Learning When to Fight: Technological Diffusion and Frequency of Conflict in Medieval Europe

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Abstract

Does technological change make conflict more likely? I theorize that new technologies can generate conflict by creating uncertainty about the balance of power, but that this uncertainty diminishes after the effectiveness of new technologies is demonstrated in combat. I test this theory by examining how news of the Ottoman Empires use of cannons at the Siege of Constantinople in 1453, which saw artillery devastate the most sophisticated fortifications in Europe in a time when gunpowder artillery was still novel, 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 locations 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 this decline was due to a convergence in beliefs about the usefulness of artillery. The findings of this paper provide evidence for a new mechanism linking technological change to international conflict.

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1 Introduction

A prominent theory about the causes of war argues that uncertainty about the balance of power generates conflict.[1] This obtains because factors such as misperception or asymmetric information about military capabilities make it harder for states to reach mutually acceptable settlements that are preferable to fighting. Yet despite the theory's influence, convincing empirical tests of its predictions have proven elusive, in part because of the difficulty of measuring private information held by states (Lindsey, 2019). In this paper, I propose a causal empirical test that avoids this measurement issue using an understudied source of uncertainty about the balance of power: technological change.[2]

I argue that technological change can blur perceptions of the balance of power by complicating states' private assessments of military capabilities.[3] New technologies are often incorporated into military forces before those same technologies are used in combat. As a result, states must privately assess the effectiveness of a new technology, develop doctrine for its use, and form expectations about how adversaries may employ the technology in a potential conflict. Yet private analyses of new technologies are noisy, and can potentially lead states to arrive at contrasting judgements about how a new technology has affected the balance of power. Such contrasting private assessments may result in bargaining breakdown, leading interstate disputes to escalate into conflict (Debs, 2022; Fearon, 2021). However, once a technology is observed in conflict, information about the performance of the technology diffuses throughout the international system. Conflicts therefore serve as "demonstration points" that reveal the effectiveness of new technology and the tactics needed to employ it successfully, facilitating a convergence in beliefs about the new technology and making it less likely for states to disagree about the balance of power. (Goldman and Eliason, 2003; Horowitz, 2010).

[1]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 area of research.

[2]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. This definition excludes social, tactical, or organizational innovations. I treat those under the separate category of "doctrine."

[3]I verbally outline this theory in Section 2; however, it is formalized and elaborated in Tchaouchev (2025), another chapter of my dissertation.

In this paper, I test whether the diffusion of information about the effectiveness of a new military technology reduces conflict. To do so, I examine the incidence of siege warfare in Western and Central Europe during the periods immediately before and after the Fall of Constantinople in 1453. Siege warfare, which dominated most conflicts of the medieval and early modern eras, was transformed by the introduction of gunpowder artillery in the 14th and 15th centuries. New cannons rendered formerly stalwart fortifications vulnerable to bombardment, making sieges less costly for attackers (Bradbury, 1992). However, early bombards were crude weapons that were seen as inferior to existing siege weapons, with the historian William McNeill noting 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 1420s and 1430s that enabled it to batter down walls, this fact was recognized by only a few early adopters, including the Ottomans, while many continued to believe that existing fortifications remained impervious to siege. (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.

The 1453 Siege of Constantinople provided a demonstration point that revealed the advantages of gunpowder artillery to Western Europeans. Using a large array of bombards, the Ottomans were able to breach the walls of Constantinople, fortifications that were considered the most sophisticated in Europe (Ágoston, 2014). Given the religious overtones of the conflict, the capture of city was closely watched by Western Europeans, and accounts of the siege and subsequent fall of the city spread across the continent. These accounts universally emphasized the key role that artillery played in the siege and the tactics that the Ottomans employed, setting off a period of European-Ottoman military acculturation (Philippides and Hanak, 2011; Bisaha, 2017). Europeans that had believed fortifications remained secure from assault were confronted with evidence that this was not the case. As a result, they were more likely to surrender when faced with a besieging army equipped with cannons. I therefore hypothesize that locations more exposed to information about the siege of Constantinople should experience fewer sieges, as they would be able to perform such reassessments earlier, leading to more negotiated settlements.

I test this hypothesis using a difference-in-differences design with a continuous treatment. Due to the era's slow travel times, settlements located further from Constantinople obtained detailed reports of siege later than settlements located nearer. 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). As news of the siege diffused roughly concentrically from Constantinople and proximity to the city 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 causal evaluation of the effect of information transmission on conflict.

To carry out this empirical strategy, I collect a new dataset of 357 sieges that occurred in Western and Central Europe between 1443 and 1463, constituting by far the largest and most comprehensive account of sieges during this period. I proxy for exposure to information about Constantinople using estimates of transportation costs, which I construct computationally using historical records of shipping costs and a shortest-path algorithm (Masschaele, 1993).

I find that in the decade following the Fall of Constantinople, regions located one standard deviation closer to Constantinople, as measured by transportation costs, experienced about one fewer siege on average, supporting my hypothesis. Consistent with a theory of learning, this effect is strongest immediately after 1453 and dissipates later on, as, given enough time, the information transmitted by the siege fully diffused throughout Europe. Using historical evidence and placebo tests, I rule out alternative explanations, such as balancing by European polities against the Ottoman Empire, for the observed shift in the pattern of siege warfare. In addition, I show that the results are robust to alternative measures of proximity to Constantinople, corrections for spatial correlation, and the use of alternative functional forms.

In addition to testing the prominent claim that uncertainty about military capabilities can generate conflict, this paper contributes to two major strands of research. First, this chapter adds to the literature on the causes of war by providing empirical evidence for a new mechanism linking technological change to the frequency of conflict. Most existing international relations scholarship on the relationship between technological change and conflict has been conducted through the lens of the offense-defense balance (Glaser and Kaufmann, 1998; Hopf, 1991; Jervis, 1978; Lynn-Jones, 1995; Quester, 2002). However, the offense-defense balance, which captures the relative ease of capturing territory with military force compared to defending territory, has been criticized as an explanatory variable due to its lack of theoretical clarity and the difficulty of conducting empirical tests of its proposed effects (Levy, 1984). In particular, testing hypotheses about the offense-defense balance, such as the claim that offensive advantage makes conflict more frequent, requires measuring the offense-defense balance itself, which is not directly observable.

The approach taken in this paper circumvents such measurement issues by focusing instead on the fact that novel technologies make it harder to assess military capabilities. Moreover, the findings of this paper contradict the predictions of offense-defense theory, whose proponents have identified as gunpowder artillery as a technology that shifts the offense-defense balance in favor of the offense (Quester, 2002). The Fall of Constantinople's revelation of tactics to effectively employ cannons to capture fortifications would likely be coded as a further shift towards the offense, which would be predicted to increase the frequency of conflict, which is the opposite of what we observe empirically. The findings of the paper show that offensive advantage need not generate conflict if parties in a dispute both recognize that the attacker has an advantage and adjust their bargaining behavior accordingly.

Second, this paper contributes to scholarly understanding of the patterns of conflict observed in 15th-century Europe. Scholars have long noted a shift in the practice of warfare, or "military revolution," during this period, namely due to the increased use of artillery and strengthened fortification. This new style of warfare, along with the concomitant expansion of state administrative capacity needed to the raise the funds to support it, has been proposed as a precursor to phenomena such as the rise of the modern state and later European colonial expansion (Hoffman, 2015; Mangini and Petroff, 2022; Parker, 1996; Tilly, 2017). The conclusions of this paper offer a possible explanation for why this military revolution occurred when it did, as recognition of the effectiveness of artillery prompted leaders to invest more in fortification.

The remainder of this paper is organized as follows. Section two elaborates a theory of how technological change affects perceptions of the balance of power. Section three provides historical background and qualitative evidence for an effect of the Fall of Constantinople on siege warfare. Section four describes the data used in the study. Section five outlines the empirical strategy. Section six presents the results of the empirical analysis. Section seven considers alternative explanations for the empirical findings. Section eight concludes.

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 effective the new technology 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 for their use prior to battle.[4] Yet the process of evaluating a new technology is highly idiosyncratic, which can result in states arriving at contrasting expectations about how a new technology will affect the outcome of future conflicts. Such 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).[5]

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

[5]It can be shown that mutual optimism (i.e., both states receiving a private signal that suggests the balance of power is relatively favorable to themselves) is not necessary to produce war. Tchaouchev (2025) explains this point

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, differential doctrinal development, and internal bureaucratic competition between military services.

First, assessing the combat potential of new technologies is inherently difficult and subject to a high degree of randomness, which can result in two states arriving at opposing judgements about the utility of the same technology (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 technical and engineering efforts may be needed to adapt the new technology to a particular military 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.[6] 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 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,

in greater detail.

[6]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).

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.[7]

Finally, technological change can also create disagreements about the balance of power via the actions of bureaucratic actors within the military that promote perceptions of new technologies for their own benefit. Past research has found that the reception of an innovation is mediated by the effect that adopting the innovation will have on existing distributions of power and wealth (Juma, 2016; Mokyr, 1998; Solstad, 2023). In particular, 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; in fact, a large literature has shown that entrenched interests within militaries are particularly resistant to innovation (Evangelista, 1988; Grissom, 2006; Posen, 1984; Rosen, 1991). Military organizations have not hesitated to present slanted assessments in support of self-interested goals. Snyder (1984) argues that military staff across Europe deliberately promoted perceptions of offensive advantage prior to 1914 as a means of preserving or enhancing their budgets, prestige, and

[7] 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).

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.[8] Biased views of technological capabilities may emerge from this internal competition, resulting in conflict 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.[9]

[8] 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)

[9] 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 noticed by all, 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 Historical background and qualitative evidence

3.1 Siege warfare and firearms in Medieval Europe

Sieges in Medieval Europe were microcosms of the bargaining interactions 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 or settlement by siege required a long blockade, a risky direct assault with siege engines, difficult and expensive mining of walls, or some combination thereof (Bradbury, 1992). Neither attacker nor defender relished the prospect of a siege. Consequently, sieges were almost always preceded by a period of negotiation between the attacking and defending forces. Some regions even developed mechanisms to intentionally curtail the length of sieges (Mallett, 2009). While such a dynamic defined siege warfare for centuries, the early 14th-century brought a development that would eventually be transformative: 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).[10]

[10] 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.

Nevertheless, primitive cannons spread rapidly throughout Europe due to their inexpensive cost compared to other siege engines, whose complex mechanisms required a great deal of 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. At this time, 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).

Starting in the 1410s and 1420s, technical advancements began to improve the effectiveness of gunpowder artillery. First, the development of the process 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 larger 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 also 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 so frustrated besieging armies for the past two centuries.

Not all European military leaders recognized the significance of new technical advances in artillery and munition manufacture. Indeed, 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 general attitude of indifference toward artillery is supported by a survey of 15th-century military and fortification manuals by De la Croix (1963), who 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 at the same time, 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. Yet even these optimists sometimes hamstrung the power of their guns using poor tactics. Some accounts record that overconfident commanders would bring insufficient cannonballs to sieges and be forced to complete the siege using traditional tactics (DeVries, 2024). Consequently, by the early 1440s, Europeans had a wide range of contrasting assessments on the military effectiveness of new cannons, creating the potential for mutual optimism.

3.2 Artillery use at the Siege of Constantinople

European attitudes about gunpowder artillery would begin 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 course of the siege, the Ottomans made extensive use of gunpowder artillery, employing up to 70 cannons to fire over 5,000 projectiles (Ágoston, 2014). Of note is that the cannons the Ottomans deployed were not more sophisticated than those being 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 at Constantinople was in developing tactics to employ cannons 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. 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, the account of Michael Critobulus 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.[11]

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).

[11] Cited in DeVries (1997).

The diffusion of detailed accounts of the Fall of Constantinople happened slowly. Technological limitations during the Middle Ages made travel was long and arduous, as most travel had to be undertaken on foot, horseback, or ship. Factors such as weather and ongoing conflicts meant that journeys of even a few hundred kilometers could take months or years. These long travel times are illustrated by the fact that the first Greek refugees from Constantinople did not arrive in England until 1455, two years after the Fall of Constantinople and far later than their earliest arrival in Italy. (Harris, 2022).

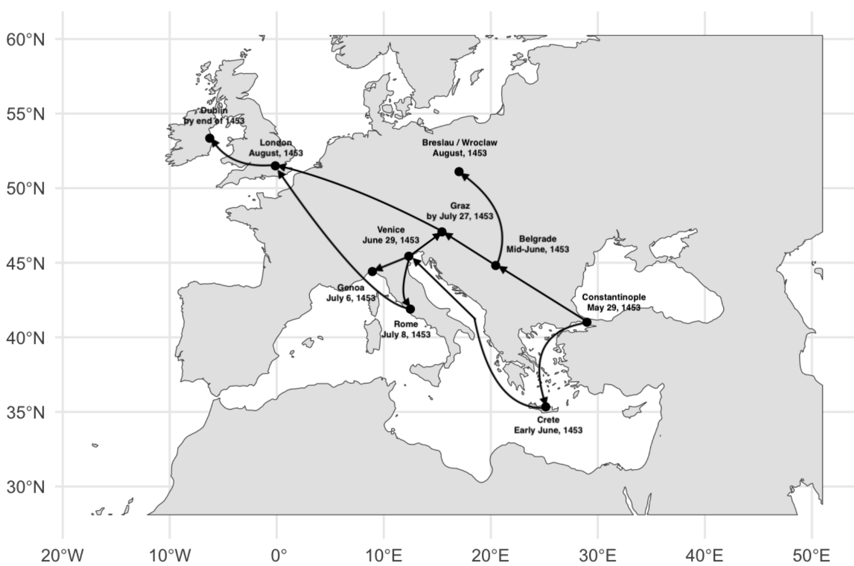

Figure 1: Diffusion of initial news about Fall of Constantinople

As a result, the spread of information about the Fall of Constantinople proceeded in a roughly concentric pattern that followed major trade routes. This pattern is depicted in Figure 1, which maps the dates that initial news of Constantinople's fall first reached selected major cities.[12] While this initial wave information communicated only that the city had fallen, along with rumors of atrocities committed during the sack and Turkish preparations to invade Italy, it is far easier

[12]This map was made using surviving letters and other primary sources. Details of the sources used to construct Figure 1 can be found in Appendix 7.

to track over time. Figure 1 reveals a clear gradient in the timing of the arrival of i news of 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.

3.3 Military reactions to the Fall of Constantinople

As news of the Fall of Constantinople diffused across Europe, political and military leaders took note of the Ottoman's effective application of cannons and changed their assessments the utility of gunpowder artillery accordingly. The most clear evidence of such a shift comes from the actions of Philip the Good, Duke of Burgundy. Upon hearing reports of the effectiveness of the Ottomans' guns at Constantinople, Philip insisted that the artillery train for a planned campaign be expanded to include "five or six hundred gunners" and then 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 intellectuals, after hearing of or observing the military effectiveness of the Ottomans, penned treatises urging their rulers to adopt Turkish artillery and field tactics.[13] While the goal of these writers was to prepare Europeans to wage a victorious 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. Primary source accounts of sieges taking place after 1453 show that Europeans began imitating artillery tactics that were used by the Ottomans at Constantinople. 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, demonstrating the second shift in artillery use after 1453: the use of cannons and bombards as

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

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 negotiations would focus on demonstrating to defenders the power of their artillery in order to awe the defenders into surrender, thus averting a siege in the first place. Indeed, prior to the first shot at Bamburgh, the leader of the besieging army arrayed his army's cannons in plain view of the defenders and threatened to execute a member of the garrison for each breach the cannons made in the castle walls:

> If ye suffer any great gun laid unto the wall and be shot, and prejudice the wall, it shall cost you the chieftain's head, and so proceeding for every gun shot to the least head of any person within said place.[14]

As firearms improved in the later parts of the 15th century, we see similar tactics employed in pitched battles as well. Indeed, 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, recounted in *The Memoirs of Philip de Commines*, took place prior to the Battle of Fornovo in 1495.[15] De Commines recalls a scenario where 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.[16]

[14] Pages lxxxvii and lxxxvii in Giles (1845).

[15] Philip de Commines (1447-1511) was knight and writer who served Charles the Bold, Duke of Burgundy, and Louis XI, King of France.

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

Together, these episodes demonstrate 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, medieval and early modern Italian mercenaries, previously silent on the use of cannons, began devoting entire 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

In summary, this section has offered evidence that immediately prior to 1453, Europeans had contrasting beliefs about the utility of gunpowder artillery in siege warfare, despite recent technical advancements that 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 closely watched by Western Europeans. European observers 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 learned from the siege of Constantinople creates a consensus among the attackers and defenders about how cannons would be used in a siege. This common reference point means both sides of a conflict will use the same information in forecasting how they would perform in a fight. Having this common information will make it less likely that the opposing sides 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 diminishes the influence of 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, such private information would be less important in face of overwhelming artillery power–an extra month of food stored away matters little when the walls are breached after a day of bombardment regardless.[17]

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.

[17]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.

4 Data

4.1 Dependent variable: sieges

The dependent variable of the study is the number of sieges occurring in a Roman Catholic diocese (c. 1450 A.D. boundaries) in a given year. To construct this variable, I collected a new 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 fortified location, such as a castle or city, where there is an attempt to blockade, destroy, or assault the fortification. Excluded are pitched battles occurring immediately beyond the defenses of a fortification and situations where individuals opportunistically barricaded themselves in structures not intended to resist attack, such as churches.[18]

Sieges included in the dataset are drawn from attestations of sieges from primary and secondary sources in several European languages.[19] Primary sources include documents such as chronicles, letters, and treaties, as well as archeological evidence recovered from the sites of sieges. Authoritative secondary sources include academic histories of individual wars, biographies of rulers, and publications of local historical or preservation societies. As a means of ensuring data reliability, only sieges with at least two distinct attestations are included in the dataset. The record of each siege in the dataset includes the date(s) of the siege, the name of the broader conflict the siege is associated with (if any), and the longitude-latitude coordinates of the location of the siege.

The complete dataset consists of 357 sieges, associated with at least 40 named conflicts.[20] Sieges are associated with many types of conflicts, including traditional interstate wars (the Hundred Years' War), rebellions or civil wars (the Revolt of Ghent), and feuds between rival noble houses (the Soest Feud). The dataset illustrates the high frequency of siege warfare during this era, with an average of nearly 18 sieges per year. However, there is significant yearly variation

[18] An example of such an *ad hoc* "siege" occurred at Stanton Harcourt Church, located near Oxford, England, in 1448. After an earlier altercation between Sir Humphrey Stafford and Sir Robert Harcourt, Stafford assembled 200 men to attack Harcourt at his manor. Harcourt took refuge in the local parish church tower, which Stafford's men surrounded and blockaded for six hours. The siege ended when Stafford's forces set fire to the tower (Mercer, 2010).

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

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

in the frequency of siege warfare. Figure 2 plots the number of sieges by year. Note that while the number of yearly sieges prior to 1453 was roughly constant, a visible decline occurred after 1453.

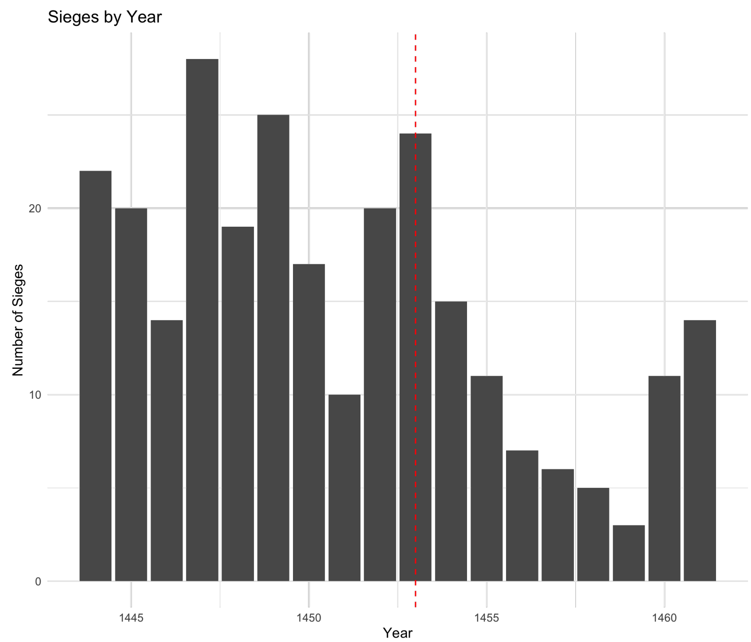

Figure 2: Sieges by year

The sieges are geocoded and matched to a diocese using boundary files taken from the Digital Atlas of Dioceses and Ecclesiastical Provinces in Late Medieval Europe (1200-1500) of the *Corpus Synodalium* project (Dorin, 2021). In 1450 A.D. there were 669 Roman Catholic Dioceses in Europe, stretching from Lisbon to Halych in present-day Western Ukraine.[21] Figure 3 overlays the locations of sieges on a map of Roman Catholic Dioceses.[22] The map shows that siege warfare was common throughout Western and Central Europe, with notable clusters in Northern Italy, the Low Countries, and Switzerland.

I aggregate sieges by diocese because it is the most granular territorial unit from the period under study for which we have reliable data on borders. In addition, dioceses were generally centered on a cathedral town that would likely be the target of a siege if the area were attacked.

[21]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 inclusion does not affect any results presented subsequently.

[22]Sieges in the Balkans were also collected for completeness, but are not included in the analysis.

Diocese borders also generally followed existing political boundaries–it was uncommon for a diocese to be divided between polities (Dorin, 2021). Finally, the portion of Europe with established dioceses corresponds to Western Christendom, the audience that would have closely followed news of the Fall of Constantinople.

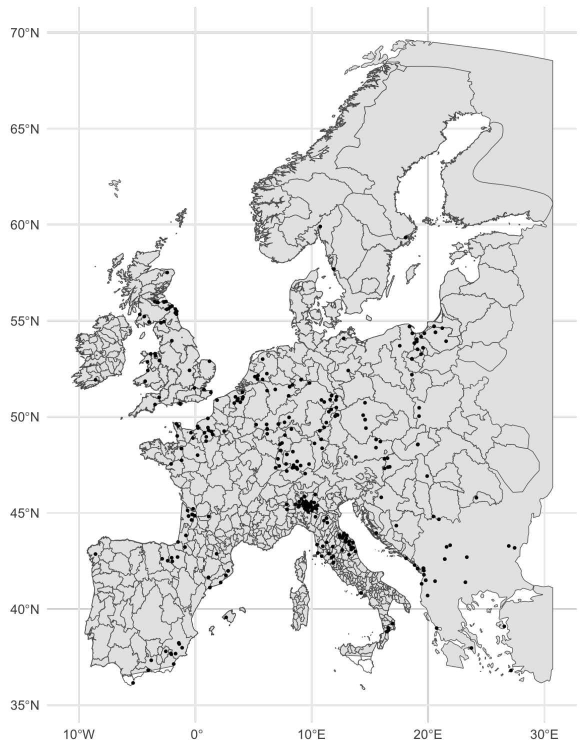

Figure 3: Dioceses and siege locations

4.2 Independent variable: transport cost

For the independent variable of the study, I construct a measure that proxies for how soon a diocese learned about information about the Fall of Constantinople. To do so, I compute the minimum transport cost, or effective distance, of a diocese from Constantinople. Such an approach assumes that that travelers follow the least expensive route available to reach their destination. Although I attempt to measure the diffusion of information, rather than goods or people, the technological limitations of the late Middle Ages meant that information, whether communicated in writing or in speech, would need to be physically conveyed by a messenger. Consequently, travelers bearing news about the Fall of Constantinople should reach locations with a smaller effective distance earlier.

Is transport cost a good proxy for information exposure? I argue that it is, for two reasons. First, surviving trade receipts and records of travel itineraries indicate that goods, passengers, and mail preferred to take cheaper and faster sea routes rather than more costly overland routes, despite the fact the that the overland routes were sometimes hundreds of kilometers shorter (Birkett, 2018; Masschaele, 1993). Second, there is evidence that before telecommunications, important news spread between major trade centers first, before diffusing into their hinterlands. For instance, in his examination of the spread of the French Revolution, Robb (2007) finds that it took seven days for a major city like Beziers to learn of the storming of the Bastille, but several days longer for that same information to reach smaller towns and villages scattered between it and Paris. To quote Robb, these "smaller towns might be closer in space but further away in time" (Robb, 2007, 140-141).

To compute the minimum transport cost of a diocese from Constantinople, I combine estimates of medieval shipping costs from Masschaele (1993) with a graph-based shortest-path algorithm. The formal procedure is as follows. Divide Europe and its surroundings into a grid of equally sized square cells. Define $d(i, j)$ to be the distance, in kilometers, between the centroids of adjacent grid cells i and j and $c(i, j)$ to be the shipping cost per kilometer of travel between those same cells. If we then let $\mathcal{P}_d$ be the set of all paths between Constantinople and a diocese d, the cost of transport from to Constantinople to that diocese is given by the cost of the shortest path $p \in \mathcal{P}_d$, or

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

The variable transportCost_d is computed for each diocese d using Dijkstra's shortest path algorithm (Dijkstra, 2022). An example of such a path between Constantinople and Winchester, England, is shown below in Figure 4, while Figure 5 visualizes the transport distance for every diocese in Europe. Dioceses on the eastern coast of Italy and those near the Black Sea are the closest to Constantinople under this measure, while those in Northern Europe are the farthest.

Note that this closely corresponds to timing of the arrival of information about the initial news of the Fall of Constantinople mapped in Figure 1.

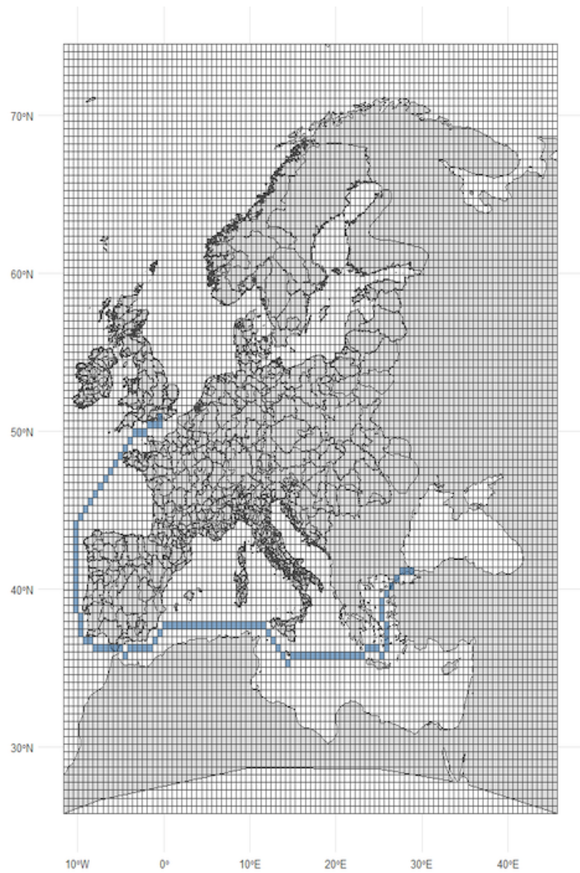

Figure 4: Cheapest path example

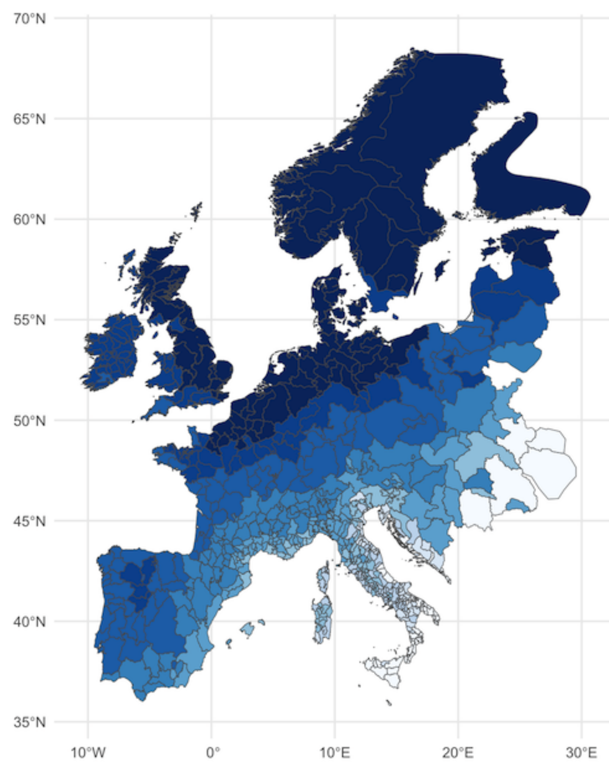

Figure 5: Transport costs by diocese

A note on interpretation–Masschaele (1993) generated his estimates of shipping costs by comparing trade receipts for similar goods shipped across between different locations or via different modes of transportation. From this, he derives relative differences in costs, normalized by the cheapest mode of transport, which was sea transport.[23] Therefore, one unit of the transport cost can be interpreted as the cost of one kilometer of transport by sea.

[23]For instance, Masschaele (1993) finds that, over all goods, sea transport in England was roughly eight times cheaper than overland transport.

4.3 Additional variables

I also collect data on control variables and additional outcome variables, such as urbanization, number of fortifications, presence on trade route, 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). For each diocese, I count the number of non-settlement fortifications (i.e., castles, fortresses, etc.) extant in 1450 A.D., sourced from a scrape of WikiData. I also record whether a diocese is on an overland trade route by georeferencing a map from Shepherd (1911). To measure the number of ongoing conflicts in a given diocese, I geocode the extent of relevant European wars collected by Brecke (1999), who attempts to catalog all historical conflicts with at least 32 battle deaths. Finally, boundary files for sovereign European political polities in the years 1400 is drawn from the historical atlas maintained by Nüssli (2009).[24]

5 Empirical strategy

5.1 Differences-in-differences

To study how exposure to information about the use of cannons at Siege of Constantinople affected the frequency of siege warfare in Western Europe, I compare dioceses at varying distances from Constantinople before and after the Fall of Constantinople in 1453. To do so, I implement a difference-in-differences design using a two-way fixed effects estimator. Specifically, I estimate a fixed effects Poisson regression (Hausman, Hall and Griliches, 1984) using quasi-maximum likelihood

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

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 period t. The

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

variable $postFall_t$ is a dummy that takes value 1 in the years following the Fall of Constantinople and 0 otherwise. The terms β_d and γ_t are diocese and period 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 $postFall_t \times transportCost_d$. It takes the value of the transport cost of diocese d in post-1453 periods and zero otherwise. Therefore, the coefficient α captures how a diocese's transport cost from Constantinople affected the frequency of siege warfare in periods after the Fall of Constantinople, holding other factors fixed.

I employ a Poisson regression model for ease of interpretation and robustness. In the Poisson model a regression coefficient α can be interpreted as a semi-elasticity. The transformation $100 \times (e^{\alpha} - 1)$ yields the expected percentage change in the outcome variable associated with a one-unit increase in the predictor. In contrast, the coefficient α in a linear model is expected change in the value of the outcome variable for a one-unit increase in the predictor. The latter interpretation is questionable in the context of my theory, which argues that better information about military capabilities makes it easier to reach a negotiated settlement. It is not clear why better information about capabilities would produce a fixed decrease in sieges across all dioceses, especially as the baseline frequency of disputes that could result in sieges differs significantly across dioceses, due to variables such as population and wealth. The interpretation of Poisson coefficients captures the idea that better information about capabilities reduces the probability of disputes escalating to conflict, reducing the observed rate of sieges. 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).

The fixed-effect Poisson model has also been shown to be highly robust, producing consistent estimates even when the data does not follow a Poisson distribution (Wooldridge, 1999, 2023). In fact, the model requires only a correct specification of the conditional mean for consistency. 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, especially in comparison to the Poisson and negative binomial models (Cohn, Liu and Wardlaw, 2022; King, 1988). However, to ensure that conclusions drawn from the empirical analysis are not driven by a particular functional form assumption, I also perform the empirical analysis using a ordinary least squares model. These results can be found in Appendix E.

5.2 Identification

Under a difference-in-differences identification strategy, interpreting the coefficient α as the causal effect of information transmission about cannons on conflict requires the assumption that dioceses had parallel trends in sieges prior to the Fall of Constantinople. This means that, prior to 1453, varying transport costs from Constantinople should have a constant effect on the number of sieges in a diocese. I take two approaches to assess the validity of this assumption.

First, in Figure 6 I plot the mean number of sieges in dioceses whose transport costs to Constantinople are greater and less than average for dioceses that had at least one siege at any point between 1443 and 1463. 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.

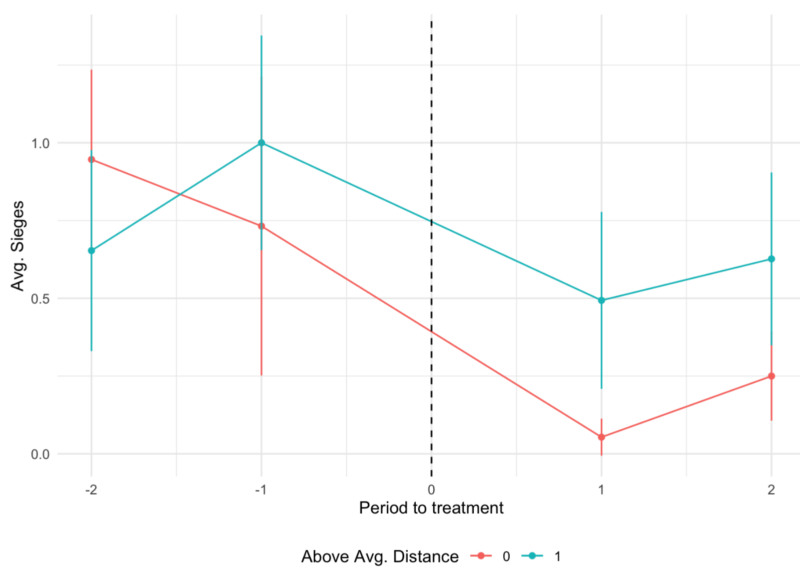

Figure 6: Trends in sieges

However, Figure 6 also shows that the groups may be trending in opposite directions before

1453, suggesting a potential violation of parallel trends. Therefore, as an additional test for pre-trends that may be more suited to a continuous treatment, I conduct 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 7.[25] 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. Together, these results provide evidence for both the absence of pre-trends and the existence of a post-1453 effect. The plot also shows that the effect fades over time, particularly after 1458. Such a trend is consistent with the idea that once information had about the siege of Constantinople had fully diffused throughout Europe, there would be less variance in expectations about the efficacy of bombards by geography.

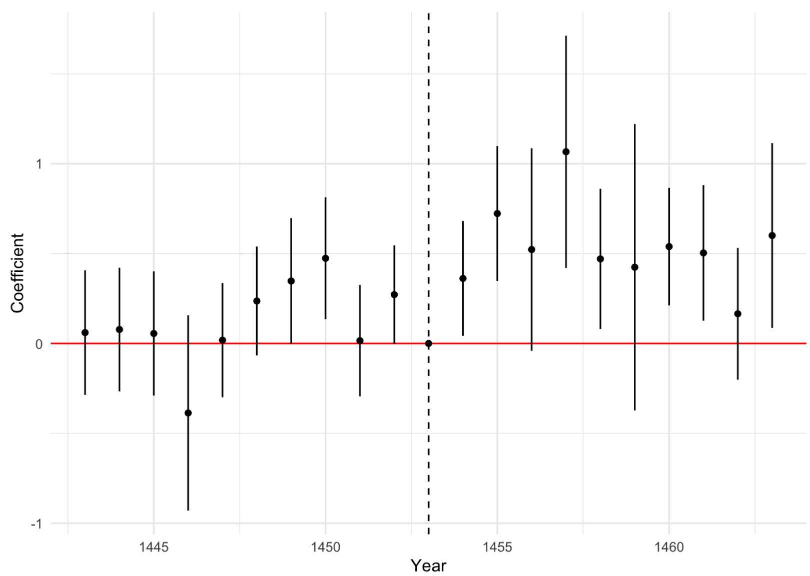

Figure 7: Event study

An additional threat to inference is the potential existence of time-varying confounders correlated with transport costs to Constantinople, which may bias the estimate of α. For instance, it may be the case that polities nearer to Constantinople experienced more conflict prior to 1453,

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

the resolution of which would mean fewer wars and sieges in period after 1453. As these shifts are regional, common period fixed affects will not capture this confounding. Thus, I employ sovereign polity $\times$ period fixed effects, using 1400 A.D. boundaries, which will account for such time-varying polity level confounders. In addition, there may be time-varying shocks that 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. Such controls include the number of major settlements in a diocese, the number of castles in a diocese, and whether an overland trade route passes through a diocese.

Therefore, my final specification is

$$E[sieges_{dpt} \mid \beta_d, \gamma_t, \delta_{pt}, X_d] = \exp\left(\alpha\ postFall_t \times \text{transportCost}_d + \beta_d + \gamma_t + \delta_{pt} + \lambda^T X_d \times t\right) \tag{1}$$

where δ_{pt} are polity $\times$ period fixed effects and X_d is a vector of diocese-level controls.

6 Results

6.1 Main results

First, to demonstrate how the geography of siege warfare changed after 1453, I plot the empirical densities of siege locations before and after 1453. 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. Note that 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 indicates 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 away from

Constantinople is less pronounced but still noticeable when extending the period length to 10 years. This consistent with a 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 we should observe less distinction in siege incidence by proximity to Constantinople.

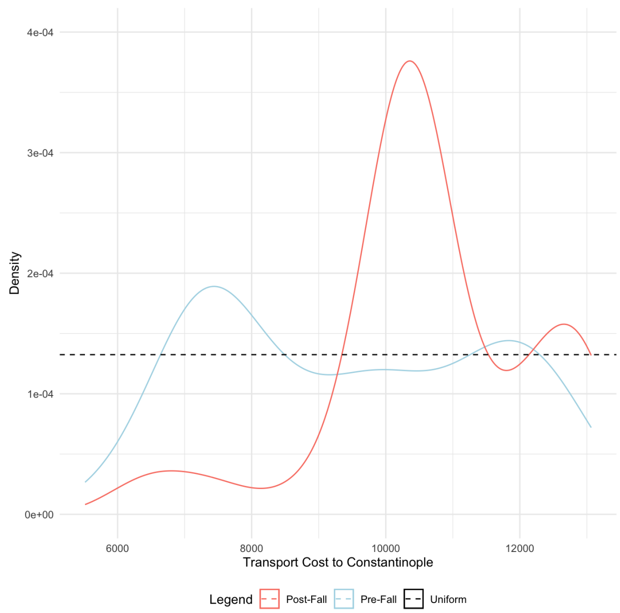

Figure 8: Empirical siege density (10-year)

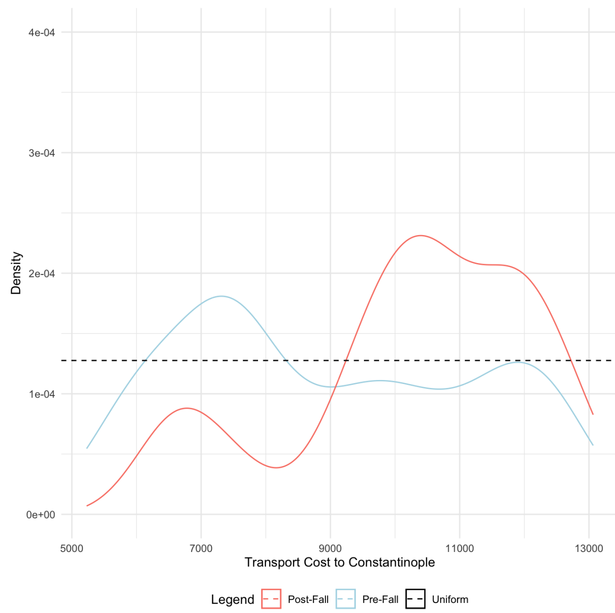

Figure 9: Empirical siege density (20-year)

I now evaluate the patterns displayed in Figures 8 and 9 using the 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 year $\times$ polity fixed effects. Column 3 adds diocese-level controls interacted with year dummies. 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.

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 ex-

	Num. sieges (10 year)			Num. sieges (20 year)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Post-1453 × Transport Cost	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
Year × Polity FEs	-	✓	✓	-	✓	✓
Year × Controls	-	-	✓	-	-	✓
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)

perienced more sieges in the decade following the capture of the city. Using the full specifications (columns 3 and 6), 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 $-100(\exp(-2.364 \times 1.19) - 1) = 94\%$. This corresponds to an average decrease of 0.18 sieges per diocese-year, or 0.9 fewer sieges in the five years following 1453. 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 the transport cost reduces the yearly count of sieges in a diocese by $-100(\exp(-2.364 \times 0.70) - 1) \times 100 = 80\%$. As before, this corresponds to an average decrease of 0.097 sieges per diocese-year on average, or about 0.97 fewer over the ten years after 1453. The results support the hypothesis that there were fewer sieges in dioceses greater exposure to information about the use of cannons at Constantinople. Moreover, we see that the effect is concentrated in the five years following the Fall of Constantinople. The fact that the coefficient and effect size are smaller in the 20-year window again coincides with 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, and we should observe less variation in siege incidence by proximity to Constantinople.

Figure 10 maps the geographical distribution of sieges before and after the Fall of Constantino-

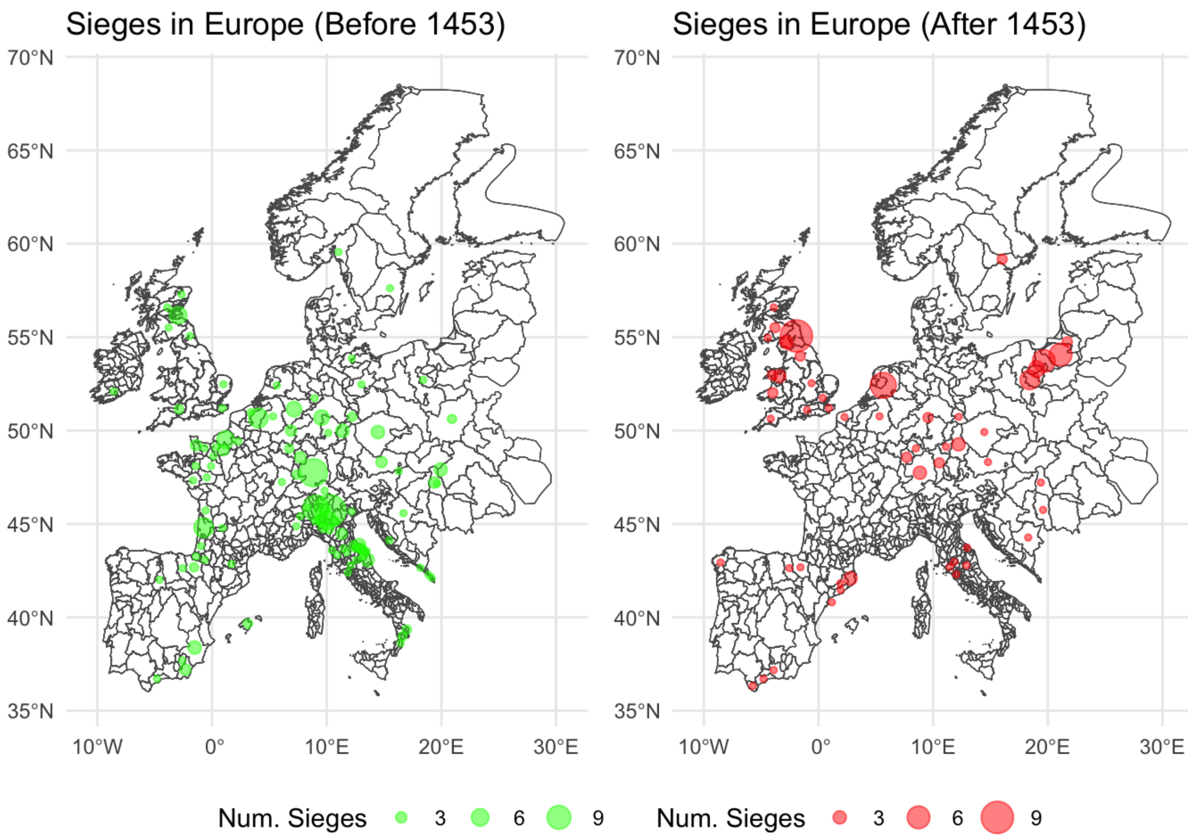

Figure 10: Sieges before and after FoC

ple in 1453. Observe that there is a geographic shift in the concentration of siege warfare from the Mediterranean Basin and Central Europe to Northern Europe. In particular, we see little change in the incidence of siege warfare Great Britain, the Low Countries, and Switzerland, but declines in Italy and Eastern Europe. This visualization supports the statistical results displayed in Table 1.

6.2 Robustness checks

Alternative measures of proximity to Constantinople

It is possible that the results presented in the previous section are sensitive to the choice of the 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. The great circle distance is the length in kilometers of the shortest arc over the Earth's surface linking Constantinople to a diocese. Travel time is an estimate of the number of days of nonstop travel that would have been needed to go from Constantinople to a diocese. This variable is constructed computationally using a procedure similar to the one used for transport costs. Details of variable construction and the empirical results can be found in Appendix C. Both alternative measures yield conclusions similar to those obtained for transport costs. This provides evidence that the post-1453 decline in sieges in locations nearer to Constantinople is unlikely to be driven by choice of proxy variable.

Spatial correlation

Spatial correlation is a potential issue in my study 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. As 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 both of these methods are reported in Appendix D. 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 form

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. To do so, I redo the main analysis using a linear model with a logged outcome. The results are shown in Appendix E. Conclusions regarding the direction of the effect of information exposure on siege warfare and its statistical significance are unchanged under the alternative model.

Outlier polities

Another potential concern is that the statistical findings of the main analysis 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 subset analysis by excluding each 1400 A.D. polity one by one and estimating the main specifications again (Table 1). The results are reported in Appendix F.

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 potential confounders: balancing by European polities against the Ottoman Empire and the end of the Hundred Years' War in October 1453. To assess whether these simultaneous 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, the primary buffer state between the Catholic West and the Islamic East. As leaders of the Ottoman Empire had repeatedly openly professed expansionist aims and a desire to conquer Western Europe, polities located near the Ottoman Empire (and thus Constantinople) may have seen the Fall of Constantinople as heralding a threat to their own security (DeVries, 2017). Under a balance of power logic, the European polities closest to Constantinople may have ceased fighting among each other in order to form a coalition against the Ottoman Empire (Waltz, 1979). Polities in Northern Europe, located further from the Near East, were more insulated from the potential threat of an Ottoman invasion, and therefore less inclined to join a balancing coalition. Consequently, another channel through which proximity to Constantinople could influence siege warfare is through the decline in conflict between the states nearest to the Ottoman Empire. Fewer wars would result in fewer sieges.

Little evidence in the historical record shows that such 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 among the Europeans. The inclination of many leaders was to exploit the attempts to organize a crusade for personal benefit. For instance, negotiations for a crusade 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?[26]

Moreover, Pius identified that reluctance to crusade against the Turks came from the fact that Europeans feared each other more than they did the Turks, lamenting that: "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 construing a plan to take back Constantinople (Schwoebel, 2023). Indeed, the chronicler of the city of Speyer, present at the "Turkish Diets," recounted that the princes "had too many quarrels among themselves on their hands to 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 and one of the most prominent attendees at the diets, 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 specification

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

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

[26] Quoted in Cipolla (1965).

polities to cease fighting among each, the coefficient on $postFall_t \times \text{transportCost}_d$ 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	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
Year × Polity FEs	-	✓	✓	-	✓	✓
Year × Controls	-	-	✓	-	-	✓
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. This is consistent with the contention of historians such as Rogers (2018), who have claimed 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. Thus, once a castle or settlement became aware that an army armed with cannons was approaching, there was a strong incentive to preempt a siege by sending forces to the meet the attackers in the field, where artillery would not offer as great an advantage. The fact that sieges but not wars declined with proximity to Constantinople lends support to the hypothesis that the decline in sieges is due to better understanding of the effectiveness of gunpowder artillery.

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 Europeans. 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.

During the 1430s and 1440s, Charles VII of France commenced an effort to modernize French artillery. He 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 undoubtedly 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). 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 that the English had held for three centuries 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 Rouen) 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.

	Num. sieges (10 year)		Num. sieges (20 year)	
	Gascony	Normandy	Gascony	Normandy
Post-1450 × Transport Cost		0.16		−0.15
		(0.83)		(0.44)
Post-1453 × Transport Cost	−1.13*		−0.69	
	(0.65)		(0.44)	
DV Mean:	0.19	0.20	0.12	0.12
Year × Polity FEs	✓	✓	✓	✓
Year × Controls	✓	✓	✓	✓
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

Why did the Gascony and Normandy campaigns not postively 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 conquest less impressive, even 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

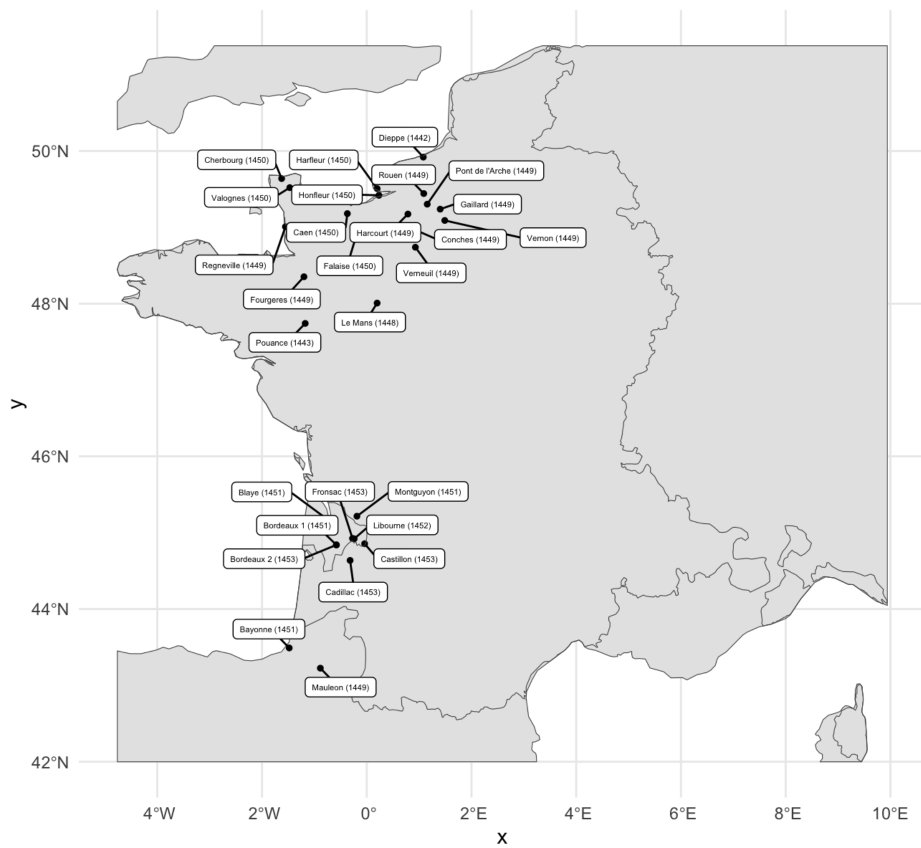

Figure 11: Sieges of the Hundred Years' War, 1443-1453

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 generated

[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

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 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 Roses.

Consequently, the resolution and aftermath of the Hundred Years' War is associated with a decline in sieges in France following 1453, but an increase in sieges in Great Britain after 1453. 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 analysis again on a subset of the dataset which excludes Great Britain and France. The results are shown in Appendix F.1. The results of the analysis on this subset do not change any conclusions about the effect of proximity to Constantinople on siege warfare.

8 Conclusion

In this paper, 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 develop new tactics to use the technology and make assessments of the technology's effect on military capabilities. I also hypothesize that such uncertainty can be mitigated if states both observe the new technology being used in combat, which provides a common reference point to judge the efficacy of the new technology.

I evaluate 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 em-

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).

ployment of gunpowder artillery to great effect against the most sophisticated fortifications in Europe at the time. European observers noticed the tactics the Ottomans used and spread word of them throughout the continent. 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.

To test whether such a relationship holds systematically, I exploit the fact that slow travel times meant news of the Ottomans's employment of artillery came later in locations farther from Constantinople. Using an original dataset of European sieges, I find that locations more proximate to Constantinople, as measured by transportation cost, experience fewer sieges in the period after the city's capture. Consistent with a theory of learning, this effect was strongest immediately after the 1453. I also rule out that changes in the frequency of siege warfare are due to other contemporaneous events, such as balancing by European polities against the Ottoman Empire or the end of the Hundred Years' War.

This paper makes two contributions to the study of international security. First, it offers empirical evidence for a new theory linking technological change to conflict through the mechanism of uncertainty about military capabilities. The implications of this theory differ sharply from the predictions of offense-defense theory, the dominant framework through which the effect of technological change on conflict has been analyzed to date. The findings of the paper suggest that greater attention should be paid to how states perceive or interpret new technologies, rather than focusing on the attributes of the technologies themselves. Second, this paper demonstrates the potential promise that historical political economy approaches have for empirically testing of major general theories in international security. While these approaches have become more common in American politics and comparative politics, they remain underutilized in international security. Looking to the past may yield fruitful causal tests of important theories about the causes and consequences of war that have proven difficult to assess using contemporary data.

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A Data appendix

A.1 List of wars

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 4: List of wars, 1443-1463

A.2 List of sovereign polities

Polity	Num. Dioceses	Num. Sieges
Bishopric of Ösel-Wiek	1	0
Counties of Hainaut and Holland	2	1
County of Mantua	1	0
County of Provence	14	0
County of Savoy	12	2
County of Sovana	2	1
Crown of Aragon	17	8
Crown of Bohemia	8	8
Crown of Castile	28	9
Duchy of Bar	1	0
Duchy of Brabant	1	0
Duchy of Brunswick-Lüneburg	1	0
Duchy of Lorraine	1	0
Duchy of Lower Bavaria in Straubing	1	0
Duchy of Mecklenburg	2	1
Duchy of Milan	27	46
Duchy of Pomerania of Stettin	1	0
Duchy of Upper Bavaria-Munich	2	1
Earldom of Desmond	3	1
Giudicato of Arborea	18	0
Habsburg Dominions	14	12
House of Este	5	1
Kalmar Union between the Kingdoms of Denmark, Sweden and Norway	20	2
Kingdom of Bosnia	5	1
Kingdom of Bréifne	3	0
Kingdom of England	38	38
Kingdom of France	110	26
Kingdom of Granada	5	6
Kingdom of Hungary	23	12
Kingdom of Leinster	1	0
Kingdom of Naples	141	5
Kingdom of Navarre	2	3
Kingdom of Portugal	10	0
Kingdom of Scotland	13	9
Kingdom of Sicily	11	0
Kingdom of Thomond	4	0
Kingdom of Tír Conaill	1	0
Kingdom of Tír Eógain	3	0
Landgraviate of Thuringia and Margravate of Meissen	1	3
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 Padua	1	0
Lordship of Zeta and The Sea	5	2
Lordships of the House of Burgundy	1	7
Mac Carthy Mor Lordship	1	0
Margravate of Montferrat	2	0
Margravate of Savona	1	0
Monastic State of the Teutonic Knights	9	23
Republic of Florence	4	3
Republic of Venice	12	8
Small States of the Holy Roman Empire	26	39
State of the Church	63	30
United Kingdom of Poland and Lithuania	12	1

Table 5: 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 6: 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 7: Descriptive statistics

A.5 Diffusion of initial news about Fall of Constantinople

This section describes construction of Figure 1, 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.

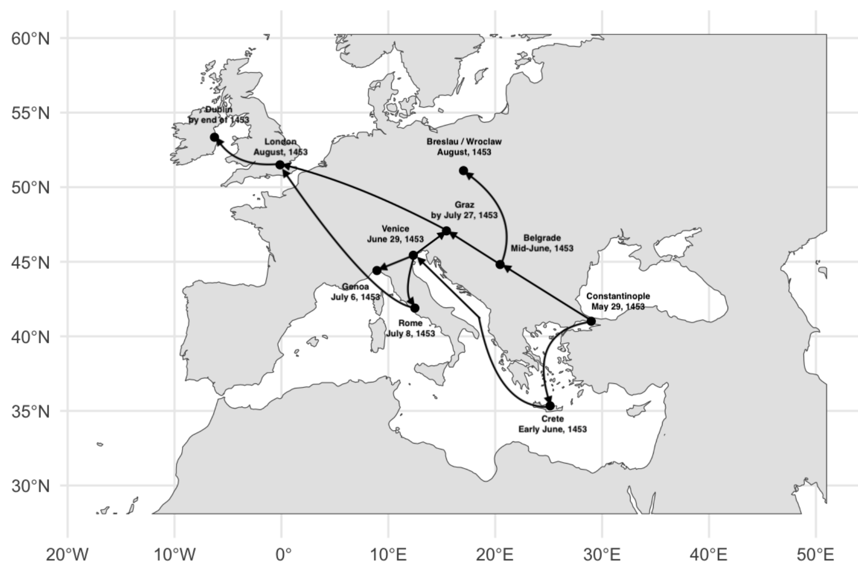

Figure 1 maps the dates that news of Constantinople's fall first reached selected major cities and charts the path that the news took from Constantinople. Dates were recovered by consulting primary sources, such as letters and chronicles. The first ships escaping Constantinople reached Crete, then a 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, 1976). 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 (2002).

A.6 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 12 and 13 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.

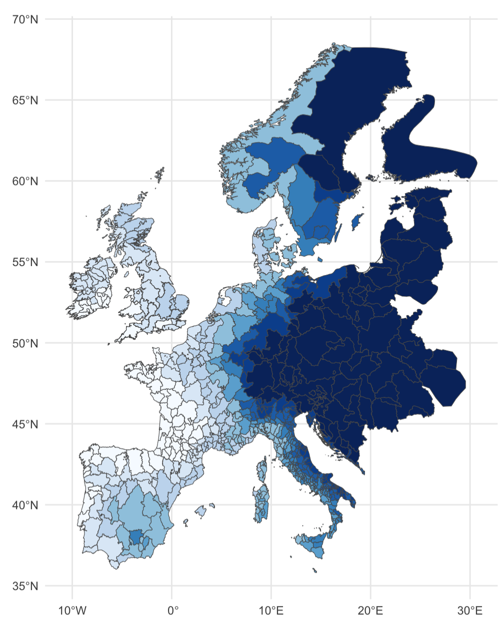

Figure 12: Transport cost to Gascony

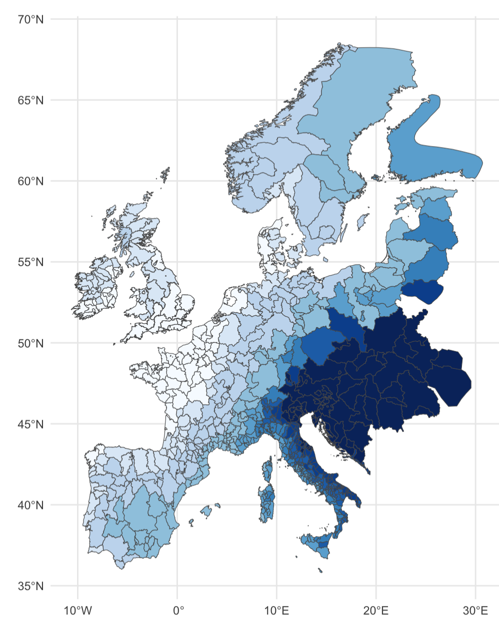

Figure 13: Transport cost to Normandy

Table 8 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 8: Correlation between transport costs (Gascony and Normandy)

A.7 Maps

This section contains maps depicting the distribution of relevant spatial variables.

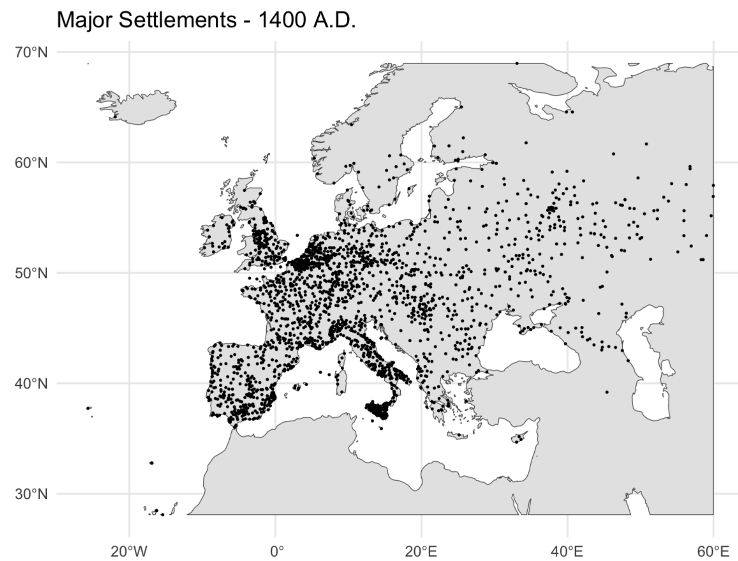

Figure 14: Settlements with 1,000 or more inhabitants, 1400 A.D.

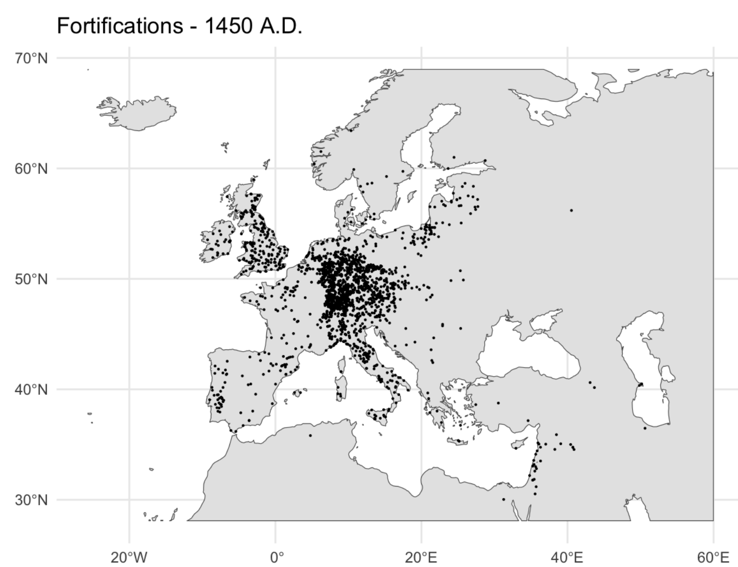

Figure 15: Non-settlement fortifications, 1450 A.D.

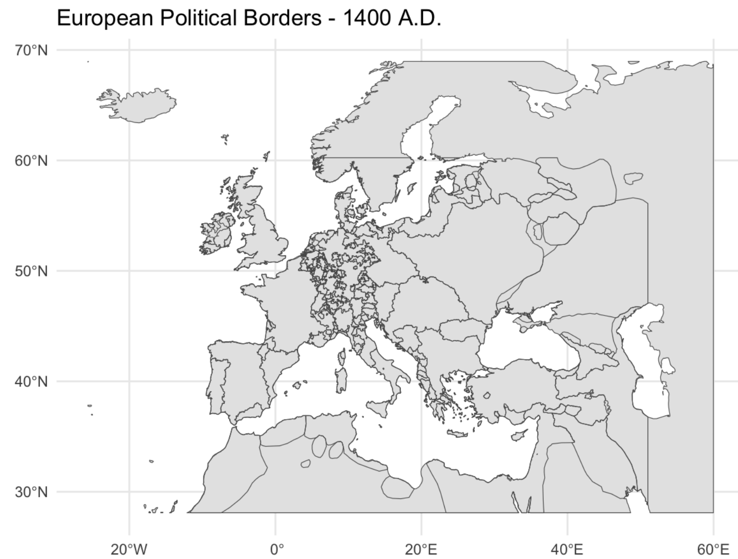

Figure 16: Political boundaries, 1400 A.D.

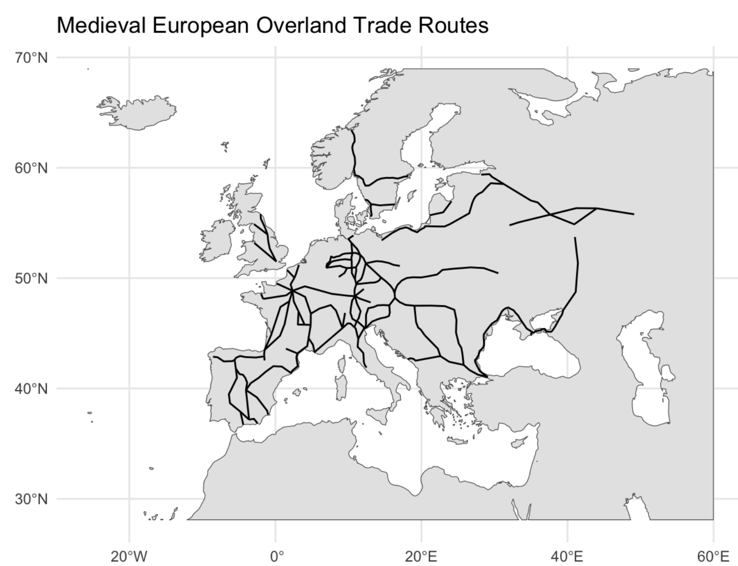

Figure 17: Medieval overland trade routes, from Shepherd (1911)

B Event study

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 9.

	Num. sieges
	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 9: Event study of exposure to Constantinople on sieges (transport costs)

C Alternative measures of treatment intensity

In this section, I conduct the main empirical analysis of the paper using two alternative methods to operationalize exposure to information about the Fall of Constantinople: great circle distance and total travel time from Constantinople.

C.1 Great circle distance

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 10. 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)
DV Mean:	0.19	0.19	0.19	0.12	0.12	0.12
Year × Polity FEs	-	✓	✓	-	✓	✓
Year × Controls	-	-	✓	-	-	✓
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 10: Effect of exposure to Constantinople on sieges (distance)

C.2 Travel time

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 analysis

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 11. 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)
DV Mean:	0.19	0.19	0.19	0.12	0.12	0.12
Year × Polity FEs	-	✓	✓	-	✓	✓
Year × Controls	-	-	✓	-	-	✓
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 11: Effect of exposure to Constantinople on sieges (travel time)

C.3 Comparison of different methods

Table 12 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 12: Correlation between distance measures

Figures 18 through 20 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.

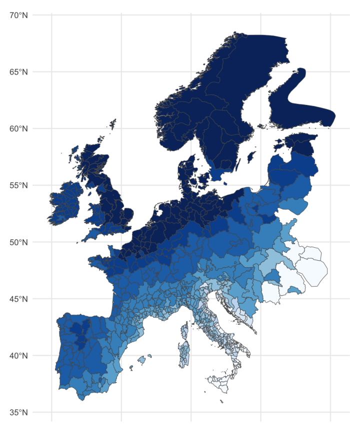

Figure 18: Transport cost

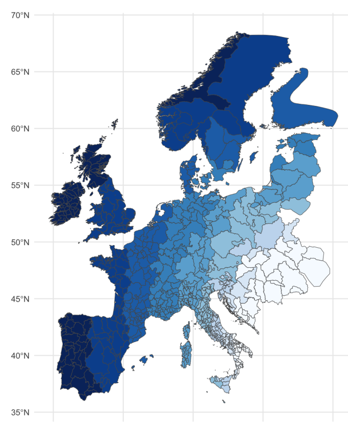

Figure 19: Distance

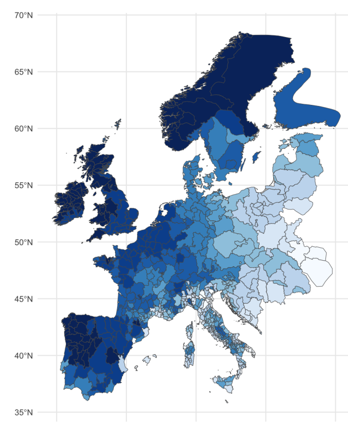

Figure 20: Travel Time

D Adjustments for spatial correlation

Table 13 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
Year × Polity FEs	✓	✓
Year × Controls	✓	✓
N	803	2751

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

Table 13: Standard errors adjusted for spatial correlation

E Alternative functional form

E.1 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.

The results are shown in Table 14. 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)
DV Mean:	0.11	0.11	0.11	0.07	0.07	0.07
Year $\times$ Polity FEs	-	✓	✓	-	✓	✓
Year $\times$ Controls	-	-	✓	-	-	✓
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 14: Effect of exposure to Constantinople on sieges (OLS)

F Subset analysis

F.1 Excluding individual polities

I exclude each individual polity from the data and estimate Equation 1 again with the modified dataset for the 10-year window. The results are displayed below in Figure 21. 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.

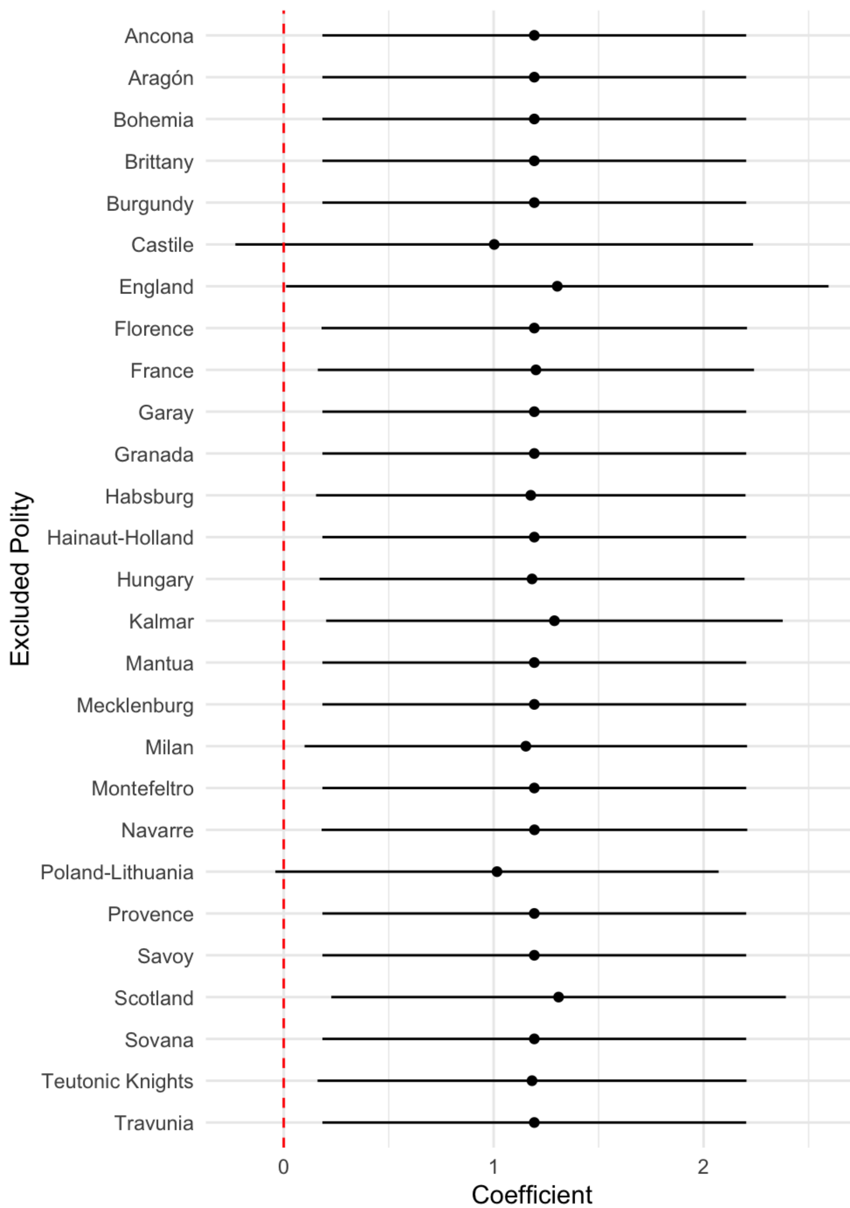

Figure 21: Excluding polities (10 year window)

F.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 15. The coefficients and standard errors on Post-1453 $\times$ 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 $\times$ 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 $\times$ Transport Cost	0.41^{**}	1.56^{***}	1.53^{**}	0.27^{**}	0.37	0.45
	(0.18)	(0.49)	(0.77)	(0.11)	(0.37)	(0.40)
DV Mean:	0.20	0.20	0.20	0.12	0.12	0.12
Year $\times$ Polity FEs	-	✓	✓	-	✓	✓
Year $\times$ Controls	-	-	✓	-	-	✓
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 15: Effect of exposure to Constantinople on sieges (no Britain or France)