Learning When to Fight:
Technological Change and Conflict in the
Gunpowder Revolution[*]

Denis Tchaouchev[†]

Word Count: 11,664

Abstract

Does technological change make conflict more likely? I argue that new technologies can generate conflict by creating uncertainty about the balance of power, but demonstrations of the effectiveness of new technology in combat subsequently diminish this uncertainty. During the Siege of Constantinople in 1453, gunpowder artillery–then a new and unproven technology–devastated the most sophisticated fortifications in Europe. I examine how this informational shock affected the frequency of siege warfare in Western Europe. Using a difference-in-differences design and an original dataset of siege locations, I find that areas more exposed to information about the Ottomans' use of cannons at Constantinople experienced fewer sieges in the decade after the city's capture. Contemporary sources support the claim that the decline in siege warfare was due to a convergence in beliefs about the usefulness of gunpowder artillery.

[†]Postdoctoral Fellow, Perry World House, University of Pennsylvania. 3803 Locust St, Philadelphia, PA 19104. Email: tchaouc@upenn.edu.

1   Introduction

Advances in artificial intelligence, robotics, and other fields have inspired a wave of research aimed at understanding the implications of technological change for international security.[1] The resulting scholarly output has yielded no consensus. Some studies portray emerging technologies as exerting a destabilizing influence on the international system. They claim that new technologies enable rapid shifts in military capabilities at low cost, which can incite arms races, disrupt the balance of power, and erode deterrence (Ellman, Samp and Coll, 2017; Johnson, 2019; Schneider, 2021; Volpe, 2021). Others are more sanguine, arguing that most new technologies have an incremental effect on capabilities that is insufficient to alter existing interstate power dynamics (Biddle, 2004; Rid, 2012). A few conclude that some new technologies may promote peace by reducing the risk of conflict escalation (Kroenig, 2021; Lin-Greenberg, 2022; Williams, 2021).

I argue that uncertainty about the implications of new technologies is itself a cause of conflict. Contrasting beliefs about how a new technology has altered the balance of power may cause rival states to miscalculate their opponent's willingness to fight, leading disputes to escalate into war (Blainey, 1988; Fearon, 1995). However, war can resolve debates about the effectiveness of new military technologies. During a conflict, states witness the combat performance of a new technology for the first time, learning how and when to use the technology to obtain the greatest advantage (Hoffman, 2015). Wartime demonstrations serve as common reference points that influence future assessments of military capabilities, including for states not directly involved in the conflict (Goldman and Eliason, 2003; Horowitz, 2010). Conflicts therefore serve as public signals of a new technology's effectiveness which facilitate a convergence in beliefs about the new technology and diminish one source of uncertainty about the balance of power.

---

[1]I use"technology" to refer to physical equipment (i.e., weapons or vehicles) produced via the application of scientific knowledge. The term "technological change" refers to the introduction of new such equipment.

In this article, I test whether better information about the battlefield effectiveness of new military technology makes conflict less likely. The present's low frequency of conflict and high speed of information diffusion preclude convincing assessments of the effect of knowledge about new technology on conflict. Therefore, I test my theory using an earlier era of transformational change in military technology: the introduction of gunpowder artillery (i.e., cannons and bombards) in Late Medieval Europe. Specifically, I analyze how the diffusion of knowledge about how to employ gunpowder artillery to destroy fortifications influenced the likelihood of peaceful settlements in siege warfare. Siege warfare would eventually be transformed by the introduction of gunpowder artillery in the 14th and 15th centuries, which rendered formerly stalwart fortifications vulnerable (Bradbury, 1992). However, early cannons were crude weapons that were perceived as inferior to older siege engines (DeVries, 2013; Hale, 1983). Indeed, some historians have argued that "for more than a century after 1326, catapults continued to surpass anything a gun could do, except when it came to making noise" (McNeill, 2013, 83). Although gunpowder artillery underwent technical improvements in the 1430s that enabled it to batter down walls, this fact was recognized by only a few early adopters, while many continued to believe that existing fortifications remained impregnable (Duffy, 2013; Rogers, 2018). As a result, there were contrasting beliefs about the ability of existing fortifications to withstand a siege by forces equipped with cannons.

Attitudes shifted in 1453, when the Siege of Constantinople demonstrated the ability of gunpowder artillery to destroy existing defenses. Employing a large array of bombards, the forces of the Ottoman Empire breached the walls of Constantinople, fortifications that were considered the most sophisticated in Europe (Ágoston, 2014). The capture of city was closely watched by Europeans, and accounts of the siege spread across the continent (Bisaha, 2017; Schwoebel, 2023). These accounts universally emphasized the decisive role played by artillery and described the tactics that the Ottomans employed, setting off a period of European-Ottoman military acculturation (Christensen, 1987; Philippides and Hanak, 2011). Europeans who had believed their fortifications remained secure from assault were confronted with evidence that this was not the

case. Contemporary sources suggest that after 1453, siege defenders became more inclined to surrender when faced with a besieging army equipped with cannons (Rogers, 2018).

Using a difference-in-differences design, I exploit variation in when different locations learned about the Fall of Constantinople to study how information about artillery's effectiveness influenced decisions to fight. Due to the era's slow travel times, settlements located further from Constantinople obtained detailed reports of siege later than settlements located nearer.[2] As proximity to the Constantinople is primarily determined by geography, this provides plausibly exogenous variation in information about the effectiveness of cannons. Therefore, comparing the number of sieges occurring in locations of varying proximity from Constantinople before and after its capture permits an evaluation of the causal effect of information transmission on conflict. I carry out this empirical strategy on a new dataset of 356 sieges that occurred in Western and Central Europe between 1443 and 1463, constituting the most comprehensive account of sieges during this period. I proxy for exposure to information about Constantinople using estimates of transportation costs, which I construct using historical shipping records and a shortest-path algorithm.

I find that in the decade following the Fall of Constantinople, places one standard deviation closer to Constantinople experienced about one fewer siege on average, supporting my hypothesis. Consistent with a theory of learning, the effect is strongest immediately after 1453 and dissipates later on, as, given enough time, information about the siege fully diffused throughout Europe. Using historical evidence and placebo tests, I rule out alternative explanations, such as balancing by European powers against the Ottoman Empire, for the shift in the geography of siege warfare. In addition, I show that the results are robust to alternative measures of proximity to Constantinople, corrections for spatial correlation, the use of different functional forms, and the presence of outliers. Documentary evidence corroborates the claim that the decline in siege warfare resulted from greater agreement about the power of gunpowder artillery.

---

[2]For example, some eyewitnesses to the siege, such as Greek refugees, arrived in Northern Europe years after they had reached Italy or the Balkans (Harris, 2022).

This article contributes to at least four active areas of research. First, it offers and tests a new theory linking technological change to the frequency of conflict via uncertainty about military capabilities. Most prior scholarship on technological change and conflict has been conducted through the lens of offense-defense theory, which argues that new technologies affect the likelihood of conflict by modifying the relative ease of capturing territory with military force compared to defending it (Glaser and Kaufmann, 1998; Hopf, 1991; Lynn-Jones, 1995; Quester, 2002; Van Evera, 1998). In the offense-defense framework, technologies that amplify offensive advantage make international conflict more likely by increasing first-strike advantage and exacerbating security dilemmas (Jervis, 1978; Van Evera, 1999). Yet evaluating the predictions of offense-defense theory has proven difficult, as empirical tests require measuring how new technologies shift the offense-defense balance, which is not directly observable (Levy, 1984). Critics of offense-defense theory also point out that militaries can develop doctrine to apply technologies to many ends, complicating attempts to determine the "overall" effect of a new technology on offense or defense (Biddle, 2004).

Rather than attempting to identify attributes of technologies that affect conflict, the theoretical framework presented in this paper emphasizes that the significance of a new technology is subject to contestation. Building on work by scholars of military innovation, my theory argues that assessments of unproven technology can be influenced by bureaucratic competition within militaries, the external security environment, and the availability of technical resources, all of which differ across states (Grissom, 2006; Posen, 1984; Rosen, 1991). These domestic debates can lead to contrasting perceptions of new technologies and military capabilities. Disagreement about the implications of new technologies, rather than any property of the technologies themselves, is the cause of conflict. Moreover, the empirical results of this paper contrast with the predictions of offense-defense theory. New tactics that enable cannons to better destroy walls are clearly innovations that enhance offensive advantage. Yet locations that learned of these new tactics via the Fall of Constantinople experienced fewer rather than more sieges, the opposite of what offense-defense theory would predict. These results suggest that understanding the causes

of uncertainty about new technologies may be a profitable direction for future research.

Second, this article provides some of the first causal evidence for the bargaining model of war, particularly the claim that uncertainty about the balance of power can generate conflict.[3] Bargaining theorists have argued that states may misperceive the balance of power because of incentives to conceal military strength or noisy private assessments of military capabilities (Blainey, 1988; Debs, 2022; Fearon, 1995, 2021; Slantchev, 2010). This can lead to war if states in a dispute jointly believe that more can be achieved through fighting than yielding to the other's demands. Despite bargaining theory's prominence, convincing empirical tests of its predictions have proven elusive due to the difficulty of measuring private information held by states. This article takes a novel approach to the problem of private information by exploiting a historical case, the diffusion of information about the effectiveness of cannons after the Fall of Constantinople, that offers plausibly exogenous variation in the degree of potential disagreement about the balance of power. In doing so, this paper illustrates the promise of using historical data to test general theories of international politics, joining a growing quantitative literature on historical international conflict (Lindsey, 2019).

Third, this paper articulates a new mechanism linking battlefield learning to conflict that unifies disparate strands of research on wartime demonstrations of new technologies. Scholars studying the diffusion of military technology have shown that wartime demonstration of an innovation's effectiveness instigates its wider adoption by states and have outlined the financial and organizational factors that facilitate adoption (Eyre, Suchman et al., 1996; Goldman and Eliason, 2003; Horowitz, 2010). Separately, recent work has argued that states may intentionally employ new technology in ways that will influence postwar perceptions of the balance of power (Byun and Carson, 2025). The theory presented in this paper unifies and extends such work by arguing that wartime demonstrations also foster a consensus about technologies' usefulness which directly affects the likelihood of future conflict. Moreover, this paper offers new quantitative evidence that states do in fact reevaluate new technologies after even unintentional

---

[3]Early arguments of this type are due to Blainey (1988) and Fearon (1995). See Bas and Schub (2017), Ramsay (2017), and Powell (2002) for surveys of this expansive body of research.

wartime demonstrations.

Finally, the new theory and evidence presented by this paper speak to ongoing debates about the impact of emerging technologies on international politics. For instance, policymakers and scholars currently disagree whether the risks of military artificial general intelligence (AGI) adoption will arise from the arms race to become the first to achieve AGI or from the secrecy surrounding AGI development. The former argues that AGI will unlock enormous increases in capabilities, incentivizing preemptive strikes to prevent rivals from acquiring AGI (Brundage, 2025; Burdette and Demelash, 2025). Those in the latter camp instead believe that the secrecy of military AGI programs will make it hard for states to evaluate each other's intentions and capabilities, increasing the probability of miscalculation that could lead to war (Kreps, 2025). This paper's finding that reducing uncertainty about a new technology decreases conflict lends credence to the latter prediction. Moreover, the theory of this paper identifies three domestic sources of uncertainty about technology that policymakers can address to reduce uncertainty about AGI and other technologies.

2 New technology and perceptions of the balance of power

2.1 Technological change and bargaining

When states adopt a new military technology, there is often no consensus on how the new technology should be used or how it will be in combat. This arises because militaries' pursuit of combat advantage means that new military technologies diffuse far more quickly through the international system than the knowledge needed to use them effectively (Goldman and Eliason, 2003; Horowitz, 2010). Indeed, for truly novel technologies, such knowledge does not exist yet–technologies do not spring into existence with a fully developed doctrine for their use. Consequently, states must independently assess the effect of new technologies on capabilities and determine tactics prior to battle.[4] Yet the process of evaluating a new technology is highly id-

---

[4]In order words, states receive noisy private signals of how new technology affects the balance of power. Examples of formal models of crisis bargaining that use such a method to generate uncertainty about the balance of

iosyncratic, which can result in states arriving at contrasting expectations about how a new technology will affect the outcomes of future conflicts. Contrasting private assessments can produce conflict if two states in a dispute both believe that more can be achieved more through fighting than negotiating. In other words, technological change can generate mutual optimism (Blainey, 1988).

2.2   Mechanisms of uncertainty

How might states arrive at diverging private assessments of new military technology? I outline three channels through which new military technology can influence perceptions of the balance of power: technical challenges in assessing new technologies, differences in doctrine, and bureaucratic competition between military services.

First, assessing the combat potential of new technologies is inherently difficult and subject to a high degree of randomness (Miller, 1985; Sechser, Narang and Talmadge, 2019). Evaluating new military technologies requires both imagination for envisioning situations where the technology can be applied and a sober appraisal of potential drawbacks. Major engineering efforts may be needed to adapt the new technology to a particular use. Tests approximating real combat must be devised and carried out. At each step, variation in state security goals, differences in technical capacity, and even luck may influence perceptions of a new technology' usefulness in combat. For instance, states with different security concerns may envision distinct uses for the technology and evaluate it on different standards. A country that lacks scientific capital may suffer technical setbacks that generate pessimism about the new technology and discourage further investment (Jones and Hildreth, 1984).[5] This evaluation process in turn influences perceptions of the balance of power: a state that views a technology as promising and adopts it will likely have a more

_____

power include Debs (2022) and Fearon (2021).

[5]This dynamic is visible in the German nuclear program during the Second World War. The Nazis' repressive and antisemitic policies against academics created a shortage of scientific talent. This contributed to a false scientific conclusion that graphite was infeasible as a moderator for fission, leading the Germans to focus research on reactors that use expensive and hard to obtain heavy water instead (Bethe, 2000; Popp and de Klerk, 2023). By 1942, setbacks convinced German scientists and military leaders that nuclear weapons could not be produced in time to influence the course of the war and returned the nuclear program to civilian control (Bethe, 2000; Popp and de Klerk, 2023).

favorable view of its own capabilities than a state that dismissed the technology as ineffective.

Second, states adopting a new technology may develop different doctrines for the technology's use in the field. Scholars have argued that victory in war depends less on the particular tools and technologies available to a state than on how a state employs them (Biddle, 2004; Horowitz, 2010, 2020). However, new technologies lack an established doctrine and militaries must create them independently. Such doctrine is incorporated into military planning, which can become unreliable if another state develops a different doctrine. Indeed, when planning for future conflicts, a state may assume that rivals will use new technology following the same doctrine. However, this can leave them scrambling to respond during war if an adversary employs a technology in an unexpected way. Indeed, as Biddle (2004) points out, innovative new tactics can render a new technology far more effective in battle and transform perceptions of the technology's potency. Therefore, technological change can cause two states to disagree about the balance of power when one believes that it had developed a doctrine for the technology that provides it with a combat advantage, which the other state is not aware of or dismisses.[6]

Finally, technological change can also create disagreements about the balance of power via actions taken by bureaucratic actors who promote self-serving perceptions of new technologies. Past research has found that the reception of an innovation is mediated by the effect that adoption will have on existing distributions of power and wealth (Juma, 2016; Mokyr, 1998; Solstad, 2023). Interest groups may attempt to block the use of new technologies that could reduce their economic or political power (Acemoglu and Robinson, 2000; Frieden and Silve, 2023; Mokyr, 1990). Militaries are not inured to such dynamics. A large literature has shown that entrenched interests within militaries are particularly resistant to innovation (Evangelista, 1988; Grissom, 2006; Posen,

---

[6]An example is the German development of mechanized combined arms warfare and its application in the Battle of France. While the French military establishment appears to have been aware of changes in German doctrine on the use of armor, France's own doctrine subordinated tanks to the infantry as support units, and as a result perceived them to be far less mobile than the independent armored units Germany would employ during its invasion (Kier, 2017). Moreover, French military officers adopted a defensive mindset following the experience of the First World War, which influenced their view of how technology would be employed in the next war. This is exemplified by a contemporary French tank officer manual: "At the present time, the anti-tank weapon confronts the tank as, during the last war, the machine gun confronted the infantry" (Ministry of War of the French Third Republic, 1937). This attitude led to a belief that German armored units would be slow enough that, together with the Maginot Line, the French army would have enough time to mobilize and repulse a German incursion (Doughty, 1974).

1984; Rosen, 1991). Military organizations have not hesitated to present slanted assessments in support of self-interested goals–Snyder (1984) argues that European military staff deliberately promoted perceptions of offensive advantage prior to 1914 to enhance their budgets, prestige, and autonomy. New innovations can affect the budget, mandate, and/or prestige of groups within the military by rendering their role obsolete or creating competition for resources. These organizations may attempt to influence the perception of new technologies by policymakers to maintain their status.[7] Biased views of technological capabilities may emerge from this internal competition, resulting in diverging assessments of the balance of power.

2.3 Conflict as a demonstration point

Although states form initial assessments about how a new technology affects the balance of power soon after the technology is invented or adopted, they also update their assessments as new evidence becomes available. Past studies have documented that states revise their views about new technologies after using the technology in war or observing other states employing it. States applying new technologies undergo a process of "learning by doing," discarding ineffective tactics and developing best practices for the new technologies they deploy in combat (Hoffman, 2015). Similarly, wars are never private affairs—other states observe the use of the new technology and draw their own conclusions. As Horowitz (2010) points out, conflicts can serve as "demonstration points" that reveal the full capabilities of new technologies and the tactics needed to apply them successfully, leading states throughout the international system to adopt the newly discovered best practices. With the diffusion of doctrine also comes a consensus about how the new technology should be used in combat. Prior conflict therefore serves as common reference point to evaluate the technology, giving states a mutual basis for assessing military capabilities. This should ameliorate the uncertainty about the balance of power caused by the introduction of the new technology, and make it more likely for states in a dispute arrive at negotiated settlement.[8]

---

[7]An example of this dynamic at play is the lobbying of cavalry officers against the replacement of roles traditionally done by horse cavalry by mechanized transport, described in Katzenbach (1958)

[8]In other words, conflict involving a new technology provides a public signal about the effect of the technology on the balance of power, leading states to update their beliefs.

2.4 Application to gunpowder artillery and siege warfare

In the next section, I apply this theory to study how information conveyed by the Fall of Constantinople affected the frequency of siege warfare in Europe. Gunpowder artillery experienced technical advances during the first half of the 15th century that enabled it to batter down existing fortifications by mid-century. However, these advances were not universally acknowledged, and significant disagreement existed among Europeans about the usefulness of cannons in siege warfare. I show that the Ottomans' effective use of cannons at the Siege of Constantinople lead to a recognition among Europeans that cannons provided a major advantage to attackers when applied properly, leading to a documented shift in siege tactics and pre-siege negotiations.

3 Gunpowder, siege warfare and the Fall of Constantinople

3.1 Siege warfare and firearms in Medieval Europe

A medieval siege was a microcosm of the bargaining dynamic that Blainey (1988), Fearon (1995), and others argue characterize interstate disputes. For much of the medieval period, sieges were long and grinding affairs. Taking a fortress by siege required a long blockade, a risky direct assault, expensive mining of walls, or some combination thereof (Bradbury, 1992). Neither attacker nor defender relished the prospect of a siege. As a result, sieges were generally preceded by negotiation between the attacking and defending forces (Mallett, 2009). While blockades lasting months or years were typical of sieges for centuries, the early 14th-century brought a development that would transform siege warfare: gunpowder.

Gunpowder artillery is first attested in Europe in 1326. Early guns were short, squat things that were unable to launch projectiles with greater force than existing catapults and trebuchets, on top of being inaccurate, slow to fire, and prone to exploding (Cipolla, 1965; DeVries, 2024).[9] Nevertheless, primitive cannons spread rapidly throughout Europe due to their low cost com-

---

[9]To underscore just how slow the pace of cannon fire was, according to (Rogers, 2018), one 15th century German gunner who achieved the feat of firing his bombard three times a day was forced to make a pilgrimage to Rome to demonstrate that he was not performing witchcraft.

pared to other siege engines, whose complex mechanisms required skilled labor to construct. (Rogers, 2018). During sieges, cannons were used in conjunction with existing siege engines, as evinced by the fact that early cannons were primarily utilized to fire *over* the walls of fortifications rather than at them. Europeans saw cannons as new variants of existing siege weapons, and early cannons had little impact on the course or outcome of sieges for over a century after 1326 (Heuser, 2012).

Beginning in the 1410s and 1420s, gunsmiths made technical advancements that improved the effectiveness of gunpowder artillery. First, the innovation of "corning" the ingredients of gunpowder by mixing them with water to form coarse granules yielded a propellant that gave off greater energy after ignition, permitting artillery to fire projectiles at greater speeds (Gray, Marsh and McLaren, 1982). Second, by the 1430s, gunsmiths began manufacturing bombards with longer barrels. The lengthening of barrels extended the amount of time projectiles were accelerated by the ignition of gunpowder (Davies, 2019). The resulting increase in muzzle velocity improved the accuracy, range, and power of artillery. Greater accuracy had the compound effect of enabling new tactics, such as the concentration of fire by multiple bombards, that had previously been impossible. As a result of these innovations, by the early 1440s, gunsmiths could produce artillery that reliably pierced the curtain walls that had frustrated besieging armies for the past two centuries (McNeill, 2013; Rogers, 2018).

Not all European military leaders recognized the significance of the technical advances in artillery and munition manufacture. Opinion on the usefulness of gunpowder artillery remained mixed and there is little evidence of widespread European acceptance of the idea that bombards heralded a revolution in the conduct of siege warfare in the first half of the 15th century (DeVries, 2013; Hale, 1983; Heuser, 2012). A common attitude was indifference: a survey of 15th-century military and fortification manuals by De la Croix (1963)finds only a single work that mentions cannons. Even that work, a treatise on fortification by Christine de Pizan, betrayed a sense of skepticism about artillery in its claims that 248 cannons were required to capture a well-defended castle or city, an enormous number roughly equal to the total number of guns fielded by entire

Kingdom of France in the 1450s (Nicolle, 2012). Yet there were some enthusiastic adopters of artillery, such as the French artillery officers Gaspard and Jean Bureau, the Dukes of Burgundy, James II of Scotland, and Ottoman Sultan Mehmed II (Purton, 2009). These leaders saw the potential of the new bombards and expanded their use in military campaigns. But even artillery optimists sometimes hamstrung the power of their guns by using poor tactics. Some accounts record cases of overconfident commanders that brought insufficient cannonballs to sieges and were forced to revert to traditional tactics (DeVries, 2024). Consequently, by the early 1440s, Europeans held a wide range of contrasting views on the effectiveness of cannons, creating the potential for mutual optimism.

3.2 Artillery use at the Siege of Constantinople

European attitudes about gunpowder artillery began to evolve after May 29, 1453, when an Ottoman army led by Mehmed II captured Constantinople, the capital and final remnant of the Byzantine Empire, after a 53-day siege. During the siege, the Ottomans made extensive use of gunpowder artillery, employing as many as 70 cannons to fire over 5,000 projectiles (Ágoston, 2014). The cannons the Ottomans deployed were not more sophisticated than those used in Western Europe at the time; in fact, the Ottomans employed European gunsmiths to cast some of their artillery (Ágoston, 2014). The Ottomans' innovation was employing artillery tactics in ways that took full advantage of the technical advancements made in artillery construction over the preceding half century. For instance, the Ottomans created batteries of three or more cannons that fired simultaneously at a single point to maximize damage inflicted (Philippides and Hanak, 2011). In addition, the Ottomans brought enough artillery and ammunition to allow for near-continuous bombardment, preventing the defenders from repairing damage to the walls between shots. These tactics ensured the Ottomans' cannons had devastating effect on the fortifications of Constantinople, which had been regarded by contemporaries as among the most formidable in Europe. The city was defended by multiple sets of land walls, which had not been breached by a besieging army in the millennium since their construction in 413 A.D. (Runciman, 1965).

Due to the religious significance of an Ottoman conquest of Constantinople, many European observers were present at the siege of the city, with some fighting on behalf of the Byzantines. These observers noted the Ottomans' novel artillery tactics and their effectiveness against the city's fortifications. Some eyewitnesses produced detailed written accounts of siege, in which a universal emphasis was the power of the Ottoman artillery. For instance, one account records how the walls of Constantinople were unable to resist sustained bombardment:

> And the stone, borne with tremendous force and velocity, hit the wall, which it immediately shook and knocked down, and was itself broken into many fragments and scattered, hurling the pieces everywhere and killing those who happened to be nearby. Sometimes, it demolished a whole section, and sometimes a half-section, and sometimes a larger or smaller section of a tower or turret or battlement. And there was no part of the wall strong enough or resistant enough or thick enough to be able to withstand it, or to wholly resist such force and such a blow of the stone cannon-ball.[10]

Reports of the Fall of Constantinople began to spread almost as soon as the Ottomans entered the city. The religious implications of the conquest, along with the fact that Constantinople's defenses were considered nearly impregnable, meant that the city's fall was taken with shock. News of the siege and capture of the was spread orally via European eyewitnesses and Greek refugees, as well as through the publication of written accounts. The accounts of the siege produced by eyewitness were some of the first texts mass-produced by the newly invented printing press, and were widely read across Europe (Bisaha, 2017). At least four narrative accounts of the siege of Constantinople were published in the years after 1453, each emphasizing the power of the Ottomans' cannons and the tactics used to wield them (Philippides and Hanak, 2011).

---

[10]Cited in DeVries (1997).

3.3 Reactions to the Fall of Constantinople

As news of the Fall of Constantinople spread across Europe, military leaders took note of the Ottoman's effective application of cannons and changed their assessments of the utility of gunpowder artillery. The clearest evidence of a shift comes from the actions of Philip the Good, Duke of Burgundy. Upon hearing reports of the Ottomans' guns at Constantinople, Philip expanded the artillery train for a planned campaign to include "five or six hundred gunners" and later added six hundred culveriners (DeVries, 2017; Smith and DeVries, 2005). Philip was not the only one to recognize that the siege of Constantinople had demonstrated how gunpowder artillery could be used to destroy existing fortifications. European soldiers and military theorists, after hearing of or observing the military effectiveness of the Ottomans, penned treatises urging their rulers to adopt Turkish artillery and field tactics.[11] While the goal of these writers was to prepare Europeans to wage a crusade against the Ottomans, their acknowledgement of the validity of these tactics indicates a widespread shift in European opinions about artillery.

Furthermore, there is evidence that the information about guns' capabilities revealed in the Siege of Constantinople influenced the conduct of sieges in the latter half of the 15th century. Written accounts of the Siege of Constantinople described how the Ottomans would form batteries of cannons that would concentrate fire at a single point to maximize damage to walls (Philippides and Hanak, 2011). Primary source accounts of sieges taking place after 1453 show that Europeans began imitating such tactics. For instance, at the 1464 siege of Bamburgh Castle in Scotland, the besieging army coordinated the first shot of its cannons so that they fired in unison, dealing so much damage to the walls that "stones flew into the sea" (Giles, 1845). This tactic succeeded in awing the defenders to immediately surrendering, also demonstrating the second shift in artillery use after 1453: the use of cannons and bombards as negotiating tools.

While sieges were always preceded by a mixture of promises, bribes, and threats meant to achieve a peaceful outcome, sieges after 1453 are distinguished by the inclusion of cannons in these negotiations. Increasingly, attackers in pre-siege and pre-battle negotiations would focus

---

[11]See Christensen (1987) for a list of primary sources in this genre.

on demonstrating to defenders the power of their artillery in order to awe the defenders into surrender, thus averting a fight. Displays of artillery power seem to have been used as statements of resolve to bring an opponent to the negotiating table. One example of this process took place at Fornovo in 1495. The two opposing armies opened negotiations by firing their cannons into the air, trying to demonstrate the strength of their artillery and their willingness to fight:

> I shall now acquaint you with what became of the letter which the Cardinal and I had sent by a trumpeter. It was received by the proveditors, and as soon as they had read it, our great guns began to fire, and they immediately answered us; but their artillery was not so good as ours. The proveditors sent the trumpeter back, and the marquis sent another of his own with this message, that they would willingly treat, and if we would give over cannonading, they would do so too.[12]

These episodes show that a greater awareness of effective tactics for the use gunpowder artillery emerged among European military leaders in the years following the Fall of Constantinople. Evidence for this shift is corroborated by changes in the ways that Europeans discussed artillery in written sources following 1453. According to De la Croix (1963), starting in the mid-1450s, we observe a sharp increase in the mentions of gunpowder artillery in military manuals and treatises on fortification. Condottieri, Italian mercenaries, who had previously been silent on the use of cannons, began devoting chapters of manuals to the proper use of artillery in siege warfare, even offering guidance on the number of cannons and projectiles needed to successfully capture fortresses with varying levels of defenses. The articulation of such artillery tactics, as well as their uniformity across different manuals, suggests that after 1453, Europeans experienced a convergence in both attitudes toward gunpowder artillery and tactics for its use.

3.4   Conclusion and empirical hypothesis

This section has offered evidence that prior to 1453, Europeans held contrasting beliefs about the utility of gunpowder artillery in siege warfare, despite recent technical advancements that

---

[12]Page 210 in de Commynes (1817).

rendered artillery capable of destroying existing fortifications. This disagreement in part arose due to a lack of awareness of how to employ artillery in ways that took advantage of such technical advancements. In 1453, the Ottoman Empire demonstrated how to use artillery effectively during the successful siege of Constantinople, which was observed by Western Europeans. European eyewitnesses spread news of the Ottomans' tactics across the continent, which were quickly adopted by military leaders. The realization that existing fortifications could not withstand artillery fire put defenders at a disadvantage, and attacking armies began to emphasize their artillery's power in attempts to cow the defenders into surrendering without a siege. Importantly, slow travel times meant that the realization of the advantage offered by artillery' came later in locations farther from Constantinople.

Given the historical evidence and the theory sketched in Section 2, I hypothesize that the arrival of news about the use of cannons at Constantinople resulted in fewer sieges taking place. Moreover, given the long travel times of the era, locations nearer to Constantinople would have heard such news earlier and thus experience a decline in siege warfare earlier. I offer two mechanisms that justify this prediction.

First, the diffusion of artillery tactics used at the siege of Constantinople created a consensus among the attackers and defenders about how cannons would perform in a siege. This common reference point gave both sides in a siege similar information to forecast how they would perform in combat. Common expectations reduced the probability that adversaries arrive at mutually optimistic beliefs about their chances of winning. Put more formally, the Fall of Constantinople served as a public signal about the effect of gunpowder on the balance power in a potential siege, leading to convergent beliefs.

Second, the clear advantage offered by cannons to attackers in sieges diminished the influence of other private information that may cause bargaining failure. When negotiating before a siege, attackers were generally not aware of how much food the defenders had stored or how many soldiers served in the garrison, both factors that influence defenders' beliefs about how long they could resist a siege. In the classic bargaining framework, such private information may lead

the attackers to propose a settlement that the defenders find less preferable to fighting (Fearon, 1995). However, private information would be less important in the face of overwhelming artillery power–having an extra month of food stored matters little if the walls can be breached after a day of bombardment.[13]

In the sections that follow, I describe and carry out an empirical test of the hypothesis that information about the use of cannons at Constantinople induced a decline in siege warfare.

4 Data on siege warfare and proximity to Constantinople

An ideal dataset to study how exposure to information about the use of cannons at Constantinople influenced decisions to fights in siege warfare would consist of all threatened sieges in the mid-15th century and an indicator of whether the defenders surrendered, as well as the precise timing of when combatants updated their assessments of gunpowder artillery. With such data, one could examine how frequently confrontations before fortifications escalated into sieges before and after the combatants learned of artillery tactics employed at Constantinople.

Unfortunately, such detailed data do not exist. One problem is that "potential" sieges where defenders immediately surrendered upon arrival of an attacking army are rarely attested. Even perfect data on potential sieges would produce an undercount, as sometimes multiple fortifications were exchanged in an agreement to avoid or end a single siege. In such cases, it is difficult to determine whether the additional fortifications would have been besieged in a counterfactual scenario where the agreement was rejected. Likewise, detailed records of when individuals learned of the artillery tactics used at Constantinople are unavailable. Given the relative disorganization of militaries at the time, changes in thinking about artillery may not have been written down at all.

I therefore collect data on the raw number of confirmed sieges and construct multiple proxies–transport costs, distance, and travel time–for when Europeans learned about the Fall of Con-

---

[13]This result has been shown formally by Fearon (2021) and Reed (2003) using both a take-it-or-leave-it bargaining protocol and a mechanism design approach. Intuitively, private information has a greater influence on *relative power* in a dyad with near equal military capabilities than in one with a large power imbalance.

stantinople. Using the raw count of sieges as the outcome requires caution, as changes in the number of sieges may be due to other factors correlated with when a location learned about the Fall of Constantinople, such as changes in broader patterns of warfare, alliances, or even natural disasters. To account for these potential confounders, I also collect data on additional conflict, political, and economic variables for use in robustness checks.

4.1   Outcome: sieges

The dependent variable of the study is the number of sieges occurring in a Roman Catholic diocese per year. To construct this variable, I collected a novel dataset of sieges that occurred in Western and Central Europe between 1443 A.D. and 1463 A.D.. I define a siege as a military conflict involving a fortification, such as a castle or city, where there is an attempt to blockade, destroy, or assault the fortification that was met with resistance. Excluded are pitched battles occurring beyond the defenses of a fortification and situations where individuals opportunistically barricaded themselves in structures not intended to resist attack.

I focus on sieges that took place between 1443 and 1463 in order to isolate a period where military technology was constant. As described in Section 3, prior to the 1440s cannons and bombards did not have enough power to pierce the walls of most fortifications. Conversely, beginning the 1460s, rulers invested in new forms of fortification, such as the *trace italienne*, as countermeasures to resist artillery (Bradbury, 1992; Mangini and Petroff, 2022). As technological changes could have influenced decisions to fight, restricting attention to the decades around 1453 helps ensure that the effect of technology on conflict operates primarily through new information on how to use gunpowder artillery.

Sieges included in the dataset are drawn from primary and secondary sources in several languages.[14] Primary sources include documents such as chronicles, letters, and treaties. Authoritative secondary sources include histories of individual wars, biographies of rulers, and publications of local historical societies. The complete dataset consists of 356 sieges, associated with at least

---

[14]Source languages include Czech, Dutch, English, French, German, Hungarian, Italian, Latin, Polish, and Spanish.

40 named conflicts.[15] The dataset comprises the largest and most complete account of European sieges in the mid-15th century, with nearly 20 times as many sieges documented than Jaques (2006), whose data are commonly used in studies of historical conflict.
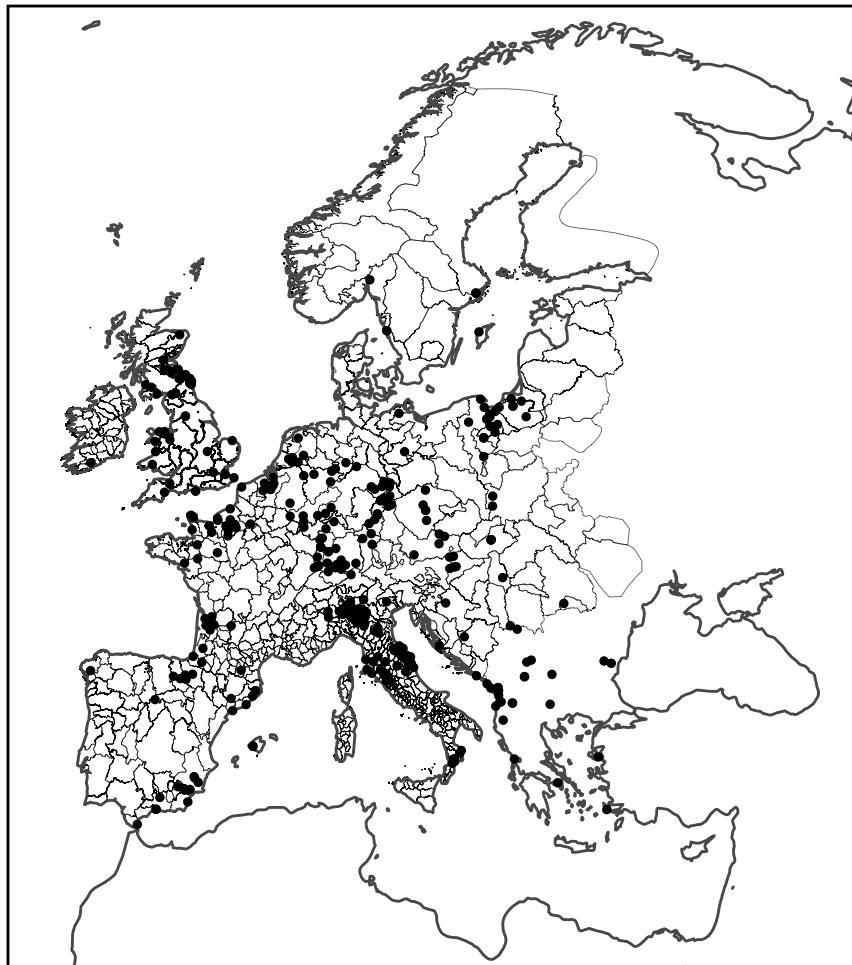
Figure 1: Diocese boundaries and siege locations

Sieges are aggregated by Roman Catholic diocese using boundaries circa 1450 A.D. Aggregating by diocese, rather than by polity or spatial grid cell, offers several advantages. First, the Roman Catholic diocese is the most granular territorial unit from the time for which there exist reliable boundary data.[16] Second, diocese borders almost always followed existing political boundaries (Dorin, 2021). Last, the portion of Europe with established Roman Catholic dioceses

---

[15] A full list of wars with associated sieges that occurred between 1443 and 1463 can be found in Appendix A.

[16] Diocese boundaries are drawn from the Digital Atlas of Dioceses and Ecclesiastical Provinces in Late Medieval Europe (1200-1500), constructed by Dorin (2021).

corresponds to Western Christendom, the audience that would have closely followed news of the Fall of Constantinople. In 1450 A.D. there were 669 Roman Catholic Dioceses in Europe, stretching from Portugal to Western Ukraine.[17] Figure 1 plots siege locations and diocese boundaries.[18] The figure shows that siege warfare was common throughout Western and Central Europe, with notable clusters in Northern Italy, the Low Countries, and Switzerland.

4.2 Treatment: transport cost

The main treatment variable of the study is the transport cost of a diocese from Constantinople, which I use as a proxy for when locals learned how cannons were employed at the Siege of Constantinople. Due to the lack of data on the cost of travel in the 15th century, I estimate the transport cost of all dioceses from Constantinople using a shortest-path approach common in the literature on international trade.[19] To do so, I divide Europe into grid cells of roughly $0.5° \times 0.5°$, with cells classified as either sea or land. The cost of traveling between adjacent cells i and j, denoted $c(i, j)$, is a function of the distance in kilometers between the centers of the cells, denoted $d(i, j)$, and a per-kilometer cost determined by the terrain of the destination cell, denoted c_j^{mode}. Technological constraints in the Middle Ages made travel by sea much cheaper than travel by land–an analysis of medieval shipping records by Masschaele (1993) reveals that the cost of shipping identical goods by land was roughly eight times more expensive than shipping them by sea. I therefore set $c^{land} = 8$ and $c^{sea} = 1$, and define the (directed) cost of travel between adjacent cells i and j as $c(i, j) = c_j^{mode} \times d(i, j)$. The transportation cost of diocese d from Constantinople is then the cost of the shortest path through adjacent cells between the cells containing d and Constantinople, or

$$\text{transportCost}_d = \min_{p \in \mathcal{P}_d} \sum_{(i,j) \in p} c(i, j)$$

---
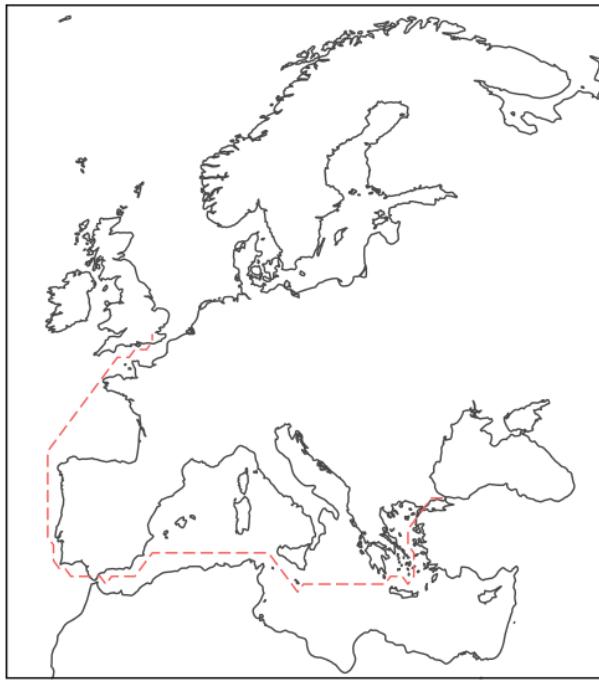
[17]The dioceses on the Canary Islands, the Faroe Islands, Greenland, and Iceland are removed from the data due to their low populations and limited contact with continental Europe during the period under study. Their exclusion does not affect any results presented subsequently.
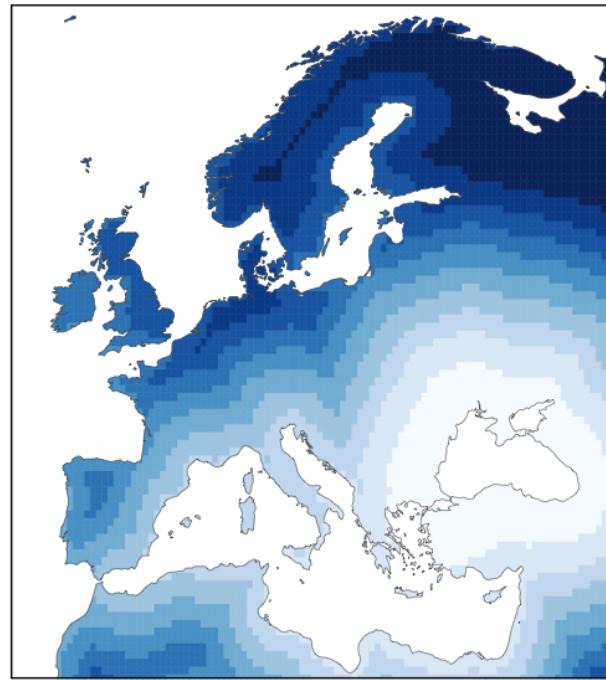
[18]Sieges in the Balkans were also collected for completeness, but are not included in the analysis.

[19]See Flückiger et al. (2024) and Juhász (2018) for recent papers that use a similar methodology.

where $\mathcal{P}_d$ is the set of all paths between Constantinople and a diocese d. The variable transportCost$_d$ is computed using Dijkstra's shortest path algorithm (Dijkstra, 2022). An example of such a path between Constantinople and London is shown below in Figure 2, while Figure 3 visualizes transport costs to Constantinople for every grid cell on land.

Figure 2: Least-cost path to London   Figure 3: Transport costs by grid cell

Proxy validation and alternative measures

The validity of the transportation cost proxy depends on an assumption that dioceses with lower transport costs learned about the use of cannons at Constantinople earlier than dioceses with greater transportation costs. To empirically assess if this is the case, I compare my transport cost estimates with the dates that major cities first learned about the Fall of Constantinople, drawn from primary sources. Note that this initial wave of information communicated few specifics about the course of the siege, mentioning only that the city had fallen and diffusing relatively

quickly throughout the continent (Pertusi, 1990; Schwoebel, 2023). Nevertheless, it is the only news that can be reliably dated. The spread of this information is plotted in Figure 4.[20] The figure illustrates a clear gradient in the timing of the arrival of news about Constantinople's capture. The news spread first to the Balkans and Italy, moved into Central Europe afterward, and reached the British Isles and Northern Europe last of all.
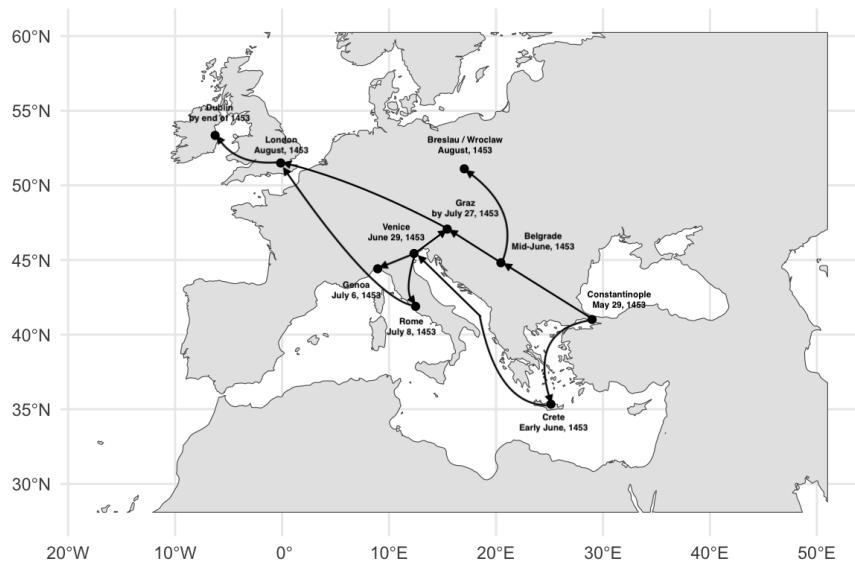
Figure 4: Diffusion of initial news about Fall of Constantinople

Figure 5 plots the time it took news of Constantinople's capture to reach a location by its estimated transport cost to Constantinople. The figure reveals that there is a strong linear relationship between transport costs and the timing of initial news the Fall of Constantinople. Although more detailed reports about the use of gunpowder artillery at Constantinople would begin to diffuse months later with the movement of refugees and the publication of firsthand accounts, the correlation displayed in Figure 5 provides some evidence that transportation costs accurately track how information spread in the mid-15th century. These results are also consistent with past research in international trade and geography on the spread of information in pre-industrial

---

[20]Details of the sources used to construct Figure 4 can be found in Appendix A.4.

times, which find that news tended to follow the movement of people and goods on trade routes
(Birkett, 2018; Robb, 2007).
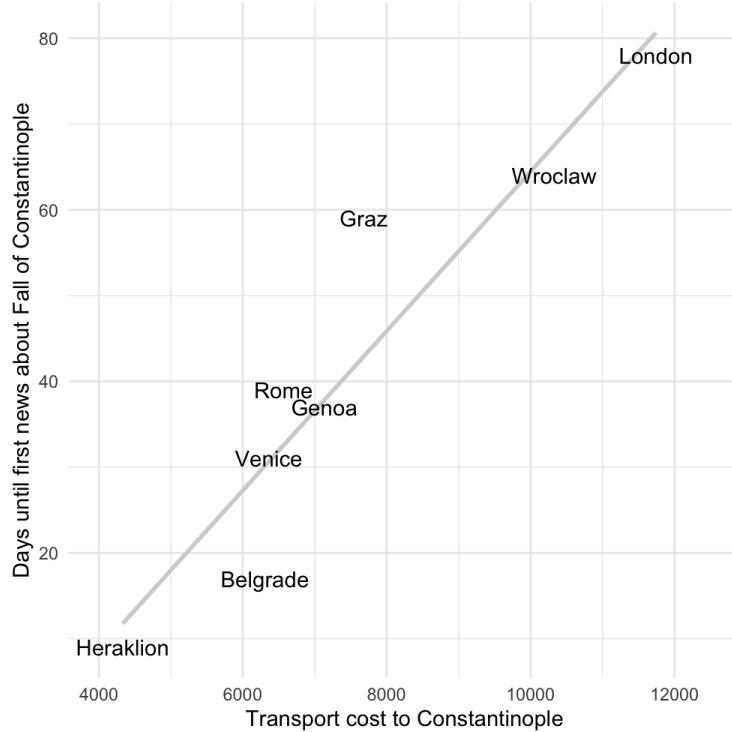
Figure 5: Timing of initial news vs. transport cost

In addition, I construct two alternative proxies for when dioceses learned about the use of artillery at Constantinople: the great circle distance and travel time. The great circle distance is defined as the shortest arc over the Earth's surface between Constantinople and the centroid of each diocese. Travel time is estimated using a shortest-path algorithm like transport costs, but incorporates terrain roughness, historical records of sailing speed, and functions that estimate walking speed by grade. Details of alternative proxy construction can be found in Appendices C.1 through C.4.

4.3 Additional variables

For use in robustness checks, I collect diocese-level data on urbanization, number of fortresses, presence on trade route, conflicts, and sovereign state affiliation. I measure a diocese's level of

urbanization by the number of settlements it contained with a population of at least 1,000 in the year 1400, drawn from Buringh (2021). The number of fortresses (i.e., castles) extant in 1450 is sourced from a scrape of crowd-sourced information on WikiData. I draw historical overland trade route data from Shepherd (1911). To measure the number of ongoing wars in a given diocese, I geocode the extent of relevant European wars included in Brecke (1999)'s catalogue of historical conflicts with at least 32 battle deaths. Finally, I determine each diocese's political affiliation in 1400 using the historical atlas maintained by Nüssli (2009).[21]

5 Empirical strategy

5.1 Differences-in-differences

To examine how exposure to information about the use of cannons at Siege of Constantinople affected the frequency of siege warfare in Europe, I employ a continuous difference-in-differences design implemented using a two-way fixed effects (TWFE) estimator. Specifically, I estimate the following fixed effects Poisson model (Hausman, Hall and Griliches, 1984) using quasi-maximum likelihood

$$E[sieges_{dt} \mid \beta_d, \gamma_t] = \exp\left(\alpha\, post1453_t \times transportCost_d + \beta_d + \gamma_t\right)$$

where d indexes dioceses and t indexes calendar years between 1443 and 1463. The main dependent variable, $sieges_{dt}$, is the number of sieges that occurred in diocese d during year t. The variable $post1453_t$ is a dummy that takes value 1 in the years following the Fall of Constantinople in 1453 and 0 otherwise. The terms β_d and γ_t are diocese and year fixed effects, respectively. The variable $transportCost_d$ is the transport cost of a diocese from Constantinople. The difference-in-difference indicator is the interaction term $post1453_t \times transportCost_d$. It takes the value of the transport cost of diocese d after 1453 and zero otherwise. Therefore, the coefficient α cap-

---

[21]Descriptive statistics and maps of the control variables can be found in Appendix A.

tures how a diocese's transport cost from Constantinople affected the frequency of siege warfare in years after the Fall of Constantinople, holding other factors fixed. Intuitively, the difference-in-differences estimator compares the frequency of siege warfare in dioceses at varying distances from Constantinople before and after 1453.

I use a Poisson regression model for ease of interpretation and robustness. In the model, the regression coefficient α can be interpreted as a semi-elasticity, meaning that the transformation $100 \times (e^{\alpha} - 1)$ yields the expected percentage change in the number of sieges associated with a one-unit increase in proximity to Constantinople. Attempts to achieve a similar interpretation using a linear model require transformations to address zero-valued outcomes, which can potentially introduce bias (O'Hara and Kotze, 2010). Moreover, the fixed-effect Poisson model is robust, producing consistent estimates for any mean-variance relationship in the outcome data, including when it does not follow a Poisson distribution (Wooldridge, 1999, 2023). Linear models lack such desirable properties when applied to count data, and have shown to perform poorly when applied to count and count-like data (Cohn, Liu and Wardlaw, 2022; King, 1988).

A potential issue with implementing a two-way fixed effect estimator via Poisson regression is the exclusion of dioceses that experienced no sieges during the 20 years under study. When fitting models that use (pseudo) maximum likelihood estimation, panel units that contain only zero observations are dropped when unit fixed effects are included. This is because the fixed effects perfectly explain the lack of observed variation and the zero counts contribute no information to the parameter likelihoods (Silva and Tenreyro, 2010). In the context of this study, this means the effect of proximity to Constantinople on siege warfare will be estimated using dioceses that experienced at least one siege in between 1443 and 1463. The exclusion of dioceses that had no sieges is not necessarily problematic. Many dioceses were sparsely populated and had no castles or fortified towns–in these cases the diocese fixed effects do fully explain the lack of sieges. Nevertheless, to account for possibility that important observations may be left out, I estimate additional Poisson models with fixed effects at the polity level, ensuring nearly all the data is used. In addition, to ensure conclusions drawn from the empirical analysis are not driven

by a particular functional form assumption, I also estimate ordinary least squares and logistic regression models. These additional models can be found in Appendix C.

5.2   Causal identification

Under a difference-in-differences empirical approach implemented using two-way fixed effects, interpreting the coefficient α as the causal effect of proximity to Constantinople on siege warfare requires four assumptions: parallel trends, no anticipation, and no heterogeneous treatment effects, and no time-varying unobserved confounders (Callaway, Goodman-Bacon and Sant'Anna, 2024; Roth et al., 2023).

No anticipation mandates that siege warfare did not begin to decline in places closer to Constantinople prior to the capture of the city in 1453. This assumption could be violated if polities nearer to Constantinople foresaw the capture of the city and feared that the Ottomans would proceed to invade Europe. Polities near Constantinople may have ceased fighting among themselves before 1453 to prepare a balancing coalition and deter an invasion. Polities far away from the Ottoman Empire, feeling less threatened, would have been less inclined to balance. However, the historical record indicates this is unlikely to be the case. While there appears to be a consensus among historians that Europeans saw the Byzantine Empire as doomed, there is evidence that the precise timing of the Fall of Constantinople came as a surprise (DeVries, 2017; Pertusi, 1990; Schwoebel, 2023). The 1453 siege was the fifth time the Ottoman Empire had attempted to capture Constantinople, with the city even resisting an eight-year blockade between 1394 and 1402. There was no guarantee that the Ottomans would succeed in 1453; indeed, some of Mehmed II's military advisors advised him to abandon the siege after early setbacks (Runciman, 1965). The Fall of Constantinople therefore came as shock to Europeans, making it unlikely that they changed their behavior prior to hearing news of the city's fall (Bisaha, 2017).

The assumption of parallel trends requires that, prior to 1453, the frequency of siege warfare in locations both near to and far from Constantinople were trending in the same direction, and that these trends would have continued had the city not fallen in 1453. Support for parallel trends come

from the fact that, whether measured by transport costs, raw distance, or travel time, proximity to Constantinople is determined by a combination of geography and population settlement decisions that took place centuries or millennia before the 1400s. Places that became cathedral cities around which dioceses formed were both settled and elevated to the seats of bishops long before the 15th century (Dorin, 2021). It is unlikely that settlement patterns in antiquity systematically influenced warfare in the mid-15th century. Any persistent cross-sectional differences in conflict are likely instead driven by idiosyncratic factors that can be accounted for by fixed effects.
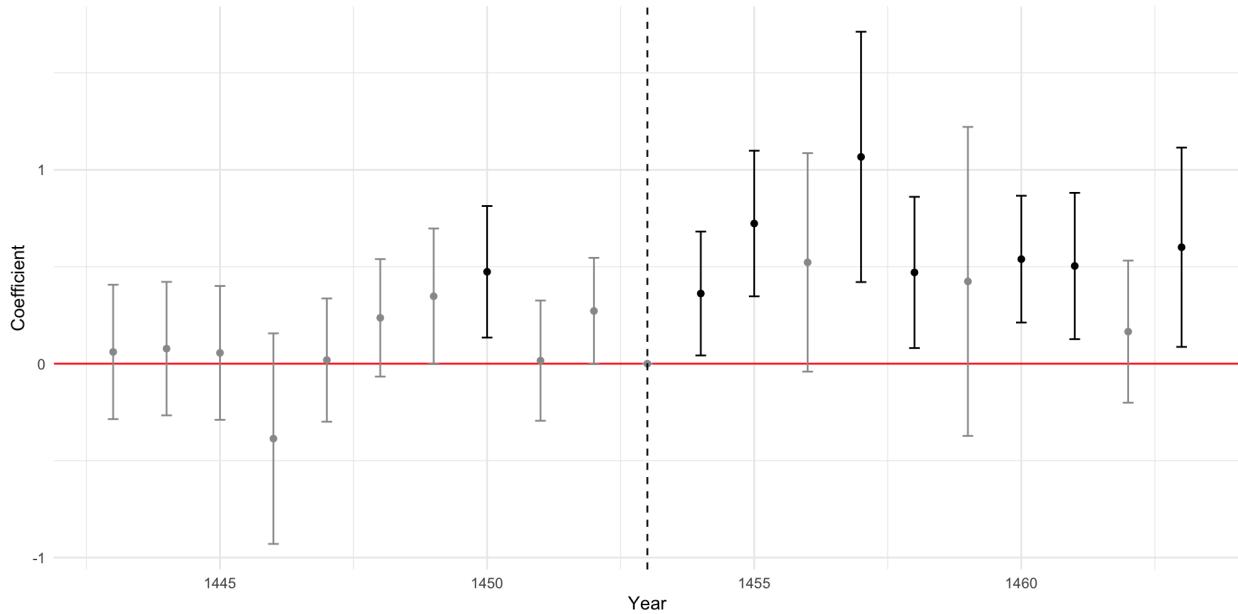
Figure 6: Event study

I empirically assess the plausibility of the no anticipation and parallel trends assumptions by conducting an event study of the effect of transport costs on sieges for each year between 1443 and 1463. The resulting coefficients and 90% confidence intervals are plotted in Figure 6.[22] The figure shows that, prior to 1453, the effect of transport costs to Constantinople on sieges is generally statistically indistinguishable from zero, indicating that transport costs were uncorrelated with siege frequency prior to the city's capture by the Ottomans. After 1453, the coefficient is always positive and statistically significant in all but three years. While the confidence intervals are wide due to the low number of sieges in individual years (an average of about 16), these results

---

[22]The specification and coefficients for the event study are reported in Appendix B.1.

provide evidence for both the absence of pre-trends and the existence of an effect starting after 1453, substantiating the no anticipation and parallel trends assumptions.

No heterogeneous treatment effects means that the influence of proximity to Constantinople on siege warfare should not vary across dioceses. The most likely source of potential heterogeneity is regional differences in the relevance of gunpowder artillery to siege warfare. In places where cannons were rarely used, information about artillery's effectiveness conveyed by the Fall of Constantinople would have little initial effect, though it may induce a rapid take-up of cannons to realize a new source of combat advantage. Such a concern can largely be ruled out by the work of historians, who have documented that cannons were widely used in 15th-century Europe, except for present-day Russia, which is not included the data (Cipolla, 1965; McNeill, 2013; Purton, 2009). Another potential source of heterogeneity is variation in the extent to which combatants changed their perceptions of cannons upon learning about the Fall of Constantinople. Military leaders in some places may have disregarded the lessons of Constantinople's fall. While it is certainly the case that some leaders were more enthusiastic about artillery, the documentary evidence provided in Section 3 indicates that acknowledgement of the significance of cannons was widespread and consistent–recognized by Italian condottieri, Flemish commanders, and Scottish kings.

Last, to address potential time-varying confounders correlated with transport costs to Constantinople, I add additional fixed effects and control variables to the baseline TWFE estimator. First, I include polity × year fixed effects which account for time-varying polity-level confounders such as changes in warfare, alliances, and natural disasters. In addition, there may be time-varying shocks that are heterogeneous across dioceses within polities, and thus not captured by any of the existing fixed effects. To address this issue, I include interaction terms of diocese-level pre-1453 controls with time. My final specification is

$$E[sieges_{dpt} \mid \beta_d, \gamma_t, \delta_{pt}, X_d] = \exp\left(\alpha \; post1453_t \times transportCost_d + \beta_d + \gamma_t + \delta_{pt} + \lambda^T X_d \times t\right)$$

$$(1)$$

where δ_{pt} are polity $\times$ year fixed effects and X_d is a vector of diocese-level controls. Additional details on the identification assumptions can be found in Appendix B.

6   Results

6.1   Main results
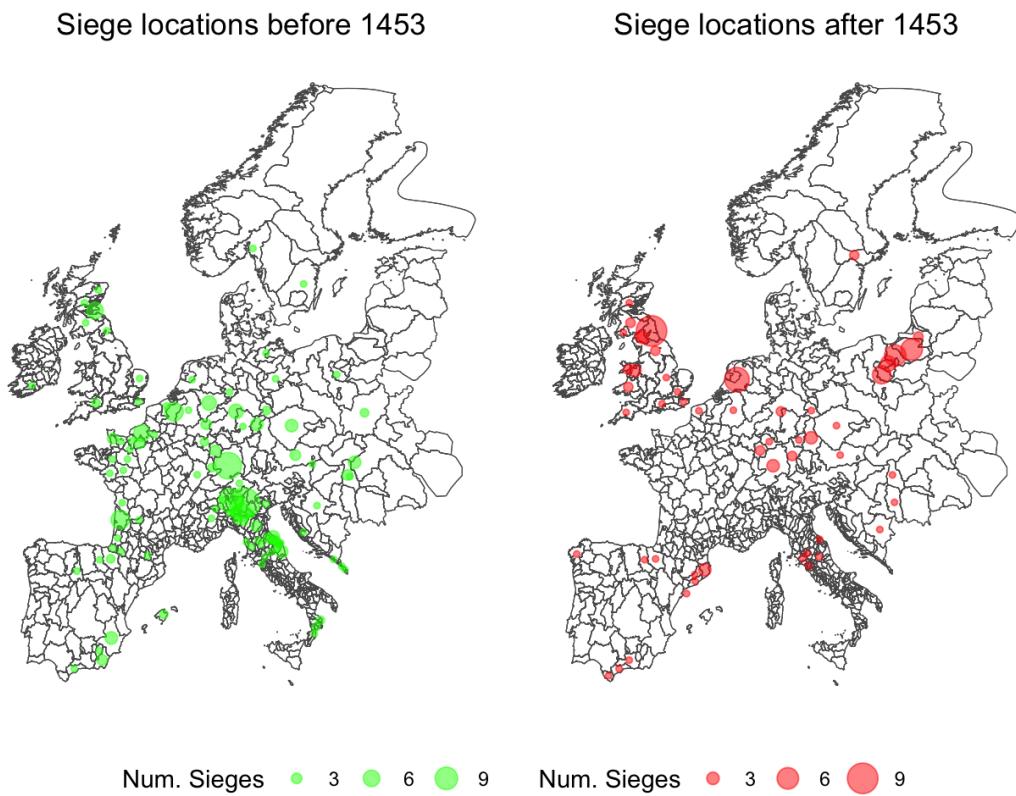
Figure 7: Siege locations before and after the Fall of Constantinople

Before describing the results of the empirical analysis, I present two illustrating that siege warfare became less frequent near Constantinople after 1453. First, Figure 7 maps the locations of sieges before and after the Fall of Constantinople in 1453, aggregated by decade. The map reveals a geographic shift in the concentration of siege warfare from the Mediterranean Basin and Central Europe, the places with the lowest transportation costs to Constantinople, to the northern and eastern fringes of the continent. In particular, there is little change in the incidence of siege

warfare Great Britain and the Low Countries, but significant declines in Italy and Eastern Europe. Figure 7 offers some visual suggestive evidence that proximity to Constantinople influenced siege warfare after 1453.
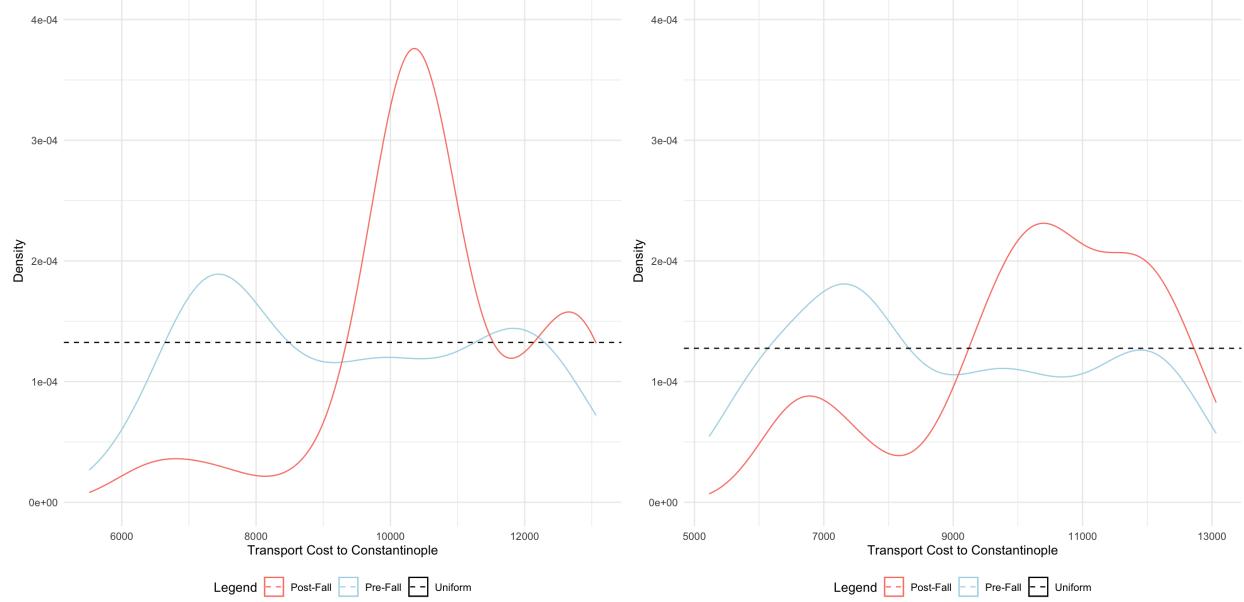
Figure 8: Empirical siege density (10-year)   Figure 9: Empirical siege density (20-year)

An alternative way to visualize how the Fall of Constantinople influenced siege warfare is to examine the relative frequency of sieges by transportation costs. Figure 8 displays the empirical densities of sieges for five-year periods before/after the Fall of Constantinople, while Figure 9 extends the period length to 10 years. In the five years preceding 1453, sieges were nearly uniformly distributed by transport cost to Constantinople, though not perfectly so as population and other factors that influence siege frequency are not uniformly distributed. This suggests that before 1453, proximity to Constantinople had little to no relationship with the incidence of siege warfare. After the capture of Constantinople by the Ottomans, sieges become far more concentrated in the latter half of the distribution, indicating that sieges became relatively less common in dioceses nearer to Constantinople. The concentration of sieges in dioceses farther from Constantinople is less pronounced but still noticeable when extending the period length to 10 years. This is consistent with the hypothesis that Europeans learned about the effectiveness of cannons from Constantinople, as ten years after the Fall Constantinople, information about

the siege would have fully diffused throughout the continent, and one would expect a smalelr gradient in siege incidence by proximity to Constantinople.

I now validate these descriptive patterns using my difference-in-differences identification strategy. Table 1 reports the results of the empirical analysis, using 10-year and 20-year windows around the Fall of Constantinople. Columns 1 through 3 display coefficients obtained when examining only sieges that took place in the five-year periods before and after the Fall of Constantinople. Column 1 shows the baseline two-way fixed effects estimator. Column 2 includes polity $\times$ year fixed effects. Column 3 adds diocese-level controls interacted with year trends. Columns 4 through 6 repeat this analysis, using sieges that occurred in the 10-years periods before and after of Fall of Constantinople. Standard errors are clustered at the level of the diocese to account for autocorrelation in outcomes.

	Num. sieges (10 year)			Num. sieges (20 year)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Post-1453 $\times$ Transport Cost (1000s)	0.32**	1.21***	1.19**	0.29***	0.56*	0.70*
	(0.15)	(0.36)	(0.52)	(0.10)	(0.32)	(0.39)
DV Mean:	0.19	0.19	0.19	0.12	0.12	0.12
Polity $\times$ Year FEs	-	✓	✓	-	✓	✓
Controls $\times$ Year	-	-	✓	-	-	✓
Num. clusters:	73	73	73	131	131	131
N	803	803	803	2751	2751	2751

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$. Note: Robust SEs clustered by diocese. Unit of analysis is diocese-year.

Table 1: Effect of exposure to Constantinople on sieges (transport costs)

For all specifications using the 10-year window, the coefficient on Post-1453 $\times$ Transport Cost is positive and statistically significant, indicating that locations further from Constantinople experienced more sieges in the decade following the capture of the city. Using the full specification (column 3), in the five years after 1453, decreasing the transport cost from Constantinople by one standard deviation (2364.5) reduces the yearly frequency of sieges in a diocese by 0.18 sieges on average, or 0.9 fewer sieges in the five years following 1453.[23] A decrease of about one siege over

---

[23]A one-standard deviation decrease in transport cost reduces the yearly frequency of siege warfare by

five years may appear to be a small effect. However, the median diocese experienced no sieges during the entire period between 1448 and 1458–removing one siege would render most dioceses completely peaceful. The results support the hypothesis that fewer sieges took place in dioceses with earlier exposure to information about the use of cannons at Constantinople.

The magnitude of the effect becomes smaller when extending the window of analysis to 20 years. In this case, a one-standard deviation decrease in transport cost reduces the yearly count of sieges in a diocese by 0.097, or about 0.97 fewer over the ten years after 1453.[24] This shows that the of proximity to Constantinople on siege warfare is concentrated in the five years following the Fall of Constantinople. The fact that the effect size are smaller in the 20-year window confirms the visual intuition of Figure 9 that as time passed after the Fall Constantinople, information about the siege would have fully diffused throughout the continent.

6.2   Robustness checks

Alternative measures of proximity to Constantinople

The results presented in the previous section may be sensitive to the choice of variable used to proxy for exposure to information about the use of cannons at Constantinople. To test whether this is the case, I conduct the analysis again using two alternative measures of proximity: the great circle distance and travel time. Details of variable construction and the empirical results can be found in Appendices C.1 and C.2. Both alternative measures yield conclusions similar to those obtained for transport costs. Therefore, the post-1453 decline in sieges in locations nearer to Constantinople is unlikely to be driven by choice of proxy variable.

$100(\exp(-2.364 \times 1.19) - 1) = -94\%$. This corresponds to an average effect of $0.94(0.19) - 0.19 = -0.18$ sieges per year.

[24]As before, the elasticity is $100(\exp(-2.364 \times 0.70) - 1) \times 100 = -80\%$. Then the average effect is $0.8(0.12) - 0.12 = -0.097$.

Spatial correlation

Spatial correlation is a potential issue because sieges are rarely lone incidents; rather, they are pieces of broader conflicts that stretch beyond the boundaries of a single diocese. Thus, sieges located in nearby dioceses are unlikely to be independent observations. Treating them as such may produce deflated estimates of standard errors and unwarranted confidence in the results of the empirical analysis.

I take two approaches to address spatial correlation. First, I use the standard error adjustment proposed by Conley (1999). This adjustment treats all observations that are within a certain distance from each other as potentially correlated. Second, I compute robust standard errors clustered by sovereign state, using both modern boundaries and boundaries as they were in 1400 A.D. Because wars are fought between or within states, this approach should also capture the fact that sieges occurring within a territory are likely part of the same conflict. However, this method is less flexible than the Conley adjustment, as clustering by polity will treat sieges from the same conflict but fought on different territories as part of independent clusters.

Standard errors obtained from these methods are reported in Appendix C.4. While accounting for spatial correlation produces larger standard errors are than those obtained from clustering by diocese, they do not change conclusions about the statistical significance of the coefficient of interest.

Alternative functional forms

The results of the analysis may be sensitive to the use of a specific modelling approach. To account for this, I show that the results are robust to changes in functional form. In Appendix C.5, I apply a logit model to a binary indicator of whether a siege occurred. In Appendix C.6, I redo the main analysis using a linear model with a logged outcome variable. For both alternative functional forms, conclusions regarding the direction of the effect of information exposure on siege warfare and its statistical significance are unchanged.

Outlier polities

Another potential concern is that the statistical findings could be driven by shifts in patterns of conflict within a single outlier polity. To examine whether this could be the case, I perform a leave-one-out analysis by excluding each polity one by one and estimating the full specifications again. The results are reported in Appendix C.8.

7   Alternative explanations

The Fall of Constantinople was not the only event with implications for siege warfare to occur in the 1450s. A second threat to identification is the existence of simultaneous unobserved confounders that are correlated with proximity to Constantinople after 1453. In this section, I examine two simultaneous shocks: balancing by European polities against the Ottoman Empire and the end of the Hundred Years' War in October 1453. To assess whether these events influenced siege warfare in the decade after the Fall of Constantinople, I combine historical evidence with a series of placebo tests.

7.1   Balancing against the Ottoman Empire

The Fall of Constantinople marked the end of the Byzantine Empire, a buffer state between the Catholic West and the Islamic East. Polities located near the Ottoman Empire (and thus Constantinople) may have seen the Fall of Constantinople as heralding a threat to their own security, as the leaders of the Ottoman Empire openly professed a desire to conquer Europe. (DeVries, 2017). Under a balance of power logic, the European polities close to Constantinople may have ceased fighting among each other in order to form a balancing coalition (Waltz, 1979). More insulated polities in Northern Europe may have been less inclined to join such a coalition. Consequently, another channel through which proximity to Constantinople could influence siege warfare after 1453 is through a decline in warfare among states near the Ottoman Empire. While the discussion of the no anticipation assumption in Section 5.2 rules out balancing before 1453,

it is still possible that states balanced after 1453.

There is little historical evidence that balancing occurred, though some calls for European unity did occur in the aftermath of the Fall of Constantinople, including in regions threatened by Ottoman expansion, such as Italy and the Habsburg domains in Central Europe. Three successive popes, Nicolas V (r. 1447-55), Callixtus III (r. 1455-58), and Pius II (r. 1458-64) made organizing a Europe-wide crusade to retake Constantinople an objective of their papacies. In addition, Holy Roman Emperor Frederick III held several "Turkish Diets," in an attempt to corral support among the German princes for a crusade.

Yet appetite for a crusade, or even the appearance of unity, was minimal. The inclination of many leaders was to exploit the attempts to organize a crusade for personal benefit. For instance, negotiations in Italy collapsed in 1455 after Alfonso V, King of Naples, attacked Genoa using a fleet of galleys purchased by the Papacy and left in Alfonso's care for the purposes of a crusade (Schwoebel, 2023). In addition, both Venice and Genoa had sought and obtained trade privileges from the Ottoman Sultan immediately after the fall of Constantinople, and opposed any military confrontation. This pattern of disunity continued throughout the decade. The frustration of several attempts at organizing a crusade even led Pope Pius II to exclaim:

> I cannot persuade myself that there is anything good in the prospect [of a crusade].
> Who will make the English love the French? Who will unite the Genoese and the
> Aragonese? Who will reconcile the Germans with the Hungarians and Bohemians?[25]

Pius attributed the reluctance to crusade against the Turks to the fact that Europeans feared each other more than they did the Turks, lamenting: "no king could be found who did not stand in terror of his neighbor and fear to leave his own house empty" (DeVries, 2017).

Attempts at unity were no more successful in the Holy Roman Empire. The German princes were more interested in extracting concessions from Emperor Frederick III or bickering among themselves than constructing a plan to take back Constantinople (Schwoebel, 2023). One chronicler recounted that the princes "had too many quarrels among themselves on their hands to

---

[25]Quoted in Cipolla (1965).

want another with the Turks" (von Pastor, 1923). Even rulers who committed to a crusade were waylaid by infighting. For instance, Phillip the Good, the Duke of Burgundy, pledged himself to the crusading effort only to reverse course a year later due to the risk of war in his own domain (Davies, 1851).

To supplement this qualitative evidence, I conduct a placebo test to quantitatively assess the hypothesis that polities near Constantinople ceased fighting to balance against the Ottoman Empire. I estimate the following fixed effect Poisson regression:

$$E[wars_{dpt} \mid \beta_d, \gamma_t, \delta_{pt}, X_d] = \exp\left(\alpha \; post1453_t \times transportCost_d + \beta_d + \gamma_t + \delta_{pt} + \lambda^T X_d \times t\right)$$

where $wars_{dpt}$ is the number of ongoing wars covering the territory of diocese d within polity p in year t. This variable is constructed by geocoding the extent of conflicts occurring between 1443 and 1463, based on a data set of historical wars collected by Brecke (1999). The remainder of the specification is identical to that used for the main analysis. Because wars occur between and within polities, I cluster standard errors at the level of the polity to account for outcome correlation between dioceses in the same polity. If proximity to Constantinople drove European polities to cease fighting among each, the coefficient on $post1453_t \times transportCost_d$ should be positive and statistically significant.

	Num. conflicts (10 year)			Num. conflicts (20 year)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Post-1453 × Transport Cost (1000s)	0.05	0.01	0.01	0.14	0.13	0.14
	(0.07)	(0.03)	(0.03)	(0.09)	(0.10)	(0.09)
DV Mean:	0.52	0.52	0.52	0.98	0.98	0.98
Polity × Year FEs	-	✓	✓	-	✓	✓
Controls × Year	-	-	✓	-	-	✓
Num. clusters:	52	52	52	56	56	56
N	6105	6105	6105	12348	12348	12348

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Note: Robust SEs clustered by polity. Unit of analysis is diocese-year.

Table 2: Effect of exposure to Constantinople on wars

The results are displayed in Table 2. In all model specifications, the coefficient on Post-1453 × Transport Cost is statistically insignificant and near zero in magnitude. This indicates that it is unlikely that proximity to the expanding Ottoman Empire induced polities to cease fighting each other and form a balancing coalition. Moreover, together with the main analysis, these results imply that while wars did not become less likely near Constantinople, the strategic significance of sieges within conflicts diminished.

The results shown in Table 2 may seem at odds with my theory. If better information about the combat effectiveness of cannons resolves uncertainty about military capabilities and makes peaceful settlements more likely, why do we observe fewer sieges but not fewer wars? The explanation has to do with the relative importance of cannons for each type of conflict. While both sieges and wars can result from bargaining failure, sieges are micro-conflicts where artillery has a large effect on which side wins, while wars are macro-conflicts whose outcomes depend on a wide range of factors. In large conflicts, military planners can employ countermeasures to minimize the advantage of artillery in ways that are not possible in sieges. Historians such as Rogers (2018) have documented that as the primacy of gunpowder artillery over fortifications became evident, pitched battles increased in importance during war. By the mid-15th century, gunpowder artillery could fire projectiles at velocities capable of piercing curtain walls, but issues of low mobility, inaccuracy, and slow rate of fire limited applications to fixed targets and situations where the artillery was not threatened by enemy forces. As a result, gunpowder artillery offered a major advantage to attackers in sieges but not yet in battles. The availability of such countermeasures is one of many additional factors that influence decisions to go to war. Thus, sieges present a special case of conflict where technology was so instrumental to victory that the effect of information on conflict escalation is detectable.

7.2   Learning from artillery use in the Hundred Years' War

My empirical approach rests on the assumption that the Fall of Constantinople in 1453 was the "demonstration point" that revealed the effectiveness of gunpowder artillery to Western Euro-

peans. However, as gunpowder artillery had been in use prior to 1453, it is possible that Europeans ascertained how to employ cannons effectively at sieges before Constantinople. If this is the case, the shift in the geographic pattern of siege warfare after 1453 may have been caused by factors besides information conveyed by the Fall of Constantinople. For the most part, while gunpowder artillery was present at many sieges throughout the 1430s and 1440s, there are few claims by modern or historical writers that gunpowder artillery decisively affected the outcome of these sieges. Most sieges during this period were still broken by starvation or the arrival of a relief army, rather than by breaches in the walls (Purton, 2009). One possible exception is the French use of artillery in the final phase of the Hundred Years' War.
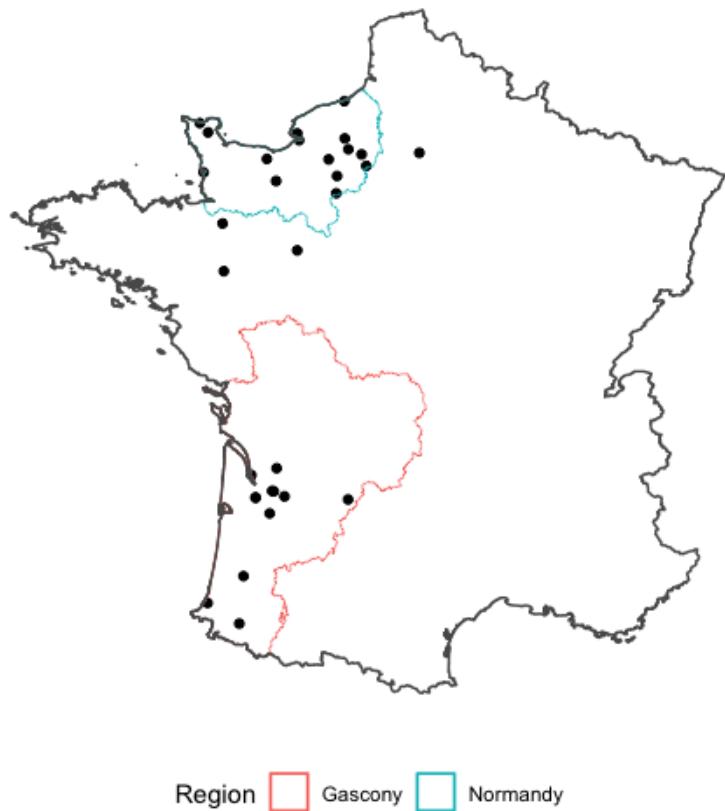

Figure 10: Sieges of the Hundred Years' War in France, 1443-1453[26]

During the 1430s and 1440s, Charles VII of France set out to modernize French artillery. He

---

[26]Due to a lack of historical boundary data, the modern French administrative divisions of Normandie and Nouvelle-Aquitaine are used. Nouvelle-Aquitaine occupies much of the territory of the former Duchy of Gascony.

delegated this task to the brothers Gaspard and Jean Bureau, who standardized the caliber of French bombards and recruited more gunners into the army. The reforms they implemented improved the effectiveness of French artillery, which some historians have credited with aiding successful French campaigns during the Hundred Years' War to reconquer the Duchies of Gascony (1450-1453) and Normandy (1449-1450) from the English (Nicolle, 2012), plotted in Figure 10. Artillery even played a prominent role in the siege of Bordeaux, the surrender of which on October 19, 1453, would mark the end of the Hundred Years' War (Kinard, 2007). The spectacular success of the French army in retaking territory from the English in just four years may have provided an earlier or simultaneous demonstration point for the effectiveness of gunpowder artillery, potentially confounding the results of the previous section.

To examine whether French employment of artillery in the Gascony and Normandy campaigns between 1449 and 1453 affected the frequency of siege warfare in the rest of Europe, I conduct another series of placebo tests. I test whether information diffusion about the use of cannons at Gascony (measured as transport cost to Bordeaux) and Normandy (measured as transport cost to Caen) affected the frequency of siege warfare. I use 1450 as the treatment date for Normandy, given the earlier end date of the campaign. The specification I estimate is otherwise identical to that used in the main analysis, The results are displayed in Table 3. I find no evidence that proximity to Normandy affected the frequency of siege warfare after the end of the campaign in 1450 using both 10-year and 20-year windows. There is weak evidence that proximity to Gascony increased the frequency of siege warfare, the reverse effect that would be expected under a learning theory. The negative coefficient may be due to the fact that transport costs to Gascony are negatively correlated with transport costs to Constantinople.

Why did the Gascony and Normandy campaigns not positively influence perceptions of gunpowder artillery? First, while both duchies had many fortified castles and settlements, none had fortifications as extensive or sophisticated as Constantinople's. Indeed, several locations captured by the French had been successfully taken by the English using traditional siege techniques 30 years before the campaigns of 1449-1453 (Allmand, 1988). These facts likely rendered the French

	Num. sieges (10 year)		Num. sieges (20 year)	
	Gascony	Normandy	Gascony	Normandy
Post-1450 × Transport Cost (1000s)		0.16		−0.15
		(0.83)		(0.44)
Post-1453 × Transport Cost (1000s)	−1.13*		−0.69	
	(0.65)		(0.44)	
DV Mean:	0.19	0.20	0.12	0.12
Polity × Year FEs	✓	✓	✓	✓
Controls × Year	✓	✓	✓	✓
Num. clusters:	68	93	127	131
N	748	1023	2667	2751

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Note: Robust SEs clustered by diocese. Unit of analysis is diocese-year.

Table 3: Effect of exposure to Gascony/Normandy on sieges

conquest less impressive, even if it involved effective use of cannons. Second, the artillery reforms implemented by the Bureau brothers may have been overshadowed by other changes that provided the French a war-fighting advantage. For instance, in 1435, the Duchy of Burgundy shifted its allegiance from England to France, depriving the English of their strongest continental ally (Nicolle, 2012). Charles VII also implemented fiscal reforms starting in the 1430s that enabled France to field a much larger army (Reyerson and Jones, 2004).

7.3   Sieges of the Hundred Years' War

The end of the Hundred Years' War in 1453 may also have directly influenced the geographic distribution of sieges.[27] The end of the war ushered in a period of peace in France, but presaged conflict in England. England's defeat in the Hundred Years' War generated domestic social unrest and political turmoil. Many wealthy nobles suffered financial costs from the loss of estates on continental territory captured by France, contributing to dissatisfaction with the rule of the already unpopular Henry VI (Postan, 1942). The years after 1453 were characterized by widespread

---

[27]Note that the Hundred Years' War is more accurately regarded as a series of on-and-off conflicts between England and France over control of French throne, rather than one continuous conflict. The year 1453 is used to mark the end of the war today, as no further fighting took place; however, at the time there was some expectation that England would attempt to take back territory lost (Nicolle, 2012).

lawlessness, including violent feuds between noble houses, that crescendoed into civil war when Richard of York decided to press his claim on the English throne in 1455. This started the series of civil wars today known as the Wars of the Roses.

Consequently, the resolution of the Hundred Years' War is associated with a decline in sieges in France, but an increase in sieges in England. As England and France were two of the largest polities during this period, comprising nearly a quarter of the dioceses in the dataset, this raises concerns that the results of the main analyses are driven by the impacts of the Hundred Years' War. To account for this issue, I conduct the main empirical analysis on a subset of the data that excludes England and France. The results are shown in Appendix D.2. The results of the analysis on the smaller sample do not change any conclusions about the effect of proximity to Constantinople on siege warfare.

8   Conclusion

I posit that technological change can increase the frequency of international conflict by introducing uncertainty about the balance of power. This uncertainty arises from the fact that states must independently assess the technology's effect on military capabilities. Such uncertainty can be mitigated if states observe the new technology being used in combat, which provides a common reference point to judge the efficacy of the new technology. I test this theory by examining how the Fall of Constantinople in 1453 influenced the frequency of siege warfare across Europe. The siege of Constantinople featured Ottoman use of gunpowder artillery to great effect against the most sophisticated fortifications in Europe. Anecdotal evidence indicates that Europeans quickly adopted these new tactics and the defenders of castles and settlements realized that existing fortifications could not withstand artillery fire, leading them to surrender more often when faced with an adversary equipped with cannons. A difference-in-differences approach confirms that locations that learned about the Fall of Constantinople earlier, as measured by transportation cost, experienced fewer sieges after the city's capture. Placebo tests rule out alternative explanations

for this relationship, strengthening the conclusion that the decline in siege warfare was due to better information about the effectiveness of gunpowder artillery.

These findings suggest that perceptions of how new technologies affect military capabilities are important factors in conflict escalation. A focus on perceptions contrasts my theory with prior research, which has sought to link particular attributes of technologies (i.e., creating offensive advantage) to conflict (Biddle, 2004; Glaser and Kaufmann, 1998; Levy, 1984). Yet the empirical results of this paper indicate that how new technologies impact capabilities contributes less to the outbreak of conflict than the degree to which states agree on what that impact is. As in the case of cannons, an "offense-enhancing" innovation need not generate conflict if states acknowledge it as such and adjust their bargaining behavior accordingly. Of course, nothing prevents states from seeking countermeasures to the new technological reality. Indeed, after the Fall of Constantinople rulers modified their military strategies to avoid sieges and invested in new cannon-resistant fortifications (Mangini and Petroff, 2022; Rogers, 2018). Therefore, the relationship between technological change and conflict may be cyclical: unproven technologies developed to counter existing equipment may blur perceptions of the balance of power.

The results of this paper also suggest a new research agenda on the sources of disagreement about the significance of new technologies. While I propose three domestic sources of differing perceptions–technical challenges in assessing new technologies, the development of doctrine, and bureaucratic competition–I neither assess their relative significance nor discuss variation. It is possible that particular regime types or forms of bureaucratic organization tend to produce more biased assessments of technology. Similarly, the effect of some types of technologies may be subject to greater controversy; for example, technologies such as flight that unlock new domains of warfare may prove harder for militaries to evaluate. Future research in this area would elaborate the mechanisms of my theory while clearly delimiting its scope.

Finally, the empirical approach taken in this paper can serve as a model for other studies seeking to conduct causal tests of theories of international relations. Historical episodes, such as the Fall of Constantinople, can serve as natural experiments for theories that are difficult to

assess using modern data. This is important because much empirical research in international security relies on designs that cannot establish causality (Torreblanca et al., 2025). Such studies can document important patterns in international conflict, but their lack of causality casts doubts on theoretical explanations and offers little benefit to policymakers. The past is a fruitful source of data for new studies that can enhance confidence in theories of international relations (Charnysh, Finkel and Gehlbach, 2023).

References

Acemoglu, Daron and James A Robinson. 2000. "Political losers as a barrier to economic development." *American Economic Review* 90(2):126–130.

Ágoston, Gábor. 2014. "Firearms and military adaptation: The Ottomans and the European military revolution, 1450-1800." *Journal of World History* pp. 85–124.

Allmand, Christopher Thomas. 1988. *The hundred years war: England and France at war c. 1300-c. 1450.* Cambridge University Press.

Bas, Muhammet A and Robert Schub. 2017. The theoretical and empirical approaches to uncertainty and conflict in international relations. In *Oxford Research Encyclopedia of Politics.*

Bethe, Hans A. 2000. "The German uranium project." *Physics Today* 53(7):34–36.

Biddle, Stephen. 2004. *Military power: Explaining victory and defeat in modern battle.* Princeton University Press.

Birkett, Helen. 2018. "News in the Middle Ages: News, communications, and the launch of the Third Crusade in 1187–1188." *Viator* 49(3):23–61.

Bisaha, Nancy. 2017. "Reactions to the Fall of Constantinople and the Concept of Human Rights." *Reconfiguring the Fifteenth-Century Crusade* pp. 285–324.

Blainey, Geoffrey. 1988. *Causes of war.* Simon and Schuster.

Bradbury, Jim. 1992. *The medieval siege.* Boydell & Brewer.

Brecke, Peter. 1999. Violent conflicts 1400 AD to the present in different regions of the world. In *1999 Meeting of the Peace Science Society.*

Brundage, Miles. 2025. Unbridled AI Competition Invites Disaster. *in* Mitre et al. (2025) pp. 9–19.

Burdette, Zachary and Hiwot Demelash. 2025. "Evaluating the Risks of Preventive Attack in the Race for Advanced AI.".

Buringh, Eltjo. 2021. "The population of European cities from 700 to 2000: Social and economic history." *Research Data Journal for the Humanities and Social Sciences* 6(1):1–18.

Byun, Joshua and Austin Carson. 2025. "Performative Violence and the Spectacular Debut of the Atomic Bomb." *American Political Science Review* pp. 1–20.

Callaway, Brantly, Andrew Goodman-Bacon and Pedro HC Sant'Anna. 2024. Difference-in-differences with a continuous treatment. Technical report National Bureau of Economic Research.

Casson, Lionel. 1951. Speed under sail of ancient ships. In *Transactions of the American Philological Association.* Vol. 82 pp. 136–148.

Charnysh, Volha, Eugene Finkel and Scott Gehlbach. 2023. "Historical political economy: Past, present, and future." *Annual Review of Political Science* 26(1):175–191.

Christensen, Stephen. 1987. "European-Ottoman Military Acculturation in the Late Middle Ages." *War and Peace in the Middle Ages* pp. 227–251.

Cipolla, Carlo M. 1965. *Guns, Sails, and Empires: Technological Innovation and the Early Phases of European Expansion 1400-1700.* Minerva Press.

Cohn, Jonathan B, Zack Liu and Malcolm I Wardlaw. 2022. "Count (and count-like) data in finance." *Journal of Financial Economics* 146(2):529–551.

Conley, Timothy G. 1999. "GMM estimation with cross sectional dependence." *Journal of econometrics* 92(1):1–45.

Cygielman, Sh A. 1987. "The Basic Privileges of the Jews of Great Poland as Reflected in Polish Historiography." *Polin: Studies in Polish Jewry* (2):117–149.

Davies, Charles Maurice. 1851. *The History of Holland and the Dutch Nation: From the Beginning of the Tenth Century to the End of the Eighteenth (...)*. Vol. 1 G. Willis.

Davies, Jonathan. 2019. *The medieval cannon 1326–1494.* Vol. 273 Bloomsbury Publishing.

de Commynes, Philippe. 1817. *The historical memoirs of Philip de Comines.* J. Davis.

De la Croix, Horst. 1963. "The Literature on Fortification in Renaissance Italy." *Technology and Culture* 4(1):30–50.

Debs, Alexandre. 2022. "Mutual optimism and war, and the strategic tensions of the July crisis." *American journal of political science* 66(2):271–284.

DeVries, Kelly. 1997. Gunpowder weapons at the siege of Constantinople, 1453. In *War and Society in the Eastern Mediterranean, 7th-15th Centuries.* Brill pp. 343–362.

DeVries, Kelly. 2013. *11 French and English Acceptance of Medieval Gunpowder Weaponry.* Boydell and Brewer: Boydell and Brewer pp. 259–274.
URL: *https://doi.org/10.1515/9781782041672-012*

DeVries, Kelly. 2017. The Lack of a Western European Military Response to the Ottoman Invasions of Eastern Europe from Nicopolis (1396) to Mohács (1526) 1. In *Medieval Warfare 1300–1450.* Routledge pp. 417–437.

DeVries, Kelly. 2024. *Guns and men in medieval Europe, 1200-1500: Studies in military history and technology.* Taylor & Francis.

Dijkstra, Edsger W. 2022. A note on two problems in connexion with graphs. In *Edsger Wybe Dijkstra: his life, work, and legacy.* pp. 287–290.

Dorin, Rowan. 2021. "Corpus Synodalium: Medieval Canon Law in a Digital Age."" *Digital Medieval Studies: Practice and Preservation* pp. 49–75.

Doughty, Robert A. 1974. "De Gaulle's Concept of a Mobile, Professional Army: Genesis of French Defeat?" *The US Army War College Quarterly: Parameters* 4(1):6.

Duffy, Christopher. 2013. *Siege Warfare: The Fortress in the Early Modern World 1494-1660.* Routledge.

Ellman, Jesse, Lisa Sawyer Samp and Gabriel Coll. 2017. *Assessing the third offset strategy.* Center for Strategic & International Studies.

Evangelista, Matthew. 1988. *Innovation and the arms race: How the United States and the Soviet Union develop new military technologies.* Cornell University Press.

Eyre, Dana P, Mark C Suchman et al. 1996. "Status, norms, and the proliferation of conventional weapons: An institutional theory approach." *The culture of national security: Norms and identity in world politics* 79.

Fabyan, Robert and Henry Ellis. 1811. *The New Chronicles of England and France: In Two Parts.* FC & J. Rivington.

Fearon, James D. 1995. "Rationalist explanations for war." *International organization* 49(3):379–414.

Fearon, James D. 2021. "Relative power and the risk of conflict.".

Fitzgerald, Vincent. 1911. *Saint John Capistran.* Longmans, Green.

Flückiger, Matthias, Mario Larch, Markus Ludwig and Luigi Pascali. 2024. "The dawn of civilization: metal trade and the rise of hierarchy.".

Frieden, Jeffry and Arthur Silve. 2023. "The political reception of innovations." *Economics & Politics* 35(2):595–628.

Gailmard, Sean. 2021. "Theory, history, and political economy." *Journal of Historical Political Economy* 1(1):69–104.

Giles, John Allen. 1845. *The Chronicles of the White Rose of York: A Series of Historical Fragments, Proclamations, Letters, and Other Contemporary Documents Relating to the Reign of King Edward the Fourth; with Notes and Illustrations, and a Copious Index.* J. Bohn.

Glaser, Charles L and Chaim Kaufmann. 1998. "What is the offense-defense balance and can we measure it?" *International security* 22(4):44–82.

Goldman, Emily O and Leslie C Eliason. 2003. *The diffusion of military technology and ideas.* Stanford University Press.

Gray, E, H Marsh and M McLaren. 1982. "A short history of gunpowder and the role of charcoal in its manufacture." *Journal of Materials Science* 17(12):3385–3400.

Grissom, Adam. 2006. "The future of military innovation studies." *Journal of strategic studies* 29(5):905–934.

Hale, John Rigby. 1983. "Gunpowder and the Renaissance: an essay in the history of ideas." *From the Renaissance to the Counter-Reformation* pp. 113–44.

Hall, Edward. 1809. *Hall's chronicle: containing the history of England, during the reign of Henry the Fourth, and the succeeding monarchs, to the end of the reign of Henry the Eighth, in which are particularly described the manners and customs of those periods.* J. Johnson.

Harris, Jonathan. 2022. "Refugees and International Networks after the Fall of Constantinople, 1453–1475." *The English Historical Review* 137(585):362–385.

Hausman, Jerry A, Bronwyn H Hall and Zvi Griliches. 1984. "Econometric models for count data with an application to the patents-R&D relationship.".

Heuser, Beatrice. 2012. "Denial of Change: The Military Revolution as Seen by Contemporaries." *International Bibliography of Military History* 32(1):3–27.

Hoffman, Philip T. 2015. *Why Did Europe Conquer the World? Princeton University Press.* Princeton University Press.

Hopf, Ted. 1991. "Polarity, the offense-defense balance, and war." *American Political Science Review* 85(2):475–493.

Horowitz, Michael C. 2010. *The diffusion of military power: Causes and consequences for international politics.* Princeton University Press.

Horowitz, Michael C. 2020. "Do emerging military technologies matter for international politics?" *Annual Review of Political Science* 23(2020):385–400.

Jaques, Tony. 2006. *Dictionary of Battles and Sieges: A Guide to 8,500 Battles from Antiquity through the Twenty-first Century [3 volumes].* Bloomsbury Publishing USA.

Jervis, Robert. 1978. "Cooperation under the security dilemma." *World politics* 30(2):167–214.

Johnson, James. 2019. "The AI-cyber nexus: implications for military escalation, deterrence and strategic stability." *Journal of Cyber Policy* 4(3):442–460.

Jones, Rodney W and Steven Hildreth. 1984. *Emerging Powers: Defense and Security in the Third World.* New York: Praeger.

Juhász, Réka. 2018. "Temporary protection and technology adoption: Evidence from the napoleonic blockade." *American Economic Review* 108(11):3339–3376.

Juma, Calestous. 2016. *Innovation and its enemies: Why people resist new technologies.* Oxford University Press.

Katzenbach, Edward L. 1958. "THE HORSE CAVALRY IN THE 20TH-CENTURY-A STUDY IN POLICY RESPONSE." *Public Policy* 8:120–149.

Kier, Elizabeth. 2017. *Imagining war: French and British military doctrine between the wars.* Princeton University Press.

Kinard, Jeff. 2007. *Artillery: An illustrated history of its impact.* Bloomsbury Publishing USA.

King, Gary. 1988. "Statistical models for political science event counts: Bias in conventional procedures and evidence for the exponential Poisson regression model." *American Journal of Political Science* pp. 838–863.

Kingsford, Charles Lethbridge. 1905. *Chronicles of London.* Clarendon Press.

Kreps, Sarah. 2025. Racing Toward Clarity: How Accelerating AGI Development Could Enhance Strategic Stability. *in* Mitre et al. (2025) pp. 5–8.

Kroenig, Matthew. 2021. "Will Emerging Technology Cause Nuclear War?" *Strategic Studies Quarterly* 15(4):59–73.

Levy, Jack S. 1984. "The offensive/defensive balance of military technology: A theoretical and historical analysis." *International studies quarterly* 28(2):219–238.

Lin-Greenberg, Erik. 2022. "Wargame of drones: remotely piloted aircraft and crisis escalation." *Journal of Conflict Resolution* 66(10):1737–1765.

Lindsey, David. 2019. "Mutual optimism and costly conflict: The case of naval battles in the age of sail." *The Journal of Politics* 81(4):1181–1196.

Lynn-Jones, Sean M. 1995. "Offense-defense theory and its critics." *Security studies* 4(4):660–691.

Mallett, Michael. 2009. *Mercenaries and their masters: warfare in Renaissance Italy.* Pen and Sword.

Mangini, Michael-David and Casey Petroff. 2022. "Conflict Technology as a Catalyst of State Formation." *Unpublished manuscript* .

Masschaele, James. 1993. "Transport costs in medieval England." *Economic History Review* pp. 266–279.

McNeill, William H. 2013. *The pursuit of power: technology, armed force, and society since AD 1000.* University of Chicago Press.

Miller, Steven E. 1985. "Technology and war." *Bulletin of the Atomic Scientists* 41(11):46–48.

Ministry of War of the French Third Republic. 1937. "Instructions for the Tactical Employment of Large Units." *Document of Doctrine of the French Army* .

Mitre, Jim, Michael C Horowitz, Natalia Henry, Emma Borden and Joel B Predd, eds. 2025. *The Artificial General Intelligence Race and International Security.* RAND.

Mokyr, Joel. 1990. *The lever of riches: Technological creativity and economic progress.* Oxford University Press.

Mokyr, Joel. 1998. The political economy of technological change: Resistance and innovation in economic history. In *Technological revolutions in Europe.* Edward Elgar Publishing pp. 39–64.

Nicolle, David. 2012. *The Fall of English France 1449–53.* Vol. 241 Bloomsbury Publishing.

Nüssli, Christos. 2009. "Euratlas Periodis Basic.".

O'Hara, Robert and Johan Kotze. 2010. "Do not log-transform count data." *Nature Precedings* pp. 1–1.

Pertusi, Agostino. 1990. *La caduta di Costantinopoli.* Milan: Mondadori.

Philippides, Marios and Walter K Hanak. 2011. *The siege and the fall of Constantinople in 1453: historiography, topography, and military studies.* Ashgate Publishing, Ltd.

Popp, Manfred and Piet de Klerk. 2023. "The Peculiarities of the German Uranium Project (1939–1945)." *Journal of Nuclear Engineering* 4(3):634–653.

Posen, Barry. 1984. *The sources of military doctrine: France, Britain, and Germany between the world wars.* Cornell University Press.

Postan, Michael M. 1942. "Some social consequences of the Hundred Years' War." *The Economic History Review* 12(1/2):1–12.

Powell, Robert. 2002. "Bargaining theory and international conflict." *Annual Review of Political Science* 5(1):1–30.

Purton, Peter Fraser. 2009. *A history of the late medieval siege, 1200-1500.* Vol. 2 Boydell & Brewer.

Quester, George H. 2002. *Offense and defense in the international system.* Transaction publishers.

Ramsay, Kristopher W. 2017. "Information, uncertainty, and war." *Annual Review of Political Science* 20(1):505–527.

Reed, William. 2003. "Information, power, and war." *American Political Science Review* 97(4):633–641.

Reyerson, Kathryn and Chris Jones. 2004. *Jacques Coeur.* Pearson, New York.

Rid, Thomas. 2012. "Cyber war will not take place." *Journal of strategic studies* 35(1):5–32.

Robb, Graham. 2007. *The Discovery of France.* W. W. Norton.

Rogers, Clifford J. 2018. The Military Revolutions of the Hundred Years War 1. In *The Military Revolution Debate.* Routledge pp. 55–94.

Rosen, Stephen Peter. 1991. *Winning the next war: Innovation and the modern military.* Cornell University Press.

Roth, Jonathan, Pedro HC Sant'Anna, Alyssa Bilinski and John Poe. 2023. "What's trending in difference-in-differences? A synthesis of the recent econometrics literature." *Journal of Econometrics* 235(2):2218–2244.

Runciman, Steven. 1965. *The fall of Constantinople, 1453.* Cambridge University Press Cambridge.

Schneider, Jacquelyn. 2021. The capability/vulnerability paradox and military revolutions: Implications for computing, cyber, and the onset of war. In *Emerging Technologies and International Stability.* Routledge pp. 21–43.

Schwoebel, Robert. 2023. *The shadow of the crescent: the Renaissance image of the Turk (1453-1517).* Brill.

Sechser, Todd S, Neil Narang and Caitlin Talmadge. 2019. "Emerging technologies and strategic stability in peacetime, crisis, and war." *Journal of strategic studies* 42(6):727–735.

Shepherd, William Robert. 1911. *Historical atlas.* H. Holt.

Silva, JMC Santos and Silvana Tenreyro. 2010. "On the existence of the maximum likelihood estimates in Poisson regression." *Economics letters* 107(2):310–312.

Slantchev, Branislav L. 2010. "Feigning weakness." *International Organization* 64(3):357–388.

Smith, Robert Douglas and Kelly DeVries. 2005. *The artillery of the Dukes of Burgundy, 1363-1477.* Vol. 1 Boydell Press.

Snyder, Jack. 1984. "Civil-Military Relations and the Cult of the Offensive, 1914 and 1984." *International Security* 9(1):108–146.

Solstad, Sondre Ulvund. 2023. "Political competition in dynamic economies." *European Journal of Political Economy* 80:102430.

Spufford, Peter. 2003. *Power and Profit: The Merchant in Medieval Europe.* New York: Thames and Hudson.

Stammann, Amrei, Florian Heiß and Daniel McFadden. 2016. Estimating Fixed Effects Logit Models with Large Panel Data. VfS Annual Conference 2016 (Augsburg): Demographic Change 145837 Verein fÃ¼r Socialpolitik / German Economic Association.
URL: *https://ideas.repec.org/p/zbw/vfsc16/145837.html*

Tobler, Waldo. 1993. "Three presentations on geographic analysis and modelling.".

Torreblanca, Carolina, William Dinneen, Guy Grossman and Yiqing Xu. 2025. "The Credibility Revolution in Political Science." *arXiv preprint arXiv:2601.11542* .

Van Evera, Stephen. 1998. "Offense, defense, and the causes of war." *International Security* 22(4):5–43.

Van Evera, Stephen. 1999. *Causes of war: Power and the roots of conflict.* Cornell University Press.

Volpe, Tristan A. 2021. Dual-use distinguishability: How 3D-printing shapes the security dilemma for nuclear programs. In *Emerging Technologies and International Stability.* Routledge pp. 220–246.

von Pastor, Ludwig Freiherr. 1923. *The History of the Popes: From the Close of the Middle Ages.* Herder.

Waltz, Kenneth N. 1979. *Theory of International Politics.* McGraw-Hill.

Williams, Heather. 2021. Asymmetric arms control and strategic stability: Scenarios for limiting hypersonic glide vehicles. In *Emerging Technologies and International Stability.* Routledge pp. 195–219.

Wooldridge, Jeffrey M. 1999. "Quasi-likelihood methods for count data." *Handbook of applied econometrics volume 2: Microeconomics* pp. 321–368.

Wooldridge, Jeffrey M. 2023. "Simple approaches to nonlinear difference-in-differences with panel data." *The Econometrics Journal* 26(3):C31–C66.

Online Appendix

Table of Contents

A Data appendix

A.1 Sieges by war

Conflict	Location	Dates	Num. Sieges
Albanian-Turkish Wars	Southwestern Balkans	1432-1479	5
Albanian-Venetian Wars	Albania	1447-1448	3
Anglo-Scottish Border Wars	Anglo-Scottish Border	1440-1460	2
Bavarian War / Princes' War	Bavaria	1459-1463	9
Bonville-Courtenay Feud	Devon	1455	2
Castilian Civil War	Castille	1437-1445	1
Catalan Civil War	Catalonia	1462-1472	6
Conquest of Granada / Reconquista	Granada	718-1492	10
Crusade of Varna	Balkans	1443-1444	4
Czech Civil War	Bohemia	1450-1451	1
Czech-Polish Conflict of 1453	Bohemia & Poland	1453	1
Donia War	Frisia	1458-1463	1
Douglas Rebellion	Scotland	1455	7
Fajardo Feud	Murcia	1448	1
First Margrave War	Franconia	1449-1450	2
Hook and Cod Wars	Holland	1350-1490	2
Hundred Years' War	France	1337-1453	31
Hungarian Civil War	Hungary	1457-1458	3
Italian Wars	Italy	15th/16th Century	4
Jack Cade's Rebellion	Southeast England	1450	1
Milanese War of Succession	Lombardy	1447-1454	36
Murcia Civil War	Murcia	1450	1
Navarrese Civil War	Navarra	1451-1455	5
Old Zurich War	Switzerland	1440-1446	11
Palma Revolt	Mallorca	1450-1452	2
Recovery of Luxembourg	Luxembourg	1443	3
Revolt Against Arnold van Egmond	Netherlands	1459	1
Revolt Against Frederick III	Austria	1462	2
Revolt of Antonio Centelles	Calabria	1444-1445	4
Revolt of Ghent	Flanders	1449-1453	9
Saxon Fraticidal War	Saxony	1446-1451	6
Siewierz Conflict	Southern Poland	1443-1444	1
Silesian Succession War	Silesia	1443	1
Soest Feud	Western Germany	1444-1449	3
Swedish Wars of Union	Sweden	1448-1455	3
Thirteen Years' War	Pomerelia & Prussia	1454-1466	19
Turkish-Hungarian Wars	Hungary & Romania	1366-1526	9
Uprising of Evrard de la Marck	Wallonia	1445	1
Utrecht Schism	Netherlands	1423-1449	2
Venetian-Turkish Wars	Balkans	1463-1479	1
Von Rechberg Revolt	Austria	1452	2
Waldenfels Feud	Western Germany	1441-1446	2
Wallachian Campaign	Slovakia	1447-1451	2
War of Deposition against Karl Knutsson	Sweden	1457	1
Wars in Lombardy	Lombardy	1423-1454	3
Wars of the Roses	England & Wales	1455-1487	26
Wasselonne War	Alsace	1446-1448	2
Unknown/Minor			102

Table A.1: List of wars, 1443-1463

A.2 Dioceses and sieges by polity

Polity	Num. Dioceses	Num. Sieges
Bishopric of Ösel-Wiek	1	0
Counties of Hainaut and Holland	1	0
County of Corsica	2	0
County of Holstein	1	0
County of Mantua	1	0
County of Provence	16	2
County of Savoy	13	2
County of Sovana	2	1
Crown of Aragon	15	8
Crown of Bohemia	4	5
Crown of Castile	28	9
Duchy of Bar	1	0
Duchy of Brabant	1	0
Duchy of Brittany	9	2
Duchy of Brunswick-Lüneburg	1	0
Duchy of Finland	1	0
Duchy of Lorraine	1	0
Duchy of Lower Bavaria in Straubing	1	0
Duchy of Mazovia	1	0
Duchy of Mecklenburg	2	1
Duchy of Milan	29	46
Duchy of Split under Hrvoje Vukčič	3	1
Duchy of Spoleto	6	1
Duchy of Upper Bavaria-Munich	2	1
Duchy of Zachlumia	3	0
Earldom of Desmond	4	1
Earldom of Orkney	1	0
Earldom of Ormonde	5	0
Earldom of Ulster	3	0
Electorate of Brandenburg	3	1
Garay Lordship	10	1
Giudicato of Arborea	18	0
Habsburg Dominions	13	12
House of Este	5	1
Kalmar Union between the Kingdoms of Denmark, Sweden and Norway	19	2
Kingdom of Bosnia	2	1
Kingdom of Bréifne	3	0
Kingdom of England	28	36
Kingdom of France	81	19
Kingdom of Granada	5	6
Kingdom of Hungary	9	9
Kingdom of Leinster	1	0
Kingdom of Naples	142	5
Kingdom of Navarre	2	3
Kingdom of Portugal	10	0
Kingdom of Scotland	8	9
Kingdom of Sicily	11	0
Kingdom of Thomond	4	0
Kingdom of Tír Conaill	1	0
Kingdom of Tir Eógain	3	0
Landgraviate of Thuringia and Margravate of Meissen	1	3
Lordship of Bologna	2	2
Lordship of Caithness	1	0
Lordship of Cilli	1	1
Lordship of Connacht in Mayo	3	0
Lordship of Connacht in Sligo Under the O Conor Sligo	1	0
Lordship of Cortona	1	0
Lordship of Forli	1	0
Lordship of Padua	1	0
Lordship of Perugia	1	0
Lordship of Rimini	1	0
Lordship of the Isles	3	0
Lordship of Travunia	1	0
Lordship of Zeta and The Sea	4	2
Lordships of Romagna	5	0
Lordships of the House of Burgundy	7	10
Mac Carthy Mor Lordship	1	0
March of Ancona	10	21
Margravate of Montferrat	2	0
Margravate of Moravia	1	0
Margravate of Savona	1	0
Monastic State of the Teutonic Knights	9	23
Montefeltro Lordship	6	3
Principality of Moldavia	1	0
Principality of Wales	1	2
Republic of Florence	4	3
Republic of Genoa	9	0
Republic of Venice	12	8
Small States of the Holy Roman Empire	28	39
State of the Church	30	3
United Kingdom of Poland and Lithuania	10	1

Table A.2: List of polities, 1400 A.D.

A.3   Dioceses with most sieges

Diocese	Num. Sieges
Brescia	13
Konstanz	11
Milano	10
Cremona	7
Bordeaux	7
Cambrai	7
St. Andrews	6
Rouen	6
Cologne (Köln)	5
Mainz	5

(a) Before FoC

Diocese	Num. Sieges
Durham	9
Utrecht	7
Warmia (Ermland)	6
Pomesania	6
Gniezno	5
Chelmno	4
Carlisle	3
St. Asaph	3
Konstanz	3
Regensburg	3

(b) After FoC

Table A.3: Dioceses with most sieges

A.4   Descriptive statistics

Variable	N	Mean	Std. Dev.	Min	Pctl. 25	Pctl. 75	Max
Num. sieges	14616	0.022	0.21	0	0	0	10
Num. towns	14616	2.6	4.9	0	0	3	45
Num. castles	14616	3.1	13	0	0	1	230
On trade route	14616	0.31	0.46	0	0	1	1
Transport cost	14616	8106	2365	3475	6133	10346	14318
Distance (km)	14616	1809	647	731	1261	2282	3204
Travel time	14616	721	192	281	572	861	1246
Transport cost (Gascony)	14616	4638	1871	0	3334	5677	12703
Transport cost (Normandy)	14616	5688	2188	0	3768	7197	12513

Table A.4: Descriptive statistics

A.5   Covariate maps

This section contains maps depicting the distribution of relevant spatial variables.
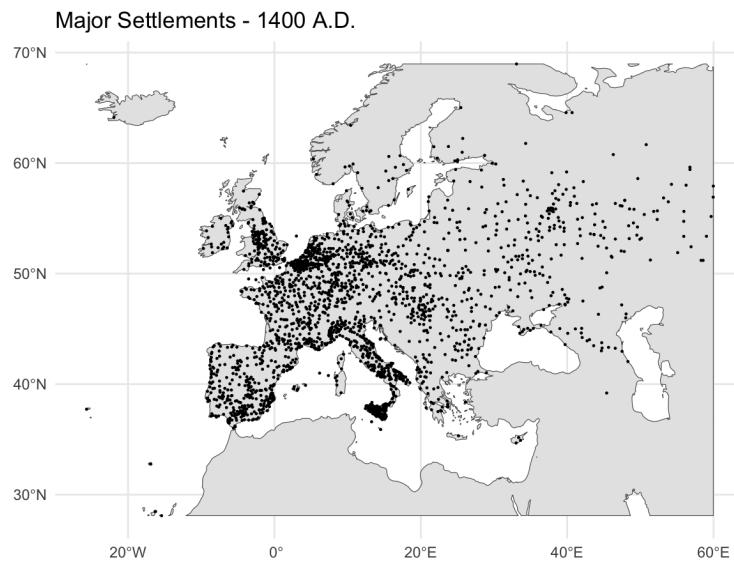
Figure A.1: Settlements with 1,000 or more inhabitants, 1400 A.D.
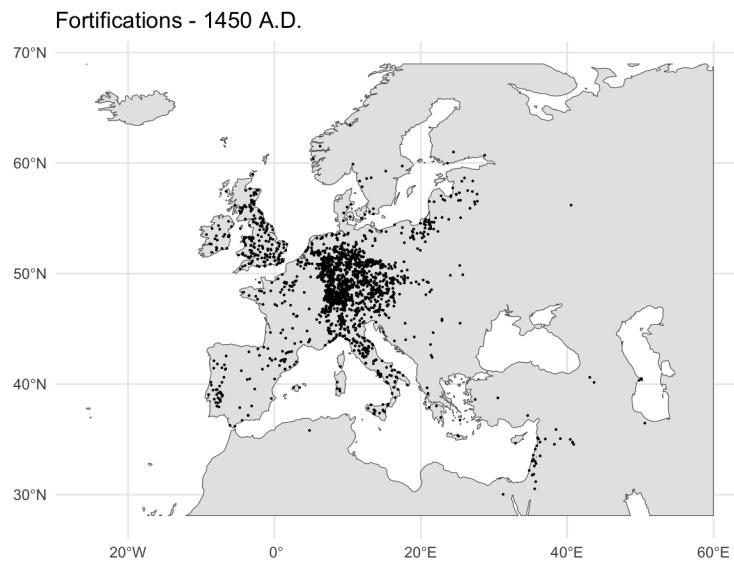
Figure A.2: Non-settlement fortifications, 1450 A.D.

European Political Borders - 1400 A.D.
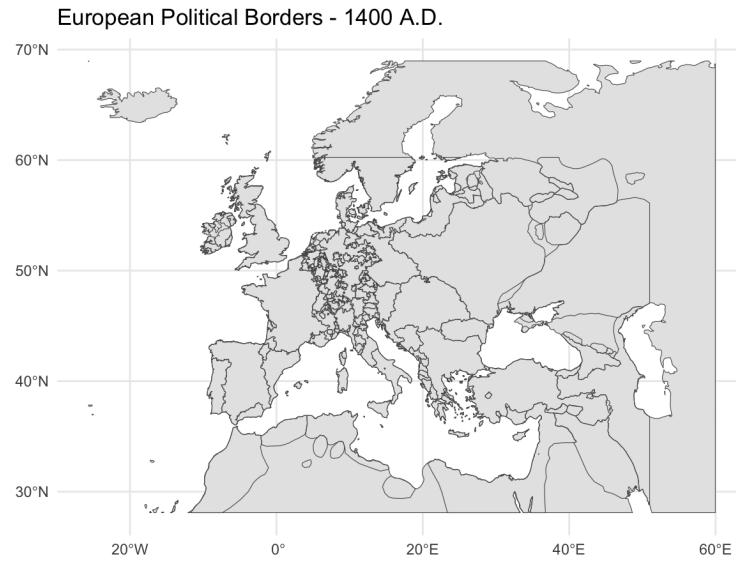
Figure A.3: Political boundaries, 1400 A.D.

Medieval European Overland Trade Routes
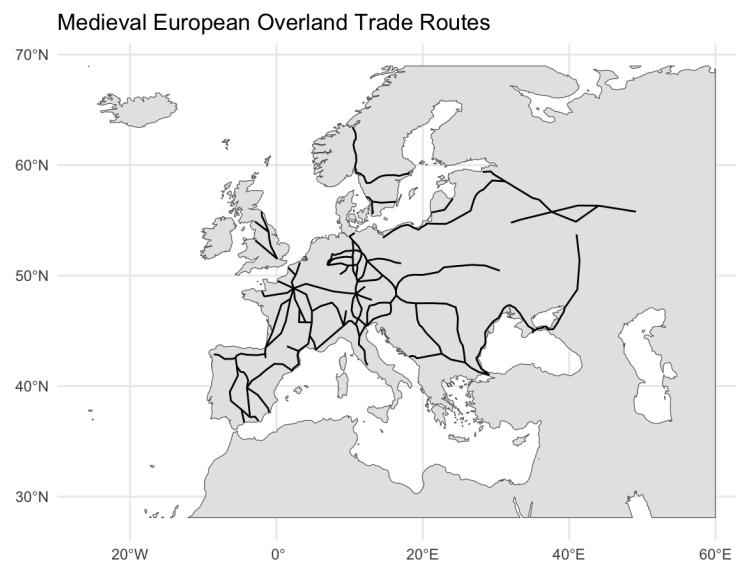
Figure A.4: Medieval overland trade routes, from Shepherd (1911)

A.6 Diffusion of initial news about Fall of Constantinople

This section describes construction of Figure 4, reprinted below, which depicts the diffusion of the initial news of the Fall of Constantinople. In this first wave, little to no information about what occurred during siege was transmitted. Moreover, the initial wave of information traveled quickly by medieval standards, diffusing throughout the continent in roughly six months. This was because it was spread primarily by letters exchanged between political rulers, which has the additional benefit of aiding more precise dating of when different locations learned about Constantinople. Consequently, despite the fact that this early trickle of information had few concrete details about artillery, it is useful to examine the spread of this initial wave to understand how information traveled across Europe during this time.

Figure A.5: Date of arrival of initial news about FoC

Figure 4 maps the dates that news of Constantinople's fall first reached selected major cities and charts the path that the news took from Constantinople. Dates were recovered by consulting primary sources, such as letters and chronicles. The first ships escaping Constantinople reached Heraklion, then a Venetian colony known as Candia, in early June. The administrators of the colony immediately dispatched a messenger to Venice, carrying a letter telling of the collapse of the city, which reached Venice and was read to the Senate on June 29. The Venetians were the first in Western Europe to hear of Constantinople's capture, and they immediately composed and sent letters of their own to Pope Nicholas V and other major political figures. The Venetian letter reached Rome on July 8, shocking the Pope, who in turn sent letters announcing the Fall of Constantinople to the leading European sovereigns Schwoebel (2023).

News of Constantinople's collapse simultaneously traveled overland through the Balkans,

reaching Serbian Despot Durad Brankovic sometime in June. Brankovic then sent a letter to Graz, where the court of Holy Roman Emperor Frederick III was located at the time. This letter reached Graz no later than July 27, the date of another letter from Bishop Aeneas Silvius Piccolomini, then at court, to Cardinal Capranica, that states the court "recently" heard of the Fall of Constantinople via Serbia (Pertusi, 1990). The same news also traveled from Serbia the Polish city of Wroclaw, arriving by August, which can be deduced from the movements and correspondence of Saint John Capistran, then an itinerant preacher in Poland (Fitzgerald, 1911; Cygielman, 1987; Schwoebel, 2023). Finally, the chronicles of Kingsford (1905), Fabyan and Ellis (1811), and Hall (1809) record the news reaching London, likely in August, though the source of the information was not recorded.[28] Note that both the overland and oversea paths illustrate a gradient in when news from Constantinople arrived at different locations in Europe. Information would first reach Italy and the Balkans, then travel into Central Europe, and arrive in Northern and Eastern Europe last of all.

---

[28]This estimate is based on the placement of entries in the chronicles, which were organized by mayoral year or regnal year. The Fall of Constantinople was the last event recorded in the mayoralty of Geoffrey Fielding, which ended on September 29, 1453. This estimate also matches the approximate time it would take a letter to reach London from Northern Italy, using estimates from Spufford (2003).

B Identification assumptions

B.1 Event study specification and results

To conduct the event study reported in Section 5.2, I estimate the following specification via Poisson psuedo-maximum likelihood

$$E[\text{sieges}_{dt} \mid \beta_d, \gamma_t] = \exp\left(\sum_{\tau=1443}^{1463} \alpha_\tau \mathbf{1}_{\tau=t}\text{transportCost}_d + \beta_d + \gamma_t\right)$$

where d indexes dioceses and t indexes years. The term β_d is a diocese fixed effect and γ_t is a year fixed effect. The variable sieges_{dt} is the number of sieges occurring in diocese d in year t. The variable transportCost_d is the transport cost of diocese d from Constantinople. The transport cost is interacted with the function $\mathbf{1}_{\tau=t}$, which is an indicator function that takes value 1 when the year is equal to t and 0 otherwise. The coefficients of interest are the α_t, terms, which represent the effect of a one-unit increase transport cost during year t. I cluster standard errors at the level of the diocese. The results are reported in Table A.5.

	Num. sieges (20 year)
	Model 1
1443 × Transport Cost	0.06
	(0.21)
1444 × Transport Cost	0.08
	(0.21)
1445 × Transport Cost	0.06
	(0.21)
1446 × Transport Cost	−0.39
	(0.33)
1447 × Transport Cost	0.02
	(0.19)
1448 × Transport Cost	0.24
	(0.18)
1449 × Transport Cost	0.35
	(0.21)
1450 × Transport Cost	0.47**
	(0.21)
1451 × Transport Cost	0.02
	(0.19)
1452 × Transport Cost	0.27
	(0.17)
1454 × Transport Cost	0.36*
	(0.19)
1455 × Transport Cost	0.72***
	(0.23)
1456 × Transport Cost	0.52
	(0.34)
1457 × Transport Cost	1.07***
	(0.39)
1458 × Transport Cost	0.47**
	(0.24)
1459 × Transport Cost	0.42
	(0.48)
1460 × Transport Cost	0.54***
	(0.20)
1461 × Transport Cost	0.50**
	(0.23)
1462 × Transport Cost	0.17
	(0.22)
1463 × Transport Cost	0.60*
	(0.31)
DV Mean:	0.12
Num. clusters:	131
N	2751

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Note: Robust SEs clustered by diocese. Unit of analysis is diocese-year.

Table A.5: Event study of exposure to Constantinople on sieges (transport costs)

B.2 Parallel trends plot

In Figure A.6 I plot the mean number of sieges taking place in dioceses with greater or less than average transport costs to Constantinople. Sieges are aggregated at five-year intervals to account for the low number of sieges occurring in individual years, and are from dioceses that experienced at least one siege during the period under study. The figure shows that the groups experienced similar numbers of sieges before 1453 but diverged after 1453, with dioceses with higher than average transport costs to Constantinople experiencing more sieges.
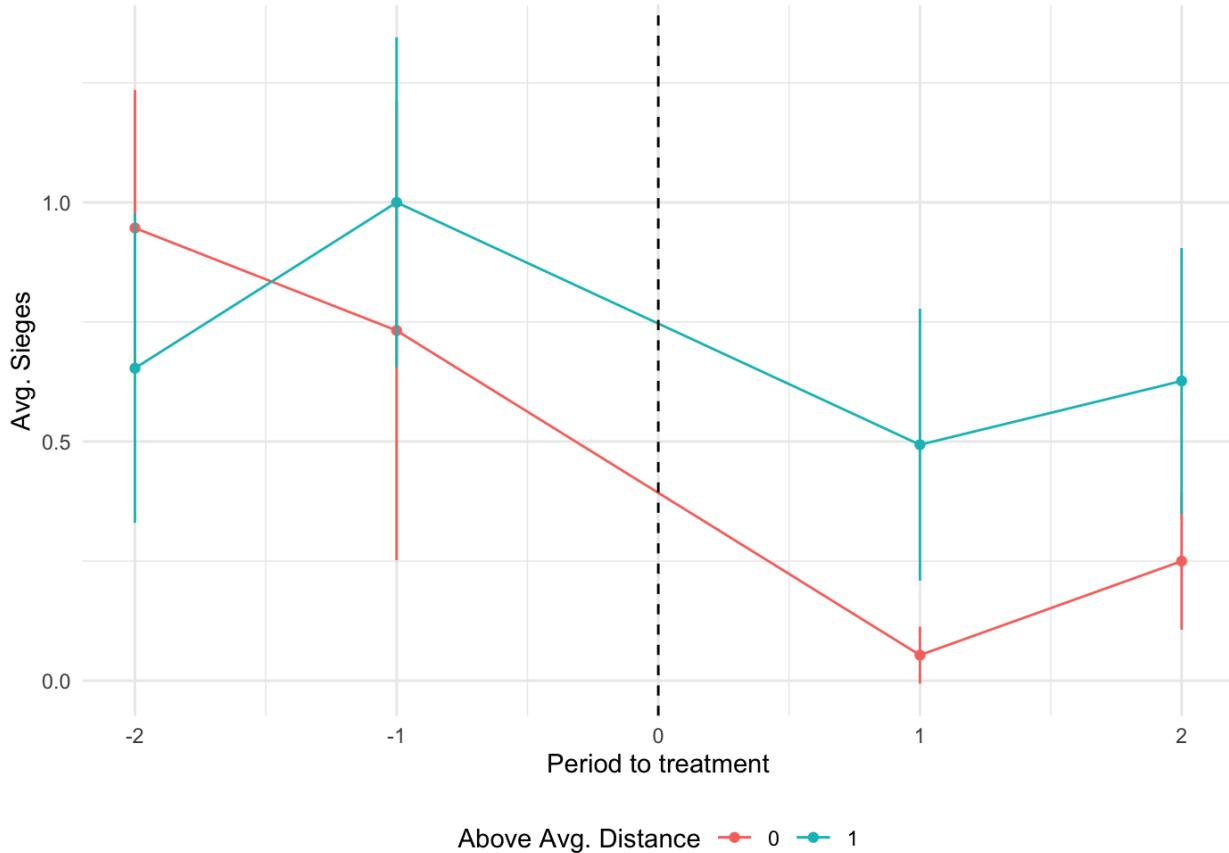

Figure A.6: Trends in sieges

C   Robustness checks

In this appendix, I assess the robustness of my empirical results. First, I test my hypotheses with two alternative methods to proxy for exposure to information about the Fall of Constantinople: great circle distance and total travel time. Second, I perform standard error adjustments to account for spatial correlation. Third, I estimate the effect of proximity to Constantinople on sieges using alternative function forms: ordinary least squares and logistic regression. Finally, I perform a leave-one-out analysis to ensure the results are not driven by an outlier polity.

C.1   Distance alternative treatment

The great circle distance of a diocese from Constantinople is the length in kilometers of the shortest arc over the Earth's surface linking the centroid of the diocese to Constantinople. This measure of information exposure explicitly ignores all geographic and social factors save distance. The mean diocese is located 1,809 kilometers from Constantinople. The nearest diocese is Halych (in southwestern Ukraine), located 731 kilometers away, while the farthest diocese is Lisbon, located 3,203 kilometers away.

I conduct the main analysis again, using great circle distance as the treatment. I estimate the following via Poisson psuedo maximum likelihood

$$E[sieges_{dpt} \mid \beta_d, \gamma_t, \delta_{pt}, X_d] = \exp\left(\alpha\, postFall_t \times \text{distance}_d + \beta_d + \gamma_t + \delta_{pt} + \lambda^T X_d \times t\right)$$

where all variables are defined identically to Equation 1.

The results of the analysis are displayed in Table A.6. The coefficient on the great circle remains primarily positive and statistically significant. In the full specification, under the 10-year window, each additional 100 kilometers of distance from Constantinople is associated with a $100(\exp(1.02) - 1) = 177\%$ increase in the number of sieges. This corresponds to an average marginal effect of .336 additional sieges.

	Num. sieges (10 year)			Num. sieges (20 year)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Post-1453 × Distance (100km)	−0.04	0.97***	1.02***	0.08**	0.61***	0.82***
	(0.06)	(0.29)	(0.37)	(0.04)	(0.22)	(0.27)
Num. castles × Year			−0.00			−0.00
			(0.00)			(0.00)
Num. settlements × Year			0.00			−0.00
			(0.01)			(0.00)
On trade route × Year			0.10			0.12*
			(0.21)			(0.06)
DV Mean:	0.19	0.19	0.19	0.12	0.12	0.12
Polity × Year FEs	-	✓	✓	-	✓	✓
Num. clusters:	73	73	73	131	131	131
N	803	803	803	2751	2751	2751

$^{***}p < 0.01; ^{**}p < 0.05; ^{*}p < 0.1$. Note: Robust SEs clustered by diocese. Unit of analysis is diocese-year.

Table A.6: Effect of exposure to Constantinople on sieges (distance)

C.2 Travel time alternative treatment

Construction of variable

The other variable I use to operationalize exposure to Constantinople is an estimate of the time it would take travel from Constantinople using the fastest route available given modes of transport available at the time. I construct this variable computationally, similar to the procedure for transport costs. As before, I divide Europe into a grid of equally sized square cells. I define $d(i, j)$ to be the great circle distance, in kilometers, between the centroids of adjacent grid cells i and j and $t(i, j)$ to be the time in hours to travel between cells i and j.

The value of $t(i, j)$ depends on the means of transport used to traverse the cells. I assume that travelers have two options: sailing and walking. To approximate speed of travel for sailing during the 15th century, I use the average speed of 5 knots (9.26 kilometers per hour) offered by Casson (1951), who determined this number by analyzing shipping manifests from antiquity and the Middle Ages.

Computing travel time over land is more involved. To calculate walking speed, I use Tobler's hiking function, which provides an estimate of walking speed given distance and grade, fitted to empirical data on hiking speed collected during the 20th century (Tobler, 1993). Tobler's hiking function for the walking speed between grid cells i and j is

$$V(i, j) = 6e^{-\left| \frac{h(j)-h(i)}{d(i,j)} +0.05 \right|}$$

where $h(j) - h(i)$ is difference in elevation between the centroids of cells j and i, respectively.

Therefore, the travel time $t(i, j)$ needed to move between adjacent grid cells i and j is given by

$$t(i, j) = \mathbf{1}\{i \text{ or } j \text{ on sea}\}\frac{d(i, j)}{9.26} + \mathbf{1}\{i \text{ and } j \text{ on land}\}\frac{d(i, j)}{V(i, j)}$$

If we let $\mathcal{P}_d$ be the set of all paths between Constantinople and a diocese d, then the travel time from to Constantinople to that diocese is given by the cost of the shortest path $p \in \mathcal{P}_d$, or

$$\text{travelTime}_d = \min_{p \in \mathcal{P}_d} \sum_{(i,j) \in p} t(i, j)$$

The variable travelTime_d is therefore the minimum time in hours it would take a traveler to move from Constantinople to diocese d, under the speeds estimated above and constant movement. Note that this is certainly an underestimate due the assumption of uninterrupted travel. Using this measure, the nearest diocese to Constantinople is again Halych, a journey to which would require 281 hours (11.7 days) of uninterrupted travel. The farthest diocese is Moray (in northern Scotland), which requires 1,246 hours of travel (51.9 days). The mean travel time is 721 hours (30 days).

Empirical results

I conduct the main analysis again, using travel time to Constantinople as the treatment. I estimate the following via Poisson psuedo maximum likelihood

$$E[sieges_{dpt} \mid \beta_d, \gamma_t, \delta_{pt}, X_d] = \exp\left(\alpha \; postFall_t \times \text{travelTime}_d + \beta_d + \gamma_t + \delta_{pt} + \lambda^T X_d \times t\right)$$

where all variables are defined identically to Equation 1.

The results of the analysis are displayed in Table A.7. The coefficient on travel time is generally positive and statistically significant. In the full specification, under the 10-year window, each additional day of travel from Constantinople is associated with a 63% increase in the number of sieges. This corresponds to an average increase of .12 additional sieges per day of travel time.

	Num. sieges (10 year)			Num. sieges (20 year)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Post-1453 × Travel time (days)	−0.03	0.49**	0.49**	0.05	0.26**	0.29**
	(0.05)	(0.23)	(0.22)	(0.03)	(0.11)	(0.13)
Num. castles × Year			−0.00			−0.00
			(0.00)			(0.00)
Num. settlements × Year			0.01			0.00
			(0.01)			(0.00)
On trade route × Year			0.09			0.08
			(0.19)			(0.07)
DV Mean:	0.19	0.19	0.19	0.12	0.12	0.12
Polity × Year FEs	-	✓	✓	-	✓	✓
Num. clusters:	73	73	73	131	131	131
N	803	803	803	2751	2751	2751

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Note: Robust SEs clustered by diocese. Unit of analysis is diocese-year.

Table A.7: Effect of exposure to Constantinople on sieges (travel time)

C.3   Comparison of proximity measures

Table A.8 displays the correlation between the various measures of exposure to Constantinople. All are positively correlated with each other.

	Transport Cost	Great Circle Distance	Travel Time
Transport Cost	1.00	0.75	0.72
Great Circle Distance	0.75	1.00	0.79
Travel Time	0.72	0.79	1.00

Table A.8: Correlation between proximity measures

Figures A.7 through A.9 depict each diocese's exposure to Constantinople based on the three accessibility measures. The distance measure marks the dioceses at the fringe of the continent as farthest from Constantinople (i.e. the arc from Lisbon to Norway), disregarding topography and travel times. The transport cost measure marks Northern Europe as the farthest from Constantinople, and takes into account the fact that coastal dioceses are generally more accessible than inland ones. Travel time extends this by directly incorporating topography.
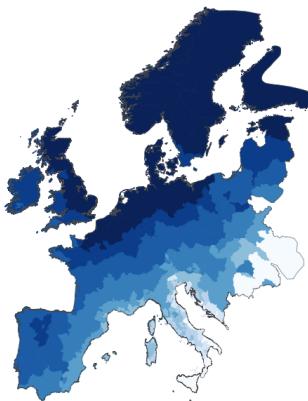
Figure A.7: Transport cost   Figure A.8: Distance   Figure A.9: Travel time
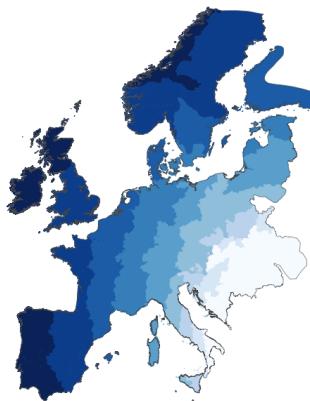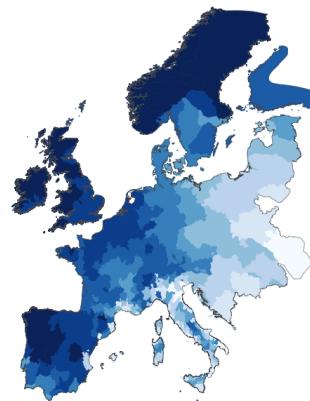
C.4 Adjustments for spatial correlation

Table A.9 displays seven additional sets of standard errors adjusted to account for spatial correlation in the residuals. Included are Conley standard errors at five different distance cutoffs ranging from 50km to 400km. The table also shows robust standard errors clustered at the level of the polity boundaries as they were in 1400 and modern state boundaries.

	Num. sieges (10 year)	Num. sieges (20 year)
Post-1453 × Transport Cost (1000s)	1.19	0.70
Conley 50km	(0.51)**	(0.39)*
Conley 100km	(0.50)**	(0.39)*
Conley 200km	(0.51)**	(0.52)
Conley 300km	(0.51)**	(0.43)
Conley 400km	(0.50)**	(0.81)
Polity 1400 A.D. cluster	(0.34)***	(0.42)*
Modern state cluster	(0.45)***	(0.48)
DV Mean:	0.19	0.12
Polity × Year FEs	✓	✓
Controls × Year	✓	✓
N	803	2751

$^{***}p < 0.01;{}^{**}p < 0.05;{}^{*}p < 0.1$

Table A.9: Standard errors adjusted for spatial correlation

C.5 Logistic regression

For this model specification, instead of using the count of sieges as the outcome, I employ a binary variable $hadSiege_{dt}$ that takes value 1 if diocese d experience one of more sieges in year t and 0 otherwise. Then, I estimate the likelihood that a siege occurs using a fixed effects logistic regression model with an algorithm devised by Stammann, Heiß and McFadden (2016) that circumvents the incidental parameter problem. The specification takes the form

$$\log \left(\frac{P(hadSiege_{dt} = 1)}{1 - P(hadSiege_{dt} = 1)} \right) = \alpha \, postFall_t \times transportCost_d + \beta_d + \gamma_t + \lambda^T X_d \times t$$

where $postFall_t$ is a dummy that takes value 1 in the years following the Fall of Constantinople and 0 otherwise. The variable $transportCost_d$ is the transport cost of a diocese from Constantinople. The term X_d is a vector of diocese-level controls. The terms β_d and γ_t are diocese and years fixed effects, respectively. Finally, δ_{pt} is a period $\times$ polity fixed effect. Standard errors are clustered at the level of the diocese to account for autocorrelation. The results are shown in Table A.10.

	Had siege = 1 (10 year)			Had siege = 1 (20 year)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Post-1453 × Transport Cost (1000s)	0.35**	1.58**	1.41*	0.28***	0.54	0.68
	(0.16)	(0.71)	(0.76)	(0.09)	(0.40)	(0.45)
Num. castles × Year			−0.00			0.00
			(0.01)			(0.00)
Num. settlements × Year			0.00			−0.00
			(0.01)			(0.00)
On trade route × Year			−0.15			0.08
			(0.25)			(0.09)
DV Mean:	0.14	0.14	0.14	0.08	0.08	0.08
Polity × Year FEs	-	✓	✓	-	✓	✓
Num. clusters:	73	73	73	131	131	131
N	803	803	803	2751	2751	2751

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$. Note: Robust SEs clustered by diocese. Unit of analysis is diocese-year.

Table A.10: Effect of exposure to Constantinople on siege ocurrence (Logit)

Column 3 shows that a one-standard deviation in transport costs to Constantinople decreases the odds of a siege occurring in diocese-year by a factor of $\exp(-2.364 * 1.41) = .036$ in the five years after the Fall of Constantinople. This corresponds to an on average 26% decrease in the probability of at least one siege occurring in a diocese-year. As before, the effect is smaller when extending the window to 20 years, and no longer statistically significant.

C.6 Ordinary least squares

I estimate the following specification via ordinary least squares

$$\log(sieges_{dpt} + 1) = \alpha postFall_t \times transpostCost_d + \beta_d + \gamma_t + \delta_{pt} + \lambda^T X_d \times t + \epsilon_{dpt}$$

where $\log(sieges_{dpt} + 1)$ is the logged count of sieges in diocese d within polity p during period t. The variable $postFall_t$ is a dummy that takes value 1 in the years following the Fall of Constantinople and 0 otherwise. The variable $transportCost_d$ is the transport cost of a diocese from Constantinople. The terms β_d and γ_t are diocese and years fixed effects, respectively. Finally, δ_{pt} is a period $\times$ polity fixed effect. Standard errors are clustered at the level of the diocese to account for autocorrelation. I focus on dioceses that experienced at least one siege at any times between 1443 and 1463 for comparability with the Poisson results.

The results are shown in Table A.11. As in the main results, the coefficient on Post-1453 $\times$ Transport Cost is positive in a case. The effect is again stronger in the 10-year window than in the 20-year one. In the five-year period following the Fall of Constantinople, a 1000 unit increase in transport costs is expected to increase the number of sieges in a diocese by $100(\exp(0.08) - 1) = 8.32\%$. In contrast, this effect is only $100(\exp(.02) - 1) = 2.02\%$ in the ten-year period after the capture of the city. Moreover, it is no longer statistically significant. The fits with the logic that the effect is weaker in the long-term, as knowledge about artillery tactics would have fully diffused throughout the system, resulting in less variation in sieges by proximity to Constantinople.

	log(Num. sieges + 1) (10 year)			log(Num. sieges + 1) (20 year)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Post-1453 $\times$ Transport cost	0.02*	0.10*	0.08**	0.01**	0.02	0.02
	(0.01)	(0.06)	(0.04)	(0.00)	(0.02)	(0.02)
Num. castles $\times$ Year			−0.00			−0.00**
			(0.00)			(0.00)
Num. settlements $\times$ Year			0.00			−0.00
			(0.00)			(0.00)
On trade route $\times$ Year			−0.02*			0.00
			(0.01)			(0.00)
DV Mean:	0.11	0.11	0.11	0.07	0.07	0.07
Polity $\times$ Year FEs	-	✓	✓	-	✓	✓
Num. clusters:	73	73	73	131	131	131
N	803	803	803	2751	2751	2751

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$. Note: Robust SEs clustered by diocese. Unit of analysis is diocese-year.

Table A.11: Effect of exposure to Constantinople on sieges (OLS)

C.7 Poisson with alternative fixed effects

In this section, I conduct the difference-in-differences estimation using polity rather than diocese fixed effects. Doing so ensures that 82% of diocese-years remain in the data set during estimation, but introduces many zero observations, reducing the amount of variation in the data. To carry out the analysis, I estimate the following baseline specification using Poisson psuedo-maximum likelihood:

$$E[sieges_{dt} \mid \beta_p, \gamma_t] = \exp\left(\alpha\ postFall_t \times transportCost_d + \beta_p + \gamma_t\right)$$

where $sieges_{dt}$ is the count of sieges take took place in diocese d in year t, $transportCost_d$ is the transport cost of diocese d to Constantinople, $postFall_t$ is an indicator function taking 1 in years after 1453, β_p is a polity fixed effect, and γ_t is a year fixed effect. To this baseline specification I also add diocese-level controls, diocese trends, and polity $\times$ year fixed effects. Standard errrors are clustered at the level of the diocese. As in the main specification, I perform the analysis for 10-year and 20-year windows around the Fall of Constantinople.

	Num. sieges (10 year)				Num. sieges (20 year)			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Post-1453 $\times$ Transport Cost (1000s)	0.25**	0.26**	0.55*	0.05	0.23***	0.25***	0.40*	−0.06
	(0.12)	(0.12)	(0.32)	(0.30)	(0.08)	(0.08)	(0.24)	(0.22)
Transport Cost (1000s)	0.19	0.18	81.66	0.23	0.07	0.09	−8.30	0.19
	(0.13)	(0.14)	(153.52)	(0.18)	(0.10)	(0.11)	(47.40)	(0.13)
Num. castles		0.01*	4.78	0.01*		0.01***	0.72	0.01***
		(0.00)	(4.39)	(0.00)		(0.00)	(0.85)	(0.00)
Num. settlements		0.03	−22.64	0.03		0.02	0.36	0.02
		(0.02)	(18.85)	(0.03)		(0.02)	(5.19)	(0.02)
On trade route		0.69	30.23	0.70		0.75**	−78.34	0.74**
		(0.46)	(203.49)	(0.47)		(0.31)	(67.51)	(0.32)
DV Mean:	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
Polity FEs	✓	✓	✓	-	✓	✓	✓	-
Year FEs	✓	✓	✓	-	✓	✓	✓	-
Polity $\times$ Year FEs	-	-	-	✓	-	-	-	✓
Diocese Trend	-	-	✓	-	-	-	✓	-
Num. clusters:	370	370	370	370	575	575	575	575
N	4070	4070	4070	4070	12075	12075	12075	12075

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$. Note: Robust SEs clustered by diocese. Unit of analysis is diocese-year.

Table A.12: Effect of exposure to Constantinople on siege frequency (Poisson with polity FEs)

The results are reported in Table A.12. Note that for most of the specifications, the coefficient on Post-1453 $\times$ Transport Cost is positive and statistically significant, as in the main analysis, though somewhat smaller. As before, the coefficients are smaller in the 20-year window than the 10-year window. However, when including polity $\times$ year fixed effects, the results are no longer statistically significant for either window. This may be a consequence of the many 0 observations added, reducing the amount of outcome variation within a polity-year on which to make inference.

C.8 Leave-one-out analysis

I exclude each polity individually from the data and estimate Equation 1 again with the modified dataset for the 10-year window. The results are displayed below in Figure A.10. On the y-axis is the excluded polity and on the x-axis is the point estimate and confidence intervals for the coefficient on Post-1453 $\times$ Transport cost. Thick bars and thin bars represent 90% and 95% confidence intervals, respectively. Table A.13 provides numerical results.
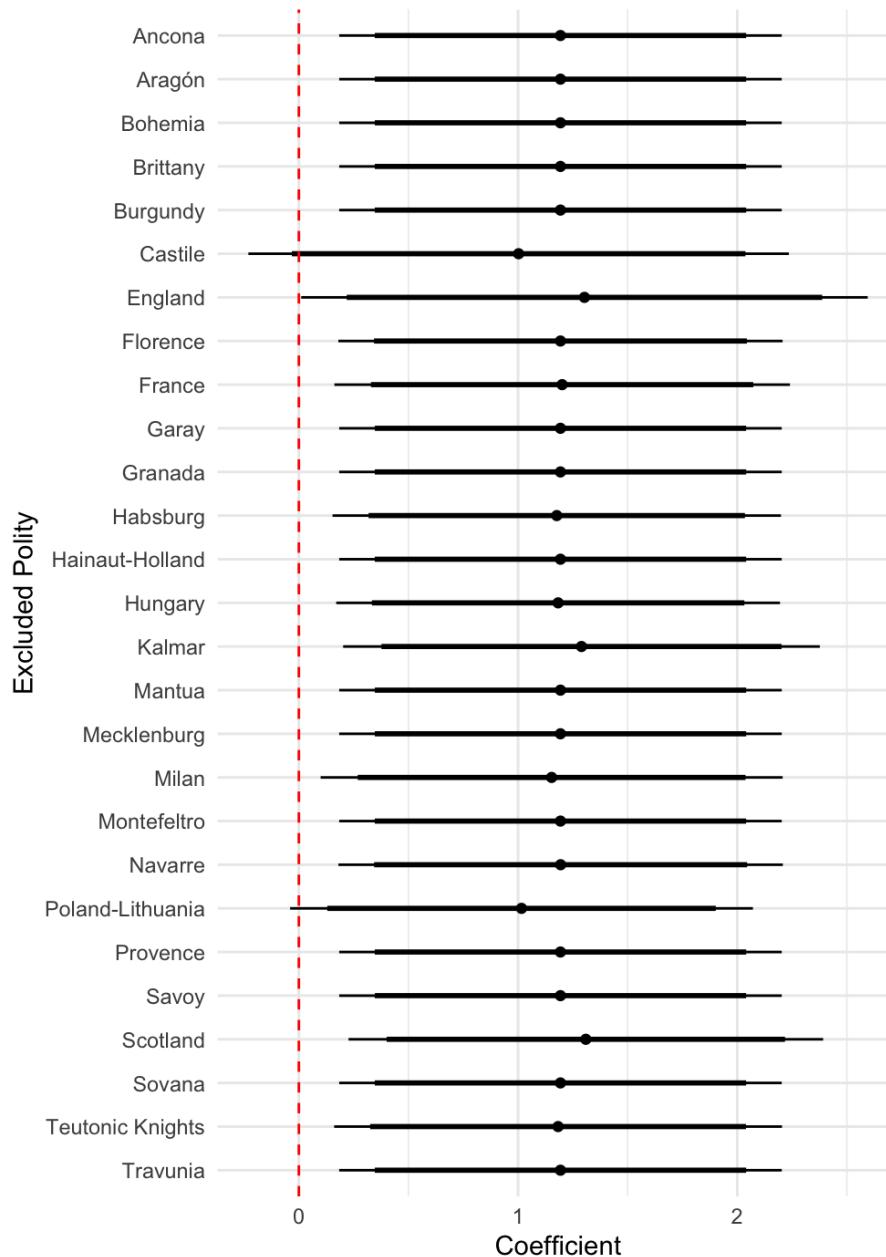

Figure A.10: Leave one-out-analysis (10 year window)

	Num. sieges (10 year)																										
	Ancona	Aragón	Bohemia	Brittany	Burgundy	Castile	England	Florence	France	Garay	Granada	Habsburg	HH	Hungary	Kalmar	Mantua	Mecklenburg	Milan	Montefeltro	Navarre	PL	Provence	Savoy	Scotland	Sovana	TK	Travunia
Post-1453 × Cost	1.19**	1.19**	1.19**	1.19**	1.19**	1.00*	1.30**	1.19**	1.20**	1.19**	1.19**	1.18**	1.19**	1.18**	1.29**	1.19**	1.19**	1.15**	1.19**	1.19**	1.02**	1.19**	1.19**	1.31**	1.19**	1.18**	1.19**
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.60)	(0.56)	(0.51)	(0.52)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.55)	(0.50)	(0.50)	(0.53)	(0.50)	(0.51)	(0.52)	(0.50)	(0.50)	(0.55)	(0.50)	(0.51)	(0.50)
Castles × Year	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Towns × Year	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Trade Route × Year	0.06	0.06	0.06	0.06	0.06	0.07	0.04	0.06	0.08	0.06	0.06	0.05	0.06	0.06	0.07	0.06	0.06	0.03	0.06	0.06	0.05	0.06	0.06	0.07	0.06	0.05	0.06
	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.15)	(0.14)	(0.14)	(0.15)	(0.14)	(0.14)	(0.20)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.15)	(0.14)
DV Mean:	0.20	0.19	0.19	0.20	0.20	0.20	0.19	0.20	0.19	0.20	0.20	0.19	0.19	0.20	0.20	0.19	0.20	0.18	0.20	0.20	0.19	0.20	0.20	0.20	0.20	0.19	0.20
Year × Polity FEs	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Num. clusters:	686	681	692	687	689	668	668	692	615	686	691	683	695	687	677	695	694	667	690	694	686	680	683	688	694	687	695
N	792	792	792	792	792	770	715	781	726	792	792	781	792	770	770	792	792	693	792	781	781	792	792	759	792	759	792

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$. Note: Conley standard errors with 200km radius used to account for spatial correlation. Unit of analysis is diocese-year. HH = Hainaut-Holland, PL = Poland-Lithuania, TK = Teutonic Knights.

Table A.13: Leave-one-out analysis (10 year window)

D   Alternative explanations

D.1   Transport costs to Gascony and Normandy

This section contains summary statistics for the data used in the placebo tests that examine whether exposure to information about the use of cannons during the Gascony (1450-1453) and Normandy (1449-1450) influenced the frequency of siege warfare. Figures A.11 and A.12 map the effective distances of each diocese to Gascony and Normandy, respectively. Distance to Gascony is operationalized as distance from Bordeaux, while distance from Normandy is operationalized as distance from Rouen.
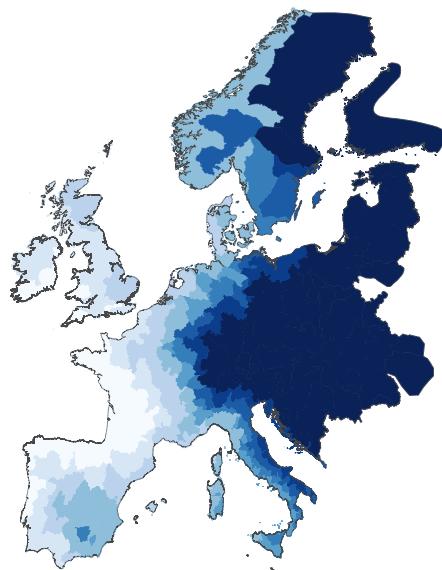

Figure A.11: Transport cost to Gascony   Figure A.12: Transport cost to Normandy
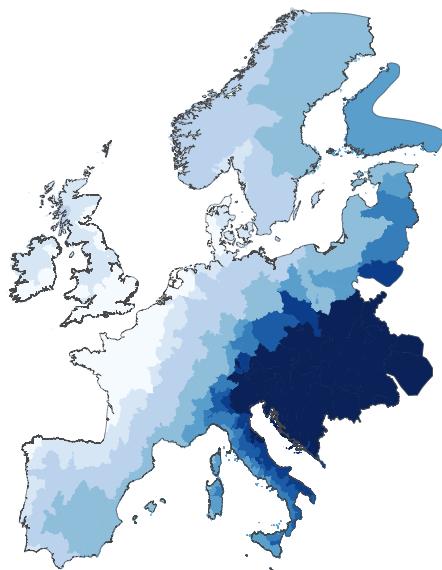
Table A.14 reports the correlation coefficients between the transport costs to Constantinople, Gascony, and Normandy. We see that transport cost to Gascony and Normandy are positively correlated with each other and negatively correlated with distance from Constantinople.

	Constantinople	Gascony	Normandy
Constantinople	1.00	-0.37	-0.79
Gascony	-0.37	1.00	0.81
Normandy	-0.79	0.81	1.00

Table A.14: Correlation between transport costs (Gascony and Normandy)

D.2 Excluding polities involved in the Hundred Years' War

In this section, I conduct the main analysis again, excluding polities involved in the Hundred Years' War and the conflicts it triggered (i.e, England, France, and Scotland) to assess whether the changes in the patterns of siege warfare after 1453 were driven by the end of the Hundred Years' War rather than better information about cannons.

The results are displayed in Table A.15. The coefficients and standard errors on Post-1453 × Transport Cost are almost identical to those obtained from fitting the models on the full sample. Compared to the full sample, the estimated effect of proximity to Constantinople on the frequency of siege warfare is slightly larger in the 10-year window and slightly smaller in the 20-year window, though the effect in the 20-year window is no longer statistically significant when including polity × year fixed effects.

	Num. sieges (10 year)			Num. sieges (20 year)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Post-1453 × Transport Cost (1000s)	0.41**	1.56***	1.53**	0.27**	0.37	0.45
	(0.18)	(0.49)	(0.77)	(0.11)	(0.37)	(0.40)
Num. castles × Year			−0.00			−0.00
			(0.00)			(0.00)
Num. settlements × Year			0.00			−0.00
			(0.01)			(0.00)
On trade route × Year			0.09			0.04
			(0.27)			(0.08)
DV Mean:	0.20	0.20	0.20	0.12	0.12	0.12
Polity × Year FEs	-	✓	✓	-	✓	✓
Num. clusters:	54	54	54	104	104	104
N	594	594	594	2184	2184	2184

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$. Note: Robust SEs clustered by diocese. Unit of analysis is diocese-year.

Table A.15: Effect of exposure to Constantinople on sieges (no Britain or France)

E Full tables

E.1 Main results

This section contains the full version of Table 1.

	Num. sieges (5 year)			Num. sieges (10 year)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Post-1453 × Transport Cost (1000s)	0.32**	1.21***	1.19**	0.29***	0.56*	0.70*
	(0.15)	(0.36)	(0.52)	(0.10)	(0.32)	(0.39)
Num. castles × Year			−0.00			−0.00
			(0.00)			(0.00)
Num. settlements × Year			0.00			−0.00
			(0.01)			(0.00)
On trade route × Year			0.06			0.07
			(0.19)			(0.06)
DV Mean:	0.19	0.19	0.19	0.12	0.12	0.12
Polity × Year FEs	-	✓	✓	-	✓	✓
Num. clusters:	73	73	73	131	131	131
N	803	803	803	2751	2751	2751

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$. Note: Robust SEs clustered by diocese. Unit of analysis is diocese-year.

Table A.16: Full table for effect of exposure to Constantinople on sieges (transport costs)

E.2 Balancing placebo

This section contains the full version of Table 2.

	Num. conflicts (10 year)			Num. conflicts (20 year)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Post-1453 × Transport Cost (1000s)	0.05	0.01	0.01	0.14	0.13	0.14
	(0.07)	(0.03)	(0.03)	(0.09)	(0.10)	(0.09)
Num. castles × Year			−0.00***			−0.00***
			(0.00)			(0.00)
Num. settlements × Year			0.00			0.00**
			(0.00)			(0.00)
On trade route × Year			0.01			−0.00
			(0.01)			(0.00)
DV Mean:	0.52	0.52	0.52	0.98	0.98	0.98
Polity × Year FEs	-	✓	✓	-	✓	✓
Num. clusters:	52	52	52	56	56	56
N	6105	6105	6105	12348	12348	12348

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$. Note: Robust SEs clustered by polity. Unit of analysis is diocese-year.

Table A.17: Full table for effect of exposure to Constantinople on wars

E.3 Learning placebo

This section contains the full version of Table 3.

	Num. sieges (10 year)		Num. sieges (20 year)	
	Gascony	Normandy	Gascony	Normandy
Post-1450 × Transport Cost (1000s)		0.16		−0.15
		(0.83)		(0.44)
Post-1453 × Transport Cost (1000s)	−1.13*		−0.69	
	(0.65)		(0.44)	
Num. castles × Year	−0.00	−0.00	−0.00	−0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Num. settlements × Year	0.00	−0.00	−0.00	0.00
	(0.01)	(0.01)	(0.00)	(0.00)
On trade route × Year	0.03	0.04	0.11	0.06
	(0.21)	(0.18)	(0.07)	(0.06)
DV Mean:	0.19	0.20	0.12	0.12
Polity × Year FEs	✓	✓	✓	✓
Num. clusters:	68	93	127	131
N	748	1023	2667	2751

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. Note: Robust SEs clustered by diocese. Unit of analysis is diocese-year.

Table A.18: Full table for effect of exposure to Gascony/Normandy on sieges