstable}$	T_F^C, T_E^C	F attacks if $W_E > W_F$; E attacks if $W_E < W_F$	War if $W_E \neq W_F$
$\omega_F = \text{Stable}, \omega_E = \text{Unstable}$	T_F^L, T_E^C	F attacks if $p/(1-p) > W_F/W_E$; E attacks if $p/(1-p) < W_F/W_E$	War if $p/(1-p) \neq W_F/W_E$
$\omega_F = \text{Unstable}, \omega_E = \text{Stable}$	T_F^C, T_E^L	F attacks if $p/(1-p) < W_E/W_F$; E attacks if $p/(1-p) > W_E/W_F$	War if $p/(1-p) \neq W_E/W_F$

ble. In contrast, he rejects inferior military technology and chooses to adopt superior technology if his domestic position is politically stable. Our theory therefore predicts that in the era of longbow supremacy (c. 1272–1450), France and Scotland were broadly politically unstable nations compared to England. The historical evidence supports this prediction (Rogers 1993, pp. 250, 251).

Late medieval France was far from the stable and dominant world power it would become in the early modern period. Between 1100 and 1450 France’s borders expanded and receded like the tide, with independent states pocketing the continuously changing territory of the country like tidal pools in the sand. Figure 2 presents four maps of France from 1086 to 1422. The chronic variation in France’s medieval borders, apparent in the figure, reflects the “chronic internal dissension” that plagued medieval France (Strickland and Hardy 2011, p. 218).³⁰ Prior to the conclusion of the Hundred Years War, maps for different years would only show different borders.

In the 12th and 13th centuries, the various kings of France attempted to claim and solidify secular power, legislate, establish kingdom-wide courts, and extend kingship beyond tenuous feudal relations. But their efforts failed, leaving late medieval France in a state of substantial political instability. Although France was often the largest and most powerful state in Europe, until the late 15th century it was plagued by chronic political instability. “The notion of public authority which made civil violence an offence against the state,” for example, “had been well developed in England since the twelfth century but it was only intermittently recognized in France before the fifteenth” (Sumption 1990, p. 23). Indeed, even “[t]he doctrine that the royal domain was inalienable did not become an overt principle of [French] royal policy until the Edict of Moulins in 1566” (Sumption 1990, p. 16).

For nearly the entire longbow period, France was more a nation of principalities than it was a kingdom (Sumption 1990, p. 33). Its regional principalities were “organized internally as kingdoms in miniature and approached independence in their relations with the king, with one another and with external powers” (Le

³⁰ Dissension indeed: in the early part of the period depicted in Figure 2, Henry II (r. 1154–89) controlled more territory in France than the French king (Sumption 1990, p. 72).

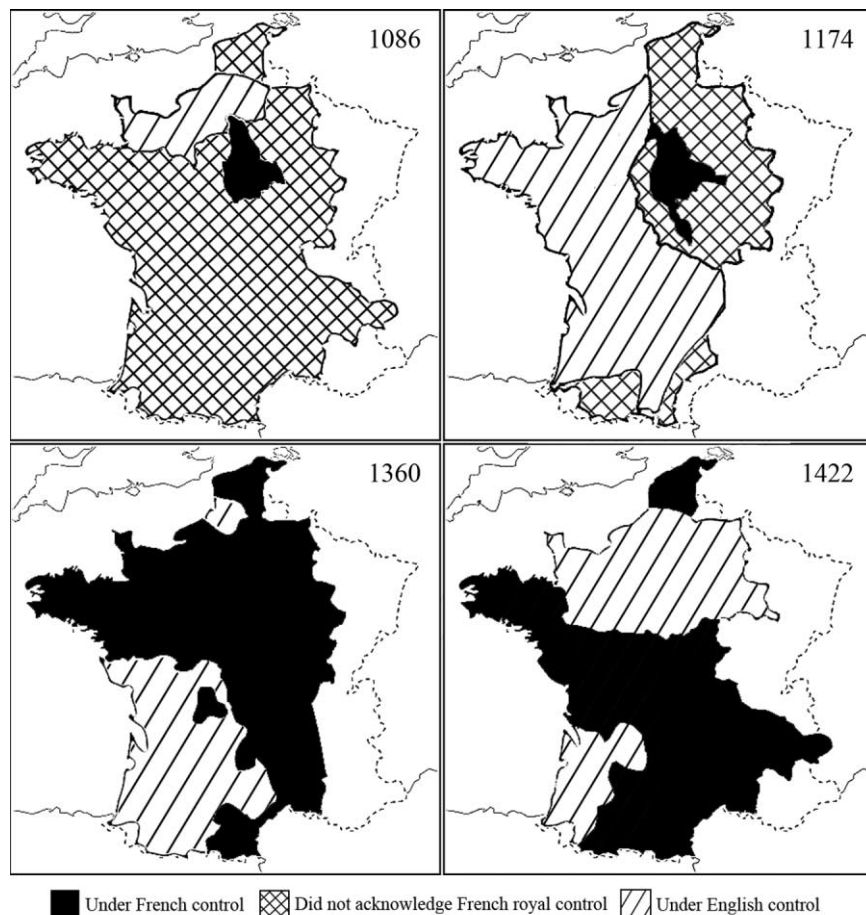


Figure 2. France in the Middle Ages. (Source: UK National Archives, *Uniting the Kingdoms? France* [<http://www.nationalarchives.gov.uk/utk/maps/>]).

Patourel 1965, p. 156). “The land was divided into loose and shifting territories that owed little or no allegiance to any central authority, ruled across large swathes by noblemen who were little more than warlords” (Jones 2012, p. 24). The king’s judges and officials had no authority over the principalities’ inhabitants (Sumption 1990, p. 18). And French nobles in them were wont to shift their allegiance to persons who were not the king, such as when several French lords shifted allegiance to England’s Edward III in 1343.

More troubling still, several of France’s princes rivaled the king. For example, although the Duke of Aquitaine became a vassal to the French king in 1259 under Henry III (r. 1216–72), the Duchy of Aquitaine—held by the English monarch since Henry II’s marriage to Eleanor of Aquitaine in 1152—remained de facto

independent of France until its final conquest in 1453.³¹ Aquitaine had long-standing commercial connections with England, and most of the lords there had allegiance to England, declining to transfer homage to France when Aquitaine became a fief in 1259 (Sumption 1990, p. 75).

The Duchy of Brittany, which occupied the land between England and Aquitaine, was also quasi-independent of the French king. Historically, Brittany was an independent kingdom. In the 12th century the Duke of Brittany became the Earl of Richmond in England. During Brittany's War of Succession (1341–64), Edward III helped win the duchy from France, and by "the end of the fourteenth century, the Duke of Brittany was contesting all but a residual sovereignty in the king of France" (Le Patourel 1965, p. 168).³²

Flanders, too, had great autonomy from the French monarch and strong ties to Germany and England (Sumption 1990, p. 35). In 1384 Flanders united with Burgundy to create a principality in France that fell in and out of French control for over a century. In Champagne, Toulouse, and Normandy the situation was similar. "The duke of Normandy or the count of Flanders," for instance, "might recognize the king as his suzerain and might occasionally attend his court; but they might also make war upon him and among themselves and establish independent relations with countries outside the kingdom" (Le Patourel 1965, p. 181).

Indeed, the entire Hundred Years War can be thought of as an ongoing French civil war (Sumption 1990, p. 37). Although it was fought principally between the Duke of Aquitaine—who was also the king of England—and the king of France, other internal conflicts during the Hundred Years War also plagued France, including the war of independence in Flanders, the war of succession in Brittany, and the reconstruction of Burgundy.

Perhaps the most significant reflection of instability in late medieval French political institutions, however, was Edward III's declaration in 1340 that he was the rightful king of France.³³ Edward III exemplifies the potential problem that a politically unstable ruler faced from a usurping noble with personal access to large numbers of archers. Despite significant military handicaps (distance from Aquitaine, the English Channel, and a smaller army), Edward III (and his descendants) managed to war with France for over a century and at several points came close to overthrowing the French monarch and capturing the royal domain.³⁴

³¹ This fundamental incongruence—that the vassal Duke of Aquitaine was simultaneously the sovereign king of England—was the fountainhead of the dispute in the Hundred Years War. Although the war's roots go back to 1259, and there were battles over territory during the reigns of Edward I and II, war officially broke out in 1337.

³² As Earl of Richmond, the duke never challenged the king of England.

³³ Although political, this was not an empty claim. When the French king Charles IV died suddenly in 1328 with no obvious male heir to succeed him, there was a succession crisis. Edward III was the grandson to Philip IV the Fair through his mother Isabella, and the closest male heir. However, he had no support in France for his claim, and Charles's cousin became King Phillip VI in France. The English claim to the French crown would last, on paper, until 1801.

³⁴ After several significant English victories, the English and French signed treaties that were very favorable for the English. The Treaty of London (1359), signed after the English victory at Poitiers, where Jean II of France was captured by the Black Prince, gave England almost all of western France. The Treaty of Troyes (1420), signed after Henry V's successful campaigns, granted that Henry V

In addition to France's suffering from fragile borders, weak territorial control, and a dearth of nationally encompassing political institutions, the security of individual late medieval French kings was also frail (Wood 1988, p. 5; Major 1994, pp. 5–19). Louis IX (r. 1226–70) had a vassal rebellion and was in constant conflict with powerful nobles, such as Hugh X of Lusignan and Henry III of England (Wood 1988, p. 7). Philip III (r. 1270–85) was generally, and correctly, regarded as a weak and timid king. Beginning with Philip IV (r. 1285–1314), troubles between the French king and the papacy erupted, resulting in a second pope being established at Avignon. Philip IV also had to contend with Edward I and the Count of Flanders, who defeated Philip at the Battle of the Golden Spurs (1302). Louis X's short reign (1314–16) was marked by noble hostility. Philip V's reign (1316–22) began with a succession crisis. And the last Capetian king, Charles IV (r. 1322–28), ended his reign without a male heir, which indirectly led to the Hundred Years War (Rowen 1980, pp. 19–20). No late medieval king of France was ever in a position of political stability that would have permitted the profitable adoption of the longbow. During this time, France's rulers were little more than feudal lords who "focused [their] efforts on the royal domain, a wisp of territory around Paris which was smaller than several of the fiefs" (Henshall 1992, p. 7).

In terms of political instability, late medieval Scotland was similar to France. Like their French counterparts, Scottish kings of this era had limited control over their largely independent nobility (Campbell 1965, p. 193). The nation lacked an independent civil service; it was instead tied completely to the royal household. Most critically, the country was bitterly divided into three warring parts: the English-speaking southeast, the Gaelic-speaking northwest, and the lands that fell between. Control over lands close to the English border was always tenuous, and over the period there were continuous succession issues. As Nicholson (1974, p. 25) summarizes the resulting situation in the country, "[C]hiefship and an emerging clan spirit were of more importance than homage, fealty, the niceties of feudal land law or royal justice," which was weak to say the least.

Scotland was particularly unstable during the 14th century. The Treaty of Birgham (1290) intended for the 6-year-old Edward II (r. 1307–27) of England to marry the granddaughter of Alexander III, the dead king of Scotland. The marriage would have united Scotland and England and settled a succession crisis, but the young Maid of Norway died before the alliance could be sealed. What followed "nearly tore the kingdom [of Scotland] apart" (Jones 2012, p. 326). Immediately, 13 different claimants came forward in the Great Cause to be the king of Scotland. In the end two remained: John Balliol and Robert Bruce. The law sided with Balliol, who was supported by Edward I, but troubles over vassalship led to wars of independence with England and civil war in Scotland. These troubles would manifest in near-perpetual instability for the next 150 years.

Under the politically unstable conditions that prevailed in late medieval

would inherit the throne of France upon the death of Charles VI of France. The premature death of Henry V thwarted the fulfillment of this treaty.

France and Scotland, it would have been regicide for their rulers to adopt the longbow as a major weapon in their military arsenals. Indeed, in a telling passage of his history of Charles VI (r. 1380–1422), the late medieval French chronicler Juvénal des Ursins ([1430] 1841) intimates that, in France at least, this is the very reason why the longbow was not adopted. According to Juvénal des Ursins, longbow adoption in France would have likely precipitated rebellion. The French king came to realize as much, and he abandoned plans for adopting the longbow because of precisely this fear (Juvénal des Ursins [1430] 1841, p. 385; authors' translation):

[I]t was decided that a closer look would be taken at larger cities and that their defenses would be strengthened. It was also put forward that no game would be tolerated but archery or crossbow shooting. After a short period of time, French archers became so proficient in archery that they overcame their fear of shooting the English and they all started practicing archery and crossbow shooting. And in fact, if they got together, they would have been more powerful than princes and nobles. And the King declared that such practice should stop and that there should be only a certain number of archers and crossbow archers in cities and villages. Then the people started playing other games as they did before.

Like France and Scotland, England in the 12th century, most of the 13th century, and most of the 15th century was politically unstable.³⁵ These periods correspond almost exactly to the reigns of several Plantagenet kings. After Henry I's son drowned at sea in 1120, a civil war known as the Anarchy (1139–54) broke out between Henry's daughter Matilda and his nephew, the usurper King Stephen. The final outcome of the Anarchy was the crowning of Matilda's son, Henry II, the first Plantagenet. Henry II ruled over a kingdom that stretched from Scotland to the Mediterranean, but his hold on political power was anything but secure. His wife, Eleanor of Aquitaine, along with each of his many sons, rebelled against him. This included the Great Revolt in 1173–74 between Henry II and his two eldest sons and their followers, reprised by a second revolt by the same contestants in 1183.

Richard I, the Lionhearted, (r. 1189–99), succeeded Henry II but was usurped by his brother John (r. 1199–1216) while on crusade. After Richard I's untimely death from a crossbow bolt, another successional dispute arose, leading to the First Barons' War between 1215 and 1217. John's son Henry III experienced another long reign characterized by instability. In 1258 England came close to civil war, and this manifested fully in the Second Barons' War between 1263 and 1267, during which time Henry III was little more than a puppet king under Simon de Montfort (Jones 2012, p. 276). Thus, prior to Edward I, tensions between the English crown and nobles were such that no English king could have felt secure.

Ironically, the troubles of John and Henry III led to the Magna Carta (1215,

³⁵ During the late medieval period, political instability had two major manifestations. The first involved the overthrow of the king. The second involved the independence of a region under the Crown. English instability tended to manifest as the former, French as the latter, and Scotland suffered both.

1225), the Provisions of Oxford (1258), and the Statute of Marlborough (1267)—all critical legal steps in the early development of Parliament and the separation of Crown from king. When the early constitutional rights were respected, English kings were limited in their ability to act as totalitarians and were more constrained than their Continental counterparts.³⁶ The first English king to recognize and cooperate under this new arrangement was Edward I (Longshanks), and his rule was remarkably stable compared to those of his Plantagenet ancestors.³⁷

Edward I's son Edward II would have no such experience. Within a year of ascending to the throne he had spent the political capital of the Crown and was faced with an armed insurrection of barons (Jones 2012, p. 365). After his defeat by the Scots at Bannockburn, Edward II avoided civil war by allowing his cousin, the Earl of Lancaster, to rule as a quasi regent and subjected himself to a baronial oligarchy based on the Ordinance of 1311. However, in 1321 civil war broke out nonetheless. Afterward Edward II ruled through a reign of terror (1322–26), but he was eventually forced to abdicate in 1327. England was briefly ruled by Edward II's Queen Isabella and her lover Roger Mortimer until the young Edward III reclaimed the crown (Prestwich 1996, p. 78).

Edward III was a king unlike any other in English history: decisive, aggressive, lucky, healthy, well married, and fully aware and accepting of the nascent constitutional rights of his nobles (Sumption 1990, p. 452). His long reign entailed a time of political stability almost unique in late medieval Europe. Unfortunately, his oldest son, the Black Prince, lived long enough to produce an heir in the despot Richard II but died before his father and was never crowned himself. England would have to wait until Henry V (r. 1413–22) for another period of political stability. Most of the 15th century, however, would be dominated by the opposite. The usurper Henry IV spent much of his reign fending off rebellions, and Henry VI's reign (1422–61, 1470–71) ended with the Wars of the Roses (1455–87).

Thus, like its Continental counterparts, for most of the 12th through 15th centuries England struggled through troubled times.³⁸ However, unlike France and Scotland during those centuries, during the reigns of Edward I, Edward III, Henry V, and the early years of Richard II and Henry VI, England enjoyed a 150-year window of relative political stability—a period coextensive with that of the longbow's adoption for the military (Sumption 1990, p. 56).³⁹ Although this win-

³⁶ Rogers (1993, p. 510) extends our longbow hypothesis: “[T]here can be little doubt that a connection does exist, and that the military enfranchisement of the non-aristocratic population contributed to its increased political influence.” Thus, a ruler does not use the longbow unless politically stable, but the use of the longbow feeds back into political stability. The longbow may be responsible for the final, and binding, reissue of Magna Carta in 1297.

³⁷ Edward I called the Model Parliament in 1295, which became the template for later parliaments and helped establish the contractual nature of taxation between the barons and king.

³⁸ Arguably, however, even in these centuries England was more politically stable than France or Scotland in terms of its borders and its political identity. The medieval English considered themselves to belong to a single community, their institutions operated uniformly across the country, and the development of Parliament allowed English kings to tax with the consent of their subjects (Sumption 1990, pp. 39–49).

³⁹ Historians disagree about whether the longbow existed before the late 13th century. Hardy (2012), Strickland and Hardy (2011), and others are adamant that the longbow had been around for

dow was interrupted by periods of instability under Edward II, the late reign of Richard II, and Henry IV, the degree of overall political insecurity in England between around 1272 and 1450 was substantially lower than that experienced by English rulers before or closely following this period and by their late medieval contemporaries in France and Scotland.⁴⁰

4.2. *English Reliance on the Longbow and Political Stability*

The variation in England's political stability during the longbow era described above supplies an additional way to test our theory of the longbow puzzle: by investigating the relationship between English political stability and English longbow usage over time. The number of archers in England could not be turned on and off like a faucet because human capital does not depreciate instantly. Thus, if a ruler's predecessor had adopted the longbow, eliminating its immediate usage among the populace was not possible.⁴¹ Nevertheless, it was possible for a new ruler confronting greater political instability to reduce longbow usage in his nation by doing less to encourage archery. Our theory therefore predicts that during spells of greater English political instability during the 150-year window of general stability, we should observe reduced reliance on the longbow in England. And we do.

Before considering the evidence for this prediction, however, it is useful to consider the question of why a politically secure English king would adopt the longbow, or increase reliance on it, when doing so could contribute to the instability of less politically secure successor English rulers. In particular, why did Edward III substantially increase his reliance on the longbow if he could not be sure that his heir apparent would also be politically secure?

Two important considerations suggest an answer to this question. First, Edward III was undoubtedly aware that his successor could scale back longbow usage significantly were he to face greater insecurity, and as we show below, this

centuries prior. Rogers (2011) maintains that any earlier bows were technically not longbows. Much of this debate hinges on the semantics of naming a bow 5 feet in length. Our theory offers a possible explanation for the ambiguous evidence of the longbow's existence before the mid-13th century: the longbow did exist; however, it was simply never used en masse until Edward I because of a lack of political stability. Hence, there is evidence of early bows but no evidence of the bow in a major military role prior to Edward I.

⁴⁰ One measure of political instability is the import and export of mercenaries. Politically unstable kings imported mercenaries for their protection and army staff because they could not trust their own lords or subjects. There were large influxes of mercenaries into England during the Baron Wars of the 13th century (Prestwich 1996, pp. 149, 151). On the other hand, "Edward I made virtually no use of mercenary troops," and during the reign of Edward III, England was a major supplier of mercenaries to the armies of Europe (Prestwich 1996, pp. 153, 154). Likewise, the various principalities of France imported mercenary archers from England throughout the 14th century. Even Edward III, as Duke of Aquitaine, brought in English archers and did not encourage archery among his Continental subjects.

⁴¹ This is exacerbated by the fact that, as we discuss below, the periods of political instability did not correspond to the entire reign of each of these rulers. For Richard II and Henry VI, the early portions of their reigns were relatively stable. Likewise, the later part of Henry IV's reign was relatively stable. A shorter window of instability makes it more likely that longbows were present during the troubled times.

is precisely what happened. Edward III's successor—his grandson, Richard II—who enjoyed significantly less stability at the end of his reign, sharply reduced England's reliance on the longbow during his reign. Second, if he was at all like other 14th-century Europeans, Edward III discounted the future heavily. According to Clark (1998), discount rates in the 13th and 14th centuries were approximately 10 percent. This implies that Edward III, and other English rulers of this period, would have had little interest in prospective events more than 20 or 30 years into the future. Given that Edward III's reign spanned 50 years, it is therefore unsurprising that his decision to increase reliance on the longbow did not reflect the potential future effects on his successors.

Figure 3 depicts the ratio of English bowmen to total English forces for battles during the longbow era for which data are available.⁴² These battles span the years 1314–1453. While it is important to keep in mind that this period encompasses the Black Death of 1347–53 and the successor plagues of the later 14th century, the figure reveals a clear pattern: England's reliance on bowmen rises and falls with England's political stability over time.

Bowmen occupied a small role in the armies of Edward II (r. 1307–27), whose reign, as discussed above, was troubled by instability. Bowmen occupied a central role during the first 50 years of the Hundred Years War in the armies of Edward III (r. 1327–77), whose reign was exceptionally stable. Reliance on bowmen declined sharply during the unstable reigns of Richard II (r. 1377–99) and Henry IV (r. 1399–1413) and then rose rapidly under the stable reign of Henry V (r. 1413–22). Bowmen occupied a smaller but still significant role in the early, stable part of Henry VI's reign (1422–61). Finally, in the later part of his reign, as England entered the period of the Wars of the Roses (1455–87) and thus exited its 150-year window of general stability, reliance on the longbow declined precipitously.

A similar relationship between English longbow reliance and English political stability over time is also observed in other actions that England's rulers took, or did not take, to encourage longbow use. "In Edward II's reign," for example, the military was administered "with the emphasis placed on defensive equipment rather than on the longbow" (Prestwich 1996, p. 134). Similarly, under Richard II and Henry IV, one finds only comparatively modest legislative efforts to support the longbow, as discussed above. In contrast, as also discussed above, in Edward III's reign—the most stable in this era—one finds the full panoply of Crown efforts to encourage archery, from compulsory, universal bow ownership and mandatory weekly practice to incentives for the importation of bow staves and restrictions on the travel of archers outside England.

Our theory also explains one other notable aspect of variation in English longbow reliance: the lack of reliance on the longbow across territories ruled by En-

⁴² Figures for the Wars of the Roses reflect the ratio of archers to total forces on the Lancaster side. The data for Figures 3 and 4 are compiled from the following sources: Falkirk (Fisher 2002), Loudoun Hill (Oliver 2009), Bannockburn (Mackenzie 1989), Neville's Cross (Tate 1866; Rollason and Prestwich 1998), Crécy (Ayton 2005; Sumption 1990), Poitiers (Perrett 1992), Otterburn (Froisart 1903), Agincourt (Curry 2000), Cravant (Smith and DeVries 2005), Sark (Rose 2002), and Castillon (Wagner 2006). Data for all other battles are from Strickland and Hardy (2011).

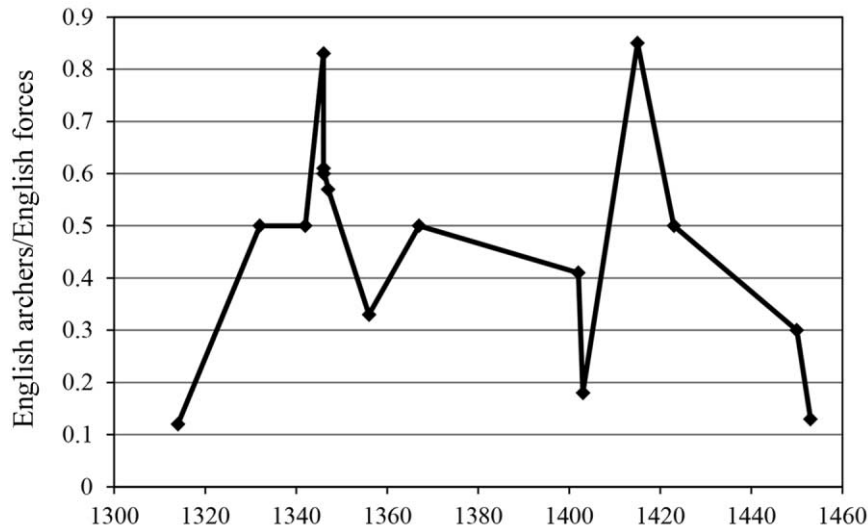


Figure 3. Ratio of English archers to total English forces over time

English kings. Unlike their subjects in England proper, English kings trained neither their subjects in Aquitaine nor those in Normandy on the bow. Institutional instability in England’s Continental territories made doing so unwise for the same reason that instability made it unwise for French kings: longbow adoption threatened to undermine their political security on the Continent. Thus, the same English kings ruling over different regions—England, Aquitaine, and Normandy—chose to adopt the longbow only in the former, where the relative stability of institutions permitted them to do so safely.

4.3. *Relative Wealth and the Longbow’s Military Advantage*

The evidence presented above points to the historical relevance of two equilibria in Table 4. The first of these is found in the second row. This equilibrium is characterized by political instability and reliance on inferior technology for both rulers, which corresponds to the episodes of relative English political instability over the period between around 1272 and 1450 and French and/or Scottish political instability over the same years. The second equilibrium of historical relevance is that found in the fourth row of Table 4. This equilibrium is characterized by political stability and reliance on superior technology for one ruler and political instability and reliance on inferior technology for the other ruler, which corresponds to relative English political stability for the bulk of this period and French and/or Scottish instability over the same years.

In addition to describing the state of political stability each ruler confronts, the equilibria in the second and fourth rows of Table 4 describe the conditions under which rulers choose whether or not to attack their enemy (hereafter, the At-

tack and Do Not Attack conditions). In the equilibrium in the second row, where both rulers confront political instability, a ruler's decision to attack depends on the relationship between W_E and W_F —his wealth relative to his enemy's. In the equilibrium in the fourth row, where one ruler confronts political instability and the other enjoys stability, a ruler's decision to attack depends on the relationship between $p/(1 - p)$ —the military advantage of the superior technology over the inferior technology—and the rulers' relative wealth, W_E/W_F .

Because the historical record furnishes information not only on political stability in England, France, and Scotland during the period of longbow supremacy but also on who was the aggressor in battles that took place over this period, we can identify which of the Attack or Do Not Attack conditions in the second and fourth rows of Table 4 our theory predicts should be observed historically. On the basis of what those conditions describe, we can then test our theory by investigating whether they in fact prevailed.

To perform this test we require information on p , the longbow's military advantage over the crossbow, and on W_E and W_F —England's wealth, France's wealth, and Scotland's wealth—during the period in question. To measure the former we use data from Table 1 on England's battle victories against its enemies under stable English rulers, which, as described above, correspond to periods in which English longbow use was heightened. To measure the latter we rely on the most current estimates of national income in England, Scotland, and France in the late Middle Ages. Both of these measures are highly imperfect. Still, they permit at least a crude investigation into the question of whether the relevant Attack or Do Not Attack conditions predicted by our theory in the second and fourth rows of Table 4 are observed historically.

With the exception of Edward I, under whose reign the longbow was first introduced as a missile weapon in England, most of England's major battles with Scotland during the longbow era occurred during the reigns of unstable English rulers: Edward II, Richard II, and Henry IV. As discussed above, under these English rulers the longbow was in retrenched usage. Moreover, each of these rulers' major battles with Scotland listed in Table 1 was initiated by Scotland. Under Edward II, Scotland attacked England, giving rise to the First War of Scottish Independence. Under Richard II, Scotland attacked England to raid Northumberland in an effort to expand the Scottish borderland into territory claimed by England. And under Henry IV, Scotland attacked England, reprising its efforts under Richard II.

Thus, in these cases of England versus Scotland, the historically relevant equilibrium in Table 4 is that found in the second row (where F denotes Scotland and E denotes England: $\omega_F = \text{Unstable}$, $\omega_E = \text{Unstable}$; $T_F = T^C$, $T_E = T^C$). Here the relevant Attack or Do Not Attack condition to be tested for in our theory is $W_E > W_F$.

The historical evidence supports this prediction. The most recent estimate of England's national wealth vis-à-vis Scotland's in the late medieval period is for 1290 (Campbell 2008). It suggests that late medieval England's national income

was approximately five times that of Scotland, which easily satisfies the Attack or Do Not Attack condition predicted by our theory.

England's major battles with France during the longbow era occurred during the reigns of stable English rulers: Edward III, Henry V, and Henry VI before the Wars of the Roses. As discussed above, under these English rulers the longbow was in heightened usage. Moreover, each of these rulers' major battles with France listed in Table 1 was initiated by England. These battles reflect England's major 14th- and 15th-century attacks on France (recall that the French sought to avoid engaging England on the battlefield) during the Hundred Years War.

Thus, in these cases of England versus France, the historically relevant equilibrium in Table 4 is that found in the fourth row (where F denotes France and E denotes England: $\omega_F = \text{Unstable}$, $\omega_E = \text{Stable}$; $T_F = T^C$, $T_E = T^L$). Here the relevant Attack or Do Not Attack condition to be tested for in our theory is $p/(1 - p) > W_E/W_F$.

The historical evidence also supports this prediction. To get a sense of p , we tabulate English victories against the French between 1337 and 1453. Table 1 lists 11 such battles. England was victorious in eight of them, which yields $p \approx .73$. This figure is, of course, an imperfect measure of the longbow's military advantage over the crossbow. It attributes victory or loss in a battle entirely to major use of the longbow versus the crossbow, which ignores other potentially contributing factors—most notably the frequently large disparity in size between the English and French armies. In addition, this figure neglects the fact that one of the most important effects of longbow superiority was to deter the French from engaging the English in battle at all.

However, both of the foregoing facts are almost certain to render $p \approx .73$ an underestimate of the longbow's military advantage. In every battle used to tabulate this figure but one, the French army was larger than the English army—typically far larger. Accounting for this disparity would increase p significantly. And accounting for the fact that the longbow led the French to avoid battling the English would increase p further.

Since in cases of England versus France our theory predicts $p/(1 - p) > W_E/W_F$, we require that $(.73/.27 =) 2.70 > W_E/W_F$. Estimates of gross domestic product (GDP) for France and England in the 14th century are few and crude, and the potential demographic influence of the Black Death must be kept in mind (see, for instance, Maddison 2003; Van Zanden 2010). But there is no question that France was wealthier than England in the late Middle Ages—even in per capita terms and following the Plague—which provides clear support for our theory's prediction. In 1400, France's per capita GDP was \$1,300, while England's was \$1,251 (purchasing power parity in 1990 dollars) (Campbell 2014). France, however, had a population of 12 million people, compared to only 2.7 million in England (Malamina 2009, p. 9).

The final category of major battles in Table 1 to be considered is that of England versus Scotland when England was politically stable. These battles include Dupplin Moor, Halidon Hill, and Neville's Cross, each of which occurred during

the secure reign of Edward III. Dupplin Moor (1332) was not actually a battle between England and Scotland but rather a battle between Scottish contestants for the Scottish Crown in which one side was supported by England. It was a battle between the supporters of the incumbent David II and Edward Balliol, the exiled son of John Balliol. Both leaders confronted substantial political insecurity. Balliol, with Edward II's permission and support from his archers, led a naval invasion into Scotland and was clearly the aggressor. Balliol had almost nothing in terms of wealth outside of an expectation of the Scottish Crown. David II had the crown, so his wealth was greater than Balliol's. Hence, the relevant Attack or Do Not Attack condition of $p/(1 - p) > W_E/W_F$ (where E denotes Balliol and F denotes David II) was clearly met.

Balliol was outnumbered 5 to 1 but effectively used the longbow to destroy the Scottish army and was crowned king of Scotland. However, he was later ambushed and fled to England. The Battle of Halidon Hill (1333) was the eventual consequence of this Scottish action. The Battle of Neville's Cross (1346) took place when David II invaded England while Edward III was fighting in France. Hence, in both cases, Scotland instigated battle with or attacked England. Under the circumstances, our theory predicts $p/(1 - p) < W_E/W_F$ (where F denotes Scotland), which is easily met according to the historical estimates described above. The Attack or Do Not Attack conditions predicted by our theory therefore appear to hold for all of the major battles of the longbow era.

5. Conclusion

The turn of the 15th century witnessed the beginning of the end of the era of longbow supremacy. By 1450 continuous advancements in armor technology and design had eroded much of the longbow's superiority over the crossbow. These advancements were at least partly driven by and reflected a response to the longbow's superiority. Although France and Scotland could not, because of their politically unstable environments, adopt the longbow, they could, and did, attempt to offset its missile superiority with armor and tactics that defended better against it.

The longbow's substantially better rate of fire became less of an advantage when its arrows became less lethal. And this is precisely what happened as France and Scotland adopted high-quality, steel plate armor, which became widely available to wealthy knights around 1380.⁴³ Consider Figure 4, which presents data on the ratio of battle deaths for England's enemies to those for England during the Hundred Years War, where such data are available.⁴⁴ Before 1380 the longbow was exceptionally lethal. However, by the 1380s the longbow's lethality had fallen to about parity with the crossbow's. Although the longbow continued to enable the English to consistently defeat its enemies on the battlefield after 1380, its abil-

⁴³ Nobles and wealthy knights could afford expensive armor. However, much of an army's infantry remained with more limited protection.

⁴⁴ Where the number of deaths was reported as "minimal," we assign a number of 100.

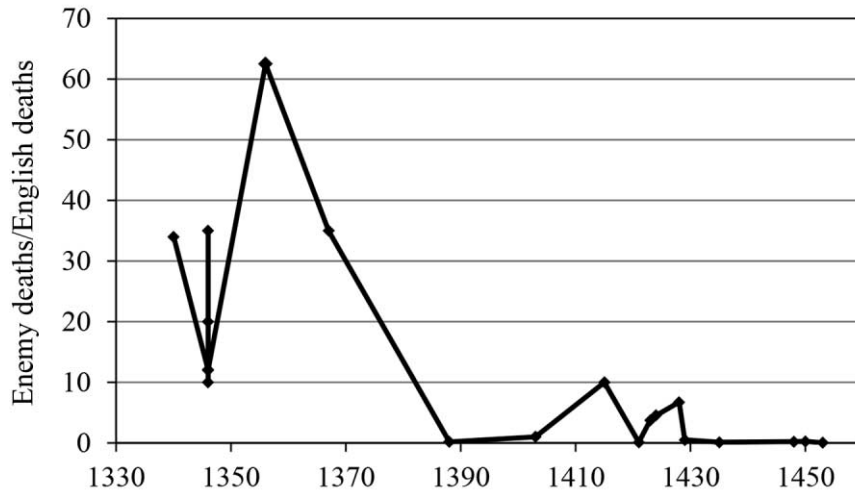


Figure 4. Ratio of enemy deaths to English deaths in battle over time

ity to do so through sheer killing force waned—largely a result of the use of heavy armor by England’s enemies.

In the second half of the 15th century the longbow was dealt another blow: the only nation that used it in a major way, England, became increasingly politically unstable. The longbow could not help but play a role in England’s civil wars of the 15th century (the Wars of the Roses), which pitted longbow against longbow—to the devastation of much of the English aristocracy. In such battles, of course, the longbow’s military advantage, on display so strikingly in English battles against the crossbow of the French and the Scots, ceased to exist.

Although after the Wars of the Roses the longbow went into permanent decline, it remained a part of England’s military arsenal, albeit in much diminished form, until the 16th century. Also in the 16th century, the crossbow went into permanent decline on the Continent. Both late medieval missile weapons were phased out to make room for a newly developed missile weapon: the arquebus, an early muzzle-loading firearm.

The arquebus was slower than the longbow and less accurate than either the longbow or the crossbow. However, it had a critical technological advantage over both older missile weapons, given the new military environment throughout Europe created by the widespread availability of increasingly heavy armor: it was powerful enough to penetrate that armor, whereas the longbow, and even the mechanically spanned crossbow, was not. Indeed, “even the finest of armour was to prove of little defence against the enormously greater penetrative power of the hand-gun, rapidly disseminating through European armies in the fifteenth century and becoming lethally effective by the early sixteenth century” (Strickland and Hardy 2011, p. 276). Crucially, while cheaper than the crossbow, for at least

the first 100 years in which it was used as a major missile weapon, the arquebus was expensive enough to remain infeasible for a usurping noble to furnish to citizens in large numbers and therefore posed little threat of being turned against a politically insecure ruler who adopted it.

Our analysis of the longbow puzzle leads to several conclusions. First, the resolution of that puzzle is found in an appreciation of the different constraints confronted by England and its Continental enemies in the late Middle Ages. According to our theory, rulers choosing between alternative military technologies may confront a trade-off with respect to internal and external security. If the adoption of a technologically superior weapon for prosecuting wars simultaneously enables disgruntled domestic rivals to effectively arm a large number of a ruler's citizens because that technology is inexpensive and easy for anyone to make, and its effective employment requires training a large population of citizens in its use, a ruler must be politically secure to be willing to adopt such a weapon. Conversely, a ruler who is not politically secure would be foolish to adopt such a weapon to improve his ability to prosecute wars with foreign enemies, since to do so would greatly increase his chances of being ousted from power by domestic enemies. The longbow was a militarily superior technology that presented such a trade-off.

The longbow puzzle consists of several central facts: the longbow was the superior late medieval missile weapon; England alone adopted it, enabling it to consistently defeat its enemies, France and Scotland, in battle; and France and Scotland refused to adopt it and clung to the crossbow, despite being aware that this put them at a serious military disadvantage on the battlefield with England. Our theory explains these facts. For a 150-year window in the late medieval period, England was relatively politically stable, which rendered the longbow the optimal missile weapon for its rulers. Over the same period, France and Scotland were politically unstable, which rendered the technologically inferior crossbow the optimal missile weapon for rulers in those nations.

Second, our analysis highlights an important but neglected potential constraint on first-best technology adoption: the effect that such adoption may have on rulers' political security. This constraint has special potential importance in the context of military technology. Because military technologies are often technologies of violence, their adoption has potential ramifications not only in terms of their ability to overwhelm external enemies but also in terms of their ability to be used by rulers' internal enemies for their own purposes. The adoption of military technologies whose effectiveness in war depends strongly on the number of citizens who are capable of wielding them proficiently, such as the longbow, is especially sensitive to this political-security constraint.

Finally, our analysis of the longbow puzzle suggests that seemingly irrational behavior may simply reflect optimizing behavior in the context of hitherto unidentified constraints.⁴⁵ On the surface, the behavior presented by the longbow puzzle seems irrational indeed: consciously choosing a military technology one

⁴⁵ For other examples of such behavior, see, for instance, Posner (1980), Johnsen (1986), Allen and Reed (2006), and Leeson (2012, 2013, 2014).

understands to be inferior in terms of its ability to win battles over a cheaper, readily available alternative one understands to be superior in winning battles when one is in the midst of a protracted war with an enemy who has chosen the superior alternative. As our analysis demonstrates, however, this choice is in fact perfectly sensible once one identifies the hitherto unidentified constraints grounded in political security that medieval rulers confronted.⁴⁶ Seen through this lens, the behavior presented by the longbow puzzle is no puzzle at all. It is the optimizing behavior predicted by rational choice.

References

- Allen, Douglas W. 2002. The British Navy Rules: Monitoring and Incompatible Incentives in the Age of Fighting Sail. *Explorations in Economic History* 39:204–31.
- . 2012. *The Institutional Revolution: Measurement and the Economic Emergence of the Modern World*. Chicago: University of Chicago Press.
- Allen, Douglas W., and Clyde G. Reed. 2006. The Duel of Honor: Screening for Unobservable Social Capital. *American Law and Economics Review* 8:81–115.
- Ayton, Andrew. 2005. The Battle of Crécy: Context and Significance. Pp. 1–34 in *The Battle of Crécy, 1346*, edited by Andrew Ayton and Philip Preston. Woodbridge: Boydell & Brewer.
- Campbell, Bruce M. S. 2008. Benchmarking Medieval Economic Development: England, Wales, Scotland, and Ireland c.1290. *Economic History Review* 61:896–945.
- . 2014. Decline, Stagnation, Stability and Growth: The Experience of Late-Medieval Italy, Spain, England and Holland. Paper presented at the University of Warwick's conference Accounting for the Great Divergence, Venice, May 22–24.
- Campbell, James. 1965. England, Scotland and the Hundred Years War in the Fourteenth Century. Pp. 184–216 in *Europe in the Late Middle Ages*, edited by John R. Hale, John R. L. Highfield, and Beryl Smalley. London: Faber & Faber.
- Churchill, Winston. 1956. *A History of the English-Speaking Peoples*. New York: Dodd, Mead.
- Clark, Gregory. 1998. The Cost of Capital and Medieval Agricultural Technique. *Explorations in Economic History* 35:265–94.
- Curry, Anne. 2000. *The Battle of Agincourt: Sources and Interpretations*. Woodbridge: Boydell.
- Davis, William S. 1988. *Life in Elizabethan Days*. Cheshire, CT: Biblio & Tannen.
- DeVries, Kelly. 1997. Catapults Are Not Atomic Bombs: Towards a Redefinition of 'Effectiveness' in Premodern Military Technology. *War in History* 4:454–70.
- Esper, Thomas. 1965. The Replacement of the Longbow by Firearms in the English Army. *Technology and Culture* 6:382–93.
- Featherstone, Donald. 1967. *The Bowmen of England: The Story of the English Longbow*. London: Jarrolds.
- Fisher, Andrew. 2002. *William Wallace*. 2nd ed. Edinburgh: Birlinn.
- Frey, Bruno S., and Heinz Buhofer. 1988. Prisoners and Property Rights. *Journal of Law and Economics* 31:19–46.
- Froissart, Jean. 1903. *Chronicle of Froissart*. London: D. Nutt.

⁴⁶ Indeed, the French strategy of refusing to engage the English ultimately led them to victory in the Hundred Years War.

- Green, David. 2014. *The Hundred Years War: A People's History*. New Haven, CT: Yale University Press.
- Hageneder, Fred. 2013. *Yew*. London: Reaktion.
- Hardy, Robert. 2012. *Longbow: A Social and Military History*. 5th ed. Sparkford: Haynes.
- Henshall, Nicholas. 1992. *The Myth of Absolutism: Change and Continuity in Early Modern European Monarchy*. London: Longman.
- Johnsen, D. Bruce. 1986. The Formation and Protection of Property Rights among the Southern Kwakiutl Indians. *Journal of Legal Studies* 15:41–67.
- Jones, Dan. 2012. *The Plantagenets: The Kings Who Made England*. London: Williams Collins.
- Juvénal des Ursins, Jean. (1430) 1841. *Histoire de Charles VI, roi de France*. Paris: A. Desrez.
- Katz, Michael L., and Carl Shapiro. 1986. Technology Adoption in the Presence of Network Externalities. *Journal of Political Economy* 94:822–41.
- Leeson, Peter T. 2012. Ordeals. *Journal of Law and Economics* 55:691–714.
- . 2013. Vermin Trials. *Journal of Law and Economics* 56:811–36.
- . 2014. Human Sacrifice. *Review of Behavioral Economics* 1:137–65.
- Leeson, Peter T., and Alex Nowrasteh. 2011. Was Privateering Plunder Efficient? *Journal of Economic Behavior and Organization* 79:303–17.
- Le Patourel, Jean. 1965. The King and the Princes in Fourteenth Century France. Pp. 155–83 in *Europe in the Late Middle Ages*, edited by John R. Hale, John R. L. Highfield, and Beryl Smalley. London: Faber & Faber.
- Loades, Mike. 2013. *The Longbow*. Oxford: Osprey.
- Lynn, John A. 1996. The Evolution of Army Style in the Modern West, 800–2000. *International History Review* 28:505–56.
- Mackenzie, W. Mackay. 1989. *Bannockburn: A Study in Medieval Warfare*. Stevenage: Strong Oak.
- Maddison, Angus. 2003. *The World Economy: Historical Statistics*. Paris: Organisation for Economic Co-operation and Development.
- Major, J. Russell. 1994. *From Renaissance Monarchy to Absolute Monarchy: French Kings, Nobles, and Estates*. Baltimore: Johns Hopkins University Press.
- Malamina, Paola. 2009. *Pre-modern European Economy: One Thousand Years (10th through 19th Centuries)*. Leiden: Brill.
- Nicholson, Ranald. 1974. *Scotland: The Later Middle Ages*. Edinburgh: Oliver & Boyd.
- Oliver, Neil. 2009. *A History of Scotland*. London: Phoenix.
- Palmer, J. J. N. 1972. *England, France, and Christendom, 1377–99*. London: Routledge & Kegan Paul.
- Perrett, Bryan. 1992. *The Battle Book*. London: Arms & Armour.
- Pickering, Danby. 1762–66. *The Statutes at Large, from Magna Charta to the End of the Eleventh Parliament of Great Britain, Anno 1761*. 24 vols. Cambridge: printed by Joseph Bentham.
- Posner, Richard A. 1980. A Theory of Primitive Society, with Special Reference to Law. *Journal of Law and Economics* 23:1–53.
- Prestwich, Michael. 1996. *Armies and Warfare in the Middle Ages: The English Experience*. New Haven, CT: Yale University Press.
- Rogers, Clifford J. 1993. The Military Revolutions of the Hundred Years' War. *Journal of Military History* 57:241–78.
- . 1998. The Efficacy of the English Longbow: A Reply to Kelly DeVries. *War in His-*

- tory 5:233–42.
- . 1999. *The Wars of Edward III: Sources and Interpretations*. Woodbridge: Boydell.
- . 2011. The Development of the Longbow in Late Medieval England and “Technical Determinism.” *Journal of Medieval History* 37:321–41.
- Rollason, David, and Michael Prestwich, eds. 1998. *The Battle of Neville’s Cross, 1346*. Stamford: Shaun Tyas.
- Rose, Alexander. 2002. *Kings in the North*. London: Phoenix.
- Rowen, Herbert H. 1980. *The King’s State: Proprietary Dynasticism in Early Modern France*. New Brunswick, NJ: Rutgers University Press.
- Smith, Robert T. D., and Kelly DeVries. 2005. *The Artillery of the Dukes of Burgundy, 1363–1477*. Woodbridge: Boydell & Brewer.
- Strickland, Matthew, and Robert Hardy. 2011. *The Great Warbow: From Hastings to the Mary Rose*. Sparkford: Haynes.
- Sumption, Jonathan. 1990. *The Hundred Years War*. Vol. 1, *Trial by Battle*. London: Faber & Faber.
- Tate, George. 1866. *The History of the Borough, Castle, and Barony of Alnwick*. Vol. 1. London: Henry Hunter Blair.
- Tullock, Gordon. 1989. *The Economics of Special Privilege and Rent Seeking*. Boston: Kluwer.
- Van Zanden, Jan Luiten. 2010. Measuring Pre 1820 Economic Growth: How Right/Wrong Are the Pre 1820 Maddison Estimates? Paper presented at the Maddison Memorial Conference, International Institute of Social History, Amsterdam, November 6–7.
- Wagner, John A. 2006. *Encyclopedia of the Hundred Years War*. Westport, CT: Greenwood.
- Wood, Charles T. 1988. *Joan of Arc and Richard III: Sex, Saints, and Government in the Middle Ages*. Oxford: Oxford University Press.