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Abstract

This paper presents a unique historical experiment to explore the dynamics of institutional change in the Middle Ages. We have assembled a novel dataset, where information on political institutions for northern-central Italian cities between 1000 and 1300 is matched with detailed information on the earthquakes that occurred in the area and period of interest. Exploiting the panel structure of the data, we document that the occurrence of an earthquake retarded institutional transition from autocratic regimes to self-government (the commune) in cities where the political and the religious leaders were one and the same person (Episcopal see cities), but not in cities where political and religious powers were distinct (non-Episcopal see cities). Such differential effect holds both for destructive seismic episodes and for events that were felt by the population but did not cause any material damage to persons or objects. Ancillary results show that seismic events provoked a positive and statistically significant differential effect on the construction and further ornamentation of religious buildings between Episcopal and non-Episcopal see cities. Our findings are consistent with the idea that earthquakes, interpreted in the Middle Ages as manifestation of the will and outrage of God, represented a shock to people's religious beliefs and, as a consequence, enhanced the ability of political-religious leaders to restore social order after a crisis relative to the emerging communal institutions. This interpretation is supported by historical evidence.

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I. INTRODUCTION

Understanding the determinants of institutional change is one of the most important issues in the political economy literature. In particular, empirical investigation of the factors leading to transitions from narrow to broader-based institutions, in both the contemporary world and the past, has recently proved of much interest to economists and social scientists alike (Lipset, 1959; Barro, 1999; Acemoglu and Robinson, 2006). One of the main challenges to this literature has been determining how to single out the mechanisms operating in such complicated process and to identify the causality. In this paper, we contribute by studying how the occurrence of natural catastrophes may impact on the stability of political regimes. We do so by considering an instructive historical case study: the emergence of communes in northern-central Italy during the Middle Ages.

Exploiting a panel dataset that covers 121 cities over the 1000-1300 period, we find that the occurrence of an earthquake reduces the probability of transition from feudal to communal institutions in cities where political and religious powers were in the hands of the same person, but not in cities where political and religious leaders were distinct. This worked similarly for destructive earthquakes and for events that did not provoke any physical damage to people or objects. Our findings are consistent with the view that earthquakes, interpreted in the Middle Ages as manifestations of God's wrath against men, reinforced the authority of political leaders who at the same time were religious leaders in the *status quo* regime.

In the period between the eleventh and thirteenth centuries, Italian cities underwent profound changes in their political and institutional configurations. This is known as the 'communal movement' whereby the power of the incumbent feudal leaders was challenged, and often replaced, by the bourgeois elite. In the feudal regime, the political leaders were either bishops, in the Episcopal see cities, or secular lords (e.g. counts or marquises), in the non-Episcopal see cities. In the former group, the bishops were simultaneously political leaders, monopolists in the provision of religious services, and the supreme religious authorities. By contrast, in the non-Episcopal cities, religious power was separated from political power. Both bishops and secular leaders ruled free of checks and balances. In the communal system, political power was exercised by representatives of all the citizens and checked by constitutional limitations and representative assemblies. Hence, the transition from the feudal regime to the commune represented a radical change toward broader-based political institutions.[1]

Our analysis is conducted on a unique large panel dataset. Starting from the sample of the largest cities in northern-central Italy for which reliable historical documents on the communal experience are available, we collect information on their political regimes, on whether or not they were seats of bishops in 1000, and on the year in which the change (if any) from feudal regime to communal institutions occurred. These data are matched with detailed information on the earthquakes (epicenter, locality, time, intensity) that occurred in northern-central Italy between 1000 and 1300 (see Stucchi et al., 2007). To impute possible missing seismic episodes due to inaccurate historical sources, we adopt three different augmenting procedures by exploiting the geographical distribution of the cities hit by the earthquakes and the location of the epicenter. In addition, we are able to distinguish between earthquakes for which physical damage to people, objects, and the earth's surface were reported and earthquakes that did not result in material damage but were still felt by the population.

Exploiting the panel structure of the dataset and the likely random nature in the timing of the seismic events, we find that, unlike non-Episcopal see cities, in cities that were seats of a bishop, the occurrence of an earthquake retarded the transition to communal institutions. This negative differential effect is statistically significant and survives several robustness checks. Moreover, the effect of the seismic event on Episcopal see cities is confined to the short period: within ten years after the tremor, it vanishes. Under the assumption that possible differential factors affecting the probability of becoming a commune in the two groups of cities followed a common trend, our finding points up the role played by the bishop in the Episcopal see cities and by the consequent overlap between religious and political authorities. This explanation is supported by the fact that our results hold for both destructive and non-destructive earthquakes. This suggests that the effect of the seismic event on the probability of transition does not depend on the material damage, increase in poverty, deaths, or the (possibly) differential material impact that those events had on the social classes involved in the political institutional change.

[1] It has been amply documented that cities adopting communal institutions reached higher levels of urbanization and rates of growth than those governed by despotic leaders (Coleman, 1999; Tabacco, 1989; Menant, 2005; DeLong and Shleifer, 1993). Recent work also suggests that communal institutions had a long term impact on trust and social capital (Guiso, Sapienza, and Zingales, 2016).

The interpretation that an earthquake was a shock to religious beliefs and, through this channel, reinforced the *status quo* regime only where the political leader was also a religious authority is also supported by the ancillary evidence that we offer in the last part of the paper. Drawing on the dataset of the National Office for Ecclesiastical Cultural Assets and Information Services of the Association of Italian Catholic Bishops (CEI - Conferenza Episcopale Italiana), we collect an original dataset including the dates of construction and further ornamentation of churches and cathedrals by city in northern-central Italy in our period of interest. Exploiting this information and relying on the same diff-in-diff design as used before, we obtain that seismic events provoked a positive and statistically significant differential effect on the construction and ornamentation of religious buildings between Episcopal and non-Episcopal see cities. Such additional evidence supports the idea that the bishops in the first group of cities were able to take advantage of the occurrence of the frightening events. Our findings can be read in the following framework.

The feudal regime and the commune can be seen as two alternative institutional configurations with which to ensure social order (e.g. to minimize the welfare losses due to the expropriation of private property from other citizens; see Djankov et al., 2003), the former relying on the obedience of the citizens to the authoritarian leader, the latter on their participation in public decisions. Before the eleventh century, the feudal society of the collapsing Carolingian Empire was characterized by scant civic capital and substantial coordination problems in social and economic relations: in this context, the feudal leader was relatively better able than the civic associations to ensure social order (Cardini and Montesano, 2006). From the eleventh century onwards, the revival of commerce, the flourishing of economic activity, and the subsequent increase in per-capita income produced incentives for citizens to participate in the management of public affairs, to regulate economic transactions, and to secure property rights (Greif, Milgrom, and Weingast, 1994). The development of devices with which to accommodate the consequent need for enforceable agreements among individuals, such as written contracts, guilds, private associations, and legal rules, enhanced the effectiveness of civic associations in city government and triggered, in some cases, the transition from feudal to communal institutions. This process came about in both Episcopal see cities, which in the *status quo* were ruled by bishops, and non-Episcopal ones ruled by secular lords.

Yet one important feature distinguished the secular leader from the bishop: the latter was, besides a political ruler, the head of the local church and the intermediary between the flock of Christians and God (Benvenuti, 2010). Hence, his authority was reinforced by the citizens' obedience to norms of conduct and their adherence to religious principles. In the Middle Ages, in Italy as well as throughout Western Europe, earthquakes were seen as mysterious and unforeseeable events that could only be explained as manifestations of God's wrath. This conviction was widespread, and it was maintained at least until the Enlightenment (Guidoboni and Poirier, 2004; Nur and Borgess, 2008; Schenk, 2010). As amply documented in the paper, after an earthquake, peoples' common reaction was panic, consternation, and an immediate urge for reconciliation with God. This resulted in a sudden increase in attendance at (and thus a greater demand for) religious services, such as collective prayers, processions, and fasts. Consistently with the idea that the earth's tremor represented a positive shock to religiosity, seismic events were likely to reinforce the religious leaders' authority, to increase (as a consequence) their ability to ensure social order and, thus, to impede transition to communal institutions in Episcopal cities. This effect was limited in time, however. Because the process of institutional change induced by improvements in the levels of civic capital, education, and juridical knowledge could not be interrupted indefinitely by an increase in religious beliefs, in the absence of a further shock, the communal movement eventually resumed.

Our study relates to two main strands of the economic literature. The first investigates the role of religion in affecting political (Barro, 1999; Murphy and Shleifer, 2004) and economic (Barro and McCleary, 2003; 2005; McCleary and Barro, 2006; Becker and Woessman 2009) outcomes.[2] We contribute to this literature by exploring how religion and the correspondence between religious and political leaders account for the probability of institutional change and the stability of political regimes in the medieval period.

The second strand of analysis relevant to our work studies the effects of economic shocks on political support (Healy and Malhotra, 2009; Achen and Bartels, 2013), institutional change (Brückner and Ciccone, 2011; Chaney, 2013), and organization into religious communities (Ager and Ciccone, 2015).[3] The historical experiment described in this paper

[2] Barro (1999) studies the relation between a country's primary religious affiliation and its electoral rights indicator, interpreted as a degree of democracy. Murphy and Shleifer (2004) highlight the role of core issues (such as religious beliefs) in building social networks and in creating popular support for political leaders. Our results are also in line with those of recent research showing that natural disasters increase people's religiosity and church attendance (Bentzen, 2015; Penick, 1981). On the economics of religion see, among others, Iannaccone (1991) and Ekelund and Tollison (2011).

[3] Healy and Malhotra (2009) show that American voters reward incumbent governments for effective disaster relief spending. Achen and Bartels (2013) find that voters tend to punish incumbent governments for natural disasters. Brückner and Ciccone (2011) offer evidence that negative rainfall shocks are followed by a significant improvement in democratic institutions in contemporary Sub-Saharan African countries. Using historical data, Chaney (2013) shows that the probability of change in Egypt's most powerful religious authority decreased

provides, to the best of our knowledge, the first example of how the occurrence of natural catastrophes (through their impact on religious beliefs) may interfere with political and institutional transitions.

The paper proceeds as follows. In Section II we outline the historical background. Section III describes the data, while Section IV presents the empirical strategy, the results, and a number of robustness checks. In Section V we report empirical evidence on the relation between seismic events and religious buildings. In Section VI we discuss alternative explanations for our results, finding no compelling and consistent (either historical or empirical) evidence supporting them, and we draw concluding remarks.

II. HISTORICAL BACKGROUND

II.A. The Status Quo Feudal Regime

At the beginning of the eleventh century, the northern-central Italian cities were formally part of the Holy Roman-German Empire. They were ruled by either secular lords (non-Episcopal see cities) or bishops (Episcopal see cities). While until the tenth century the secular rulers (e.g. counts or marquises) were directly appointed by the emperor and governed in his name, in the subsequent period they became increasingly autonomous due to the decline in the political influence of the German emperors' central authority on the fringes of the empire. As a consequence, their power over the city, and the territory surrounding the city, came to encompass the social, political, judicial, and economic spheres. In addition, the secular feudal lords obtained the establishment of a system of hereditary rule over the territory allocated (Bloch, 1961; Ascheri, 2009).

Bishops in Episcopal see cities performed the same political role as secular feudal lords did in non-Episcopal see cities. They also acted as officials of the Empire, and the emperor granted them the same rights and power as wielded by secular rulers. Formally, the city bishops were chosen by the local churches, but the elections were actually influenced by the emperors. Once elected, they were appointed to local political and judicial offices and governed the city autonomously (Pellegrini, 2009). While bishops started to hold political power at least since the late Roman Empire (since the Council of Sardica, fourth century AD), their authority strengthened during the subsequent centuries when, in the absence of a strong imperial rule, bishops were the only recognized local political officers in the cities (Cardini

during deviant Nile floods. Finally, Ager and Ciccone (2015), considering the nineteenth century United States, document that counties that faced a greater rainfall risk had a greater share of the population organized into religious communities.

and Montesano, 2006). The bishops also held religious power and were the main local authorities in the Catholic Church. They managed – and benefitted for life from – the property of the cathedral (the church that was formally the bishop's see), and they could also benefit from the exercise of local fiscal power and the collection of rents on land and other resources (Ascheri, 2009; Tabacco, 1987). Unlike secular feudal lords, the bishops did not have the right to transfer their temporal power to their heirs. However, they enjoyed life appointments.

Hence, the bishop was at the same time the head of the local church and the supreme local political authority (Cardini and Montesano, 2006). This fact merits particular emphasis since (in northern-central Italy as in the rest of western Europe) the Catholic Church was, in its turn, the monopolist of religion. There was no competition with other religious organizations and, in Episcopal see cities, the bishop was the head of the hierarchy and controlled the provision of all religious services. In cities with no Episcopal see, political power and religious services were more separated: the former was held by secular feudal lords; the latter were provided by several local representatives of the Catholic Church (e.g. parish priests or monks).

II.B. The Emergence of the Commune

During the eleventh century, the northern and central Italian cities experienced an increase in their urbanization rates and economic importance. An urban elite of merchants, entrepreneurs, and lawyers emerged from this background and became economically prominent. Members of this elite soon started to form groups of individuals who agreed, with a *patto giurato* ('sworn pact'), to provide mutual help and cooperate on issues of common interest (Guiso, Sapienza, and Zingales, 2016). Gradually, more stable institutions emerged, and the citizens signatory to the pact began to be involved in the city's government, from which they had been previously excluded. In this period, citizens learnt to regulate their economic and social relations and to settle their disputes in a decentralized manner, thus reducing the need for a central authority and support to authoritarian leaders.

The shift from the rule of secular feudal lords or bishops to the commune brought a dramatic improvement in terms of citizen participation in the political sphere and the emergence of constitutional checks and balances. The representatives of the commune exercised their power in the name of all the citizens. In particular, the city government was based on a general council of citizens and on elected *consules,* who held executive power. The general council's decisions were valid only if taken in the presence of at least a given minimum number of citizens, and resolutions were always recorded (Senatore, 2008). The *consules* exercised executive power within the limits of a constitution: the *statutum*. With the commune, personal freedoms were accorded legal protection against abuses by government officials, whose actions were subject to the control of *ad hoc* institutions, including courts of law to which citizens could appeal (Galizia, 1951). Rules, laws, and formal decisions were always made in the name of the citizens (males of majority age owning a house had political rights; women, servants, Jews, and Muslims were excluded). Overall, the commune proved to have some degree of separation of powers, and checks and balances operated similarly as in contemporary democracies.[4]

II.C. Natural Disasters and Religiosity in the Middle Ages

In the Middle Ages, the belief that God was the ultimate cause of natural events was widespread and rooted in the religious doctrine (Le Goff, 1982). Important thinkers among the early fathers of the Church supported this view. For example, Philastrius, bishop of Brescia in the fourth century, wrote: "*It is a heresy to believe that an earthquake results, not from the will and outrage of God, but from the nature of the elements themselves, thus denying the Holy Scriptures*" (Guidoboni and Poirer, 2004: 130). Isidore of Séville (1960), in his work "*De rerum natura*", maintained that God's judgment of sinners (*iudicium peccatores*) was at the origin of earthquakes. Similarly, Thomas Aquinas, whose work represented the synthesis of medieval Christian philosophy, recognized God as the ultimate cause of seismic events (Guidoboni and Poirier, 2004). In 1280, Saba Malaspina, a priest serving in Pope Martin IV's curia, described earthquakes as signs of God's wrath (Schenk, 2010). Also in the *corpus iuris civilis*, the collection of legal rules written under the Roman emperor Justinian, earthquakes were considered as resulting from sins committed by men against God, such as blasphemy (Schoell, 1895).

The Catholic liturgy prescribed specific rituals for protection from natural catastrophes. For instance, during the rogation days – the three days of prayer preceding Ascension Day – people took part in processions and fasts and sang litanies beseeching God to protect them from plagues, natural disasters, and earthquakes. Rogation days were introduced in 463 AD by Mamertus (bishop of Vienne in France) immediately after an earthquake, and they were

[4] It is worth noting that when an Episcopal see city experienced a shift from the feudal to the communal regime, the bishop lost his political power but maintained his role as religious leader and mediator between God and the people, his religious authority being granted by the Catholic Church hierarchy (Code of Canon Law, Chapter 2, Art.1 Can. 375).

then extended to the entire Catholic Church by the Council of Orleans in 511 AD (Geary, 2010).

The beliefs that earthquakes were caused by God is reflected in the narrative that contemporaries gave of seismic events. For instance, in his report on the history of the city of Milan, Landolfo the Younger (a chronicler who lived at the juncture of the eleventh and the twelfth centuries) described the 1117 earthquake – which, as we shall see, was a crucial episode in the Middle Ages – as an apocalyptic event (Castiglioni, 1934). Landolfo wrote that the earthquake was a divine ordeal: people saw drops of blood falling from heaven, a number of miracles and horrific births happened, and thunders could be heard underground and in the water (see also Figliuolo, 2010). People were terrified and felt bereft. This description resembles the representation, given by Jesus, of the destruction of Jerusalem reported in the Gospel (see, for instance, Matthew, Ch. 24). Landolfo also reported that, after the earthquake, the bishop and the clergy of Milan organized a ritual in which the whole city participated. For the ceremonials, the archbishop and the representatives of the city set up two stages, one for the bishop and the churchmen and one for the cities' representatives. Citizens crowded around them to attend the burial of vices and the revival of virtues.

In the medieval iconography, earthquakes were associated with the Apocalypse (Guidoboni and Boschi, 1989) and, in the coeval descriptions, their occurrence was often accompanied by other extraordinary natural events. For instance, the bishop of Cremona, Sicardo, reports that the 1222 earthquake was preceded by a comet (Sicardus Cremonensis, 1903); the cleric Pietro Diacono wrote that after the 1117 earthquake a new-born child foretold future prodigious happenings (Hoffman, 1980).

Finally, there is evidence in the coeval chronicles that the occurrence of seismic events was used by the Church to punish wicked people and to get rid of its enemies. An exemplary case is provided by the history of Brescia after the 1222 earthquake. The cleric Cesar of Heistenbach associated this seismic episode with the dead of heretics (Schenk, 2010). Indeed, Pope Honorius III exploited the event to justify his violent reaction against these people, that he blamed for causing the earthquake and whose houses he ordered to be destroyed (Guidoboni and Boschi, 1989). The belief that earthquakes were caused by God to punish evil behavior was not limited to Italy but was widespread in Europe. For example, a chronicle describing the life of Otto, bishop of Bamberg in Germany, reports that in 1117 an earthquake was provoked by people's sins and that the Earth was fighting for God against the 'unwise' (Jaffé, 1869).

The belief that seismic events were caused by God persisted in Europe at least until the Enlightenment. A turning point came with the earthquake that almost entirely destroyed Lisbon in 1755. Although this event was still seen by some as a manifestation of divine judgment, most thinkers started to reject this idea (Dynes, 2000).[5]

II.D. Peoples' Reaction After an Earthquake

In the Middle Ages, the common reaction after an earthquake was panic and consternation. Importantly, non-destructive earthquakes also frightened people. For example, the chronicles report that in 1279 an earthquake with its epicenter in the Umbria-Marche region was only felt to some extent in Rome. When the earthquake shook the earth, the Pope was at dinner. His table, together with the entire palace, moved "miraculously", and all the people believed that this heralded God's judgment (Valensise and Guidoboni, 2000).

After the immediate panic had subsided, there was an urge for reconciliation and an increase in demand for religious services and, in particular, processions. Many medieval chronicles refer to a procession as the very first public act in a city after a seismic event, even after episodes that did not cause any physical damage to people or objects (Riera Melis, 2010). Their purpose was to purify the city land, and they were conceived as the first step in the restoration of public order. The structure of these rituals, in which all the citizens participated, was designed to demonstrate that the authority of the religious leaders was still strong (Guidoboni and Poirier, 2004). For example, in 1222, a violent seismic event hit the city of Modena. The contemporary chronicles reported that the day after the earthquake the bishop led all the clergy and all the citizens of Modena in a procession to purify the city (Dondi, 1896). The same happened in 1293 in Pistoia, where the coeval chronicles reported that after an earthquake, which repeatedly stroke the city for eight days, all the citizens participated in a number of processions (Adrasto Barbi, 1927).

Another religious practice documented by historiography as often taking place after earthquakes and similarly dreadful natural events is the consecration (*dedicatio*). This consists in the religious ceremony with which a religious building or object is dedicated to God's worship. The ritual has evolved across the centuries and has become one of the most magnificent and solemn ecclesiastical rituals. Given its importance, since the end of the fifth century, the consecration has been conducted by the bishop and has involved a series of

[5] The belief that God was the ultimate cause of natural events and the associated rituals prescribed by the Catholic religion can be interpreted in a framework in which superstition is consistent with rational learning (Fudenberg and Levine, 2006).

religious practices, which last for some days and in which the flock of believers takes part. In the Middle Ages, a church dedication after an earthquake was an important occasion for the people, scared by the manifestation of divine wrath, to please God by offering a religious building or part of it (e.g. an altar) to his worship. At the same time, it was an opportunity for the bishop to demonstrate his power and strengthen his leadership. In Verona, for instance, the church of the Santissima Trinità was dedicated to God's worship on 12 January 1117, just nine days after the occurrence of the seismic event, which was also felt in that city.

After a natural disaster, the bishops had a crucial role in the process of reconciliation with God, not only because they were the monopolists in the provision of religious services in the Episcopal see cities, but also because there was a widespread belief that, given their role as intermediaries between God and his 'flock', the bishops could actually influence natural events. An example is provided by Savino, bishop of Piacenza, who ordered (through his official, a notary) the River Po to stop flooding before it invaded the bishop's lands (Benvenuti, 2010).

III. Data Description

III.A. Sample

Our analysis covers the largest possible number of northern-central Italian cities[6] for which we have been able to verify that they already existed at the beginning of the eleventh century and to collect reliable historical sources documenting their institutional (either communal or feudal) form during the 1000-1300 period.[7] The sample consists of two groups of cities, Episcopal and non-Episcopal see cities, and it is obtained as follows. As regards the first group, we start from the list of the Italian dioceses (Episcopal sees) existing today in northern-central Italy as reported in Conferenza Episcopale Italiana (2015) and we examine their history by scrutinizing various sources (e.g. encyclopedic references or the websites of the dioceses). Hence, we verify, first, which cities already existed in 1000 and, second, whether or not the chronology of the bishops of each single city reports a bishop's name in the year 1000. We include in our first group of cities only those that passed the two above filters.

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[6] Our definition of northern-central Italy corresponds to the area of Italy that belonged to the Holy-Roman German Empire in our period of interest, thus excluding regions that were part of the Norman Kingdom (the southern Italy) or that belonged to other governmental entities (i.e. the city of Aosta that belonged to the Duchy of Burgundy).

[7] This is the period that, according to the historians (e.g. Cardini and Montesano, 2006; Wickham, 1981), is conventionally identified as relevant for the 'communal movement'.

However, it is possible that some cities that were autonomous Episcopal sees between 1000 and 1300 lost their status (maybe because they were merged with other dioceses) in subsequent periods, so that they are not reported in the current list of Episcopal sees provided by the Conferenza Episcopale Italiana (2015). To minimize the probability of mistakenly excluding these cities from our sample, we also implement the following procedure. Like Guiso, Sapienza, and Zingales (2016), we record the cities on the map '*Italia Altomedioevale: Sedi Vescovili*' (Treccani, 2007), which reports the map of Episcopal see cities in the late Middle Ages. Whenever we find a city that is not reported in our previous list, we check in the chronology of bishops whether that city was the see of a bishop in 1000. If so we include it in our sample.

As for the non-Episcopal see cities, we consider the union of the sample of northern-central Italian cities offered by Malanima (2005) and that provided by Bairoch, Batau, and Chevre (1998). We then carefully study the history of each city in this group by examining a number of sources (e.g., again, history books, journal papers, encyclopedia entries, or the website of the city). We include in our sample only the cities for which we find evidence that they already existed in 1000. This two-step procedure yields the initial sample of cities from which we start the analysis.

III.B. Transition to Commune

For each city in the sample that we select as described above, we collect information on whether or not it became a commune during the three centuries considered and (if so) the year in which the institutional transition occurred. The date of transition is set as the first year in which the historical sources offer evidence of the presence of the *consules*, the *statutum*, an official document (e.g. a notarial act) signed by the commune's representatives, or facts identifying the beginning of the communal experience (e.g. imperial charters granting self-government to the city or the description of episodes in which the citizens ejected the feudal leader from the city and established alternative forms of self-government). Since these dates are not systematically available from uniform data sources, we adopt the following criterion. For each city, we consult history books, journal articles, encyclopedia references, and other sources in order to collect information on the city's communal experience. Whenever we find discordance between two sources, we track down a third source and opt for a date recorded in at least two of the three sources. If this criterion is not satisfied, we drop the city. This procedure determines the effective number of cities in our sample: 121, 70 Episcopal see and

TABLE I. SAMPLE AND TRANSITION DATES

City	*Year*	*Episcopal*	*City*	*Year*	*Episcopal*	*City*	*Year*	*Episcopal*
Acqui Terme	1135	Yes	Fondi	-	Yes	Pistoia	1105	Yes
Alassio	-	No	Forlì	1182	Yes	Prato	1107	No
Alba	1169	Yes	Fossombrone	-	Yes	Ravenna	1109	Yes
Albenga	1098	Yes	Galliate	-	No	Reggio Nell'Emilia	1136	Yes
Aquileia	-	Yes	Garlasco	-	No	Rieti	1171	Yes
Arezzo	1098	Yes	Genova	1080	Yes	Rovereto	-	No
Ascoli Piceno	1183	Yes	Gorizia	-	No	Rovigo	-	No
Asiago	-	No	Grado	-	Yes	Saluzzo	-	No
Asti	1095	Yes	Grosseto	1204	No	San Colombano Al Lambro	-	No
Bergamo	1098	Yes	Iesolo	-	Yes	San Gimignano	1199	No
Biella	1245	No	Imola	1084	Yes	San Severino Marche	1170	No
Bologna	1116	Yes	Imperia	-	No	Sant'Angelo Lodigiano	-	No
Bolzano	-	No	Ivrea	1171	Yes	Sarsina	-	Yes
Brescia	1127	Yes	La Spezia	-	No	Savona	1191	Yes
Bressanone	-	Yes	Livorno	-	No	Senigallia	-	Yes
Camerino	-	Yes	Lodi	1142	Yes	Siena	1147	Yes
Caravaggio	1182	No	Lucca	1081	Yes	Sora	-	Yes
Carpi	-	No	Lugo	-	No	Soresina	-	No
Castiglione Delle Stiviere	-	No	Macerata	1138	No	Stradella	-	No
Cento	-	No	Mantova	1115	Yes	Subiaco	1193	No
Cesena	1176	Yes	Massa	-	No	Sutri	-	Yes
Chiavari	1243	No	Milano	1097	Yes	Tolentino	1166	No
Chieri	1150	No	Modena	1135	Yes	Tortona	1122	Yes
Chioggia	-	No	Monselice	-	No	Treia	1157	No
Chivasso	-	No	Montefiascone	-	No	Trento	-	Yes
Civitavecchia	-	Yes	Narni	-	Yes	Treviglio	-	No
Codogno	1232	No	Nepi	1131	Yes	Treviso	1150	Yes
Comacchio	-	Yes	Novara	1116	Yes	Trieste	1295	Yes
Como	1109	Yes	Novi Di Modena	-	No	Valenza	1204	No
Corridonia	-	No	Novi Ligure	1135	No	Ventimiglia	1149	Yes
Crema	1185	No	Numana	-	Yes	Vercelli	1141	Yes
Cremona	1098	Yes	Ormea	-	No	Veroli	-	Yes
Empoli	-	No	Orvieto	1157	Yes	Verona	1136	Yes
Fabriano	1234	No	Padova	1138	Yes	Viadana	-	No
Faenza	1141	Yes	Parma	1149	Yes	Vicenza	1147	Yes
Fano	1114	Yes	Pavia	1106	Yes	Viterbo	1099	No
Feltre	-	Yes	Perugia	1139	Yes	Vittorio Veneto	-	Yes
Fermo	1199	Yes	Pesaro	1182	Yes	Voghera	1136	No
Ferrara	1105	Yes	Piacenza	1126	Yes	Volterra	1170	Yes
Fiesole	-	Yes	Pinerolo	1220	No			
Firenze	1125	Yes	Pisa	1081	Yes			

Notes. The list shows all the cities included in our sample. *Year* is the year when the first evidence of the commune, if any, was found in historical sources. '-' denotes the city never becoming a commune within the sample period (1000-1300). *Episcopal* denotes whether the city was the seat of a bishop ('Yes') or not ('No').

and 51 non-Episcopal see cities. The city names are listed in Table I, where we also report whether or not the city was the seat of a bishop and, for the cities that became communes in the sample period, the year of transition.[8]

III.C. Earthquakes

The original data on earthquakes are drawn from the DBMI04, assembled by researchers at the Italian National Institute for Geophysics and Volcanology (Stucchi et al., 2007), which contains information on earthquakes occurring in Italian cities between 217 BC and 2002. The catalogue, an extraordinarily rich source of information, is the product of a branch of seismology called historical seismology. This is a multidisciplinary endeavor which uses historical sources to identify the occurrence and effects of seismic events, even in the remote past (Guidoboni, 2002; Stucchi, 1993). It processes historical information into macroseismic parameters, such as time, epicentral location, and earthquake intensity (Guidoboni and Ebel, 2009). The sources of information range from historical records, including archives of public administrations and institutions, diaries, chronicles, letters, monastic, ecclesiastic and capitular archives, *notulae*, and the archives of notaries, to actual archaeological traces (e.g. damage to churches and buildings and subsequent restorations) left behind by seismic events. In the past three decades, the meticulous approach adopted by historical seismologists has led to a remarkable improvement in the quality of the investigation, and it has enabled acquisition of information on the effects of earthquakes, often with a surprising amount of detail (Stucchi, 1993). The material available through these sources is particularly rich in the case of Italy (Boschi, 2000). The historical records for the period studied here refer to universal chronicles, monastic annals, ecclesiastical and liturgical sources, ancient literary sources, and coeval historiography (Guidoboni, 2000).

The main source for the geographical references is the ENEL-ISTAT catalogue of Italian localities (ENEL, 1978) and updates. In the period (1000-1300) and geographical area (northern-central Italy) considered in this paper, 28 earthquakes occurred; they hit cities included in our sample 102 times (obviously, a city can be struck by more than one seismic episode). They are reported in Table II, which indicates, for each earthquake, the year and the name of the city at the epicenter (or the city nearest to the epicenter).[9] Column (1) reports the

[8] Detailed sources are available from the authors upon request.

[9] Since the DBMI04 reports the geographical coordinates of the epicenter for each earthquake, we are able to infer the current name of the city closest to it (regardless of whether or not the city existed in 1000). The

TABLE II. EARTHQUAKES

Epicenter city	*Year*	*Registered quakes*	*Polygon*		*Epicenter*		*Circles*	
			All	*Identifying*	*All*	*Identifying*	*All*	*Identifying*
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Arezzo	1005	2	6	6	17	17	4	4
Cassino	1005	0	2	2	4	4	0	0
Brescia	1065	5	7	7	18	18	4	4
Scardevara	1117	24	92	74	120	99	42	33
Firenze	1148	1	3	1	1	0	4	2
Pisa	1168	1	3	1	1	0	3	1
Ceccano	1170	0	1	1	0	0	3	3
Genova	1182	1	1	0	1	0	1	0
Cesena	1194	2	7	2	14	5	5	2
Pistoia	1196	1	2	0	1	0	3	1
Brescia	1197	8	1	0	1	0	2	1
Genova	1217	1	1	0	1	0	1	0
Lazise	1222	22	52	21	65	30	42	15
San Germano	1231	0	3	3	4	3	1	1
Ferrara	1234	4	1	0	1	0	3	2
Modena	1249	4	3	1	3	1	6	3
Treviso	1268	3	3	1	4	2	4	2
Numana	1269	1	1	1	1	1	3	2
Sansepolcro	1270	0	0	0	0	0	1	0
Piacenza	1276	5	29	10	44	14	18	5
Cividale Del Friuli	1279	1	4	4	7	6	6	5
Galeata	1279	3	6	1	7	2	7	2
Serravalle Di Chienti	1279	3	12	4	26	9	9	3
Mestre	1284	1	7	4	38	22	7	3
Ferrara	1285	2	1	0	1	0	3	2
Pistoia	1293	1	2	0	1	0	3	1
Chur	1295	4	11	3	25	12	7	1
Poggio Bustone	1298	2	13	4	37	14	9	1
Total		102	274	151	443	259	201	99

Notes. The list shows all the earthquakes included in our data. *Epicenter city* is the city closest to the epicenter of the earthquake according to the geographical coordinates provided by the DBMI04. *Year* is the year in which the earthquake occurred. *Registered quakes* are the seismic events registered for our sample cities in the DBMI04. For each of the three augmenting criteria (*polygon*, *epicenter, circles*), the number of cities in our sample hit by a seismic event (*All*) and the number of earthquakes used for identification (*Identifying*) are reported. Note that the numbers of registered earthquakes reported in column (1) may be larger than those in the next columns because the former include all earthquakes with and without registered intensity in the original dataset, whereas the latter only include earthquakes for which intensity could be assigned, as explained in the text with greater detail.

macroseismic epicenter of a historical earthquake can be identified at the barycenter of the localities where the maximal intensities were registered. The algorithm conventionally adopted for its identification was suggested by Gasperini et al. (1999) and Gasperini and Ferrari (2000).

number of cities in our sample, which registered each of the 28 earthquakes. For instance, in 1005 two earthquakes occurred. The first had its epicenter in Arezzo and was registered in two cities included in our sample, Arezzo and Pistoia; hence the number of cities in the corresponding cell is two (although more than two cities among those not included in our sample were also hit). The second had its epicenter in Cassino and was also registered by two cities, Cassino and Rome, neither of which is included in our sample; this is why the corresponding number of cities in Table II is equal to zero.

The intensity (*I* hereafter) of a seismic event is registered on the Mercalli-Cancani-Sieberg (MCS hereafter) scale, which measures the effects brought about by the seismic event on people, natural objects, buildings and other man-made objects, and the Earth's surface.[10] In what follows we distinguish between destructive earthquakes (intensity greater than 5 on the MCS scale) denoted by *D* and seismic events that were felt by the population but caused no physical damage (intensity greater than 2 and smaller than or equal to 5) denoted by *F*. For a number of seismic events, the intensity could not be registered in the original dataset (DBMI04) because of missing or inaccurate historical sources.[11]

III.D. Augmented Dataset

A possible concern about the data described above is that not necessarily all the seismic events that occurred in the Middle Ages could be originally recorded because of missing or inaccurate historical sources. Consider an earthquake with its epicenter in city *j* that occurred at time *t*. It may be that this earthquake was recorded in the DBMI04 for city *j*, but not for city *i*, which was also struck by the seismic episode, because the historical sources for this city were not handed down to the most recent periods. To take this possibility into account, we build an augmented dataset according to the three following criteria.

Polygon criterion: For all the cities that in the sample period reported a seismic event with a

[10] The scale ranges from 1 to 12: when *I* stands at 1, this means that people did not feel the earthquake; *I* at 2 means that the earthquake was felt by very few persons; *I* from 3 to 5 means that the earthquake was felt by many but did not cause damage; *I* from 6 to 7 indicates that physical damage was reported; *I* from 8 to 10 that human victims were also registered; *I* equal to 11 indicates catastrophic destruction; and *I* equal to 12 total (apocalyptic) destruction. The strongest earthquake in our sample was registered in Verona in 1117 with *I* equal to 9.

[11] Of the 102 seismic episodes registered in our sample, 48 caused material damage to buildings or people, 25 were felt by people but did not cause any physical damage, and 29 were registered with unreported intensity. In our main analysis we will only use earthquakes with reported intensity, either *D* or *F*, whereas events with unreported intensity will be employed in the robustness checks.

valid registered intensity (falling in either the *D* or *F* category) in the DBMI04, we draw the outer convex polygon and impute an earthquake as occurring in city *i* at time *t* if this city was located within the polygon.[12] Figure I.A reports an example concerning the earthquake that struck northern Italy in 1222. The empty dots represent the cities hit by the earthquake in the DBMI04. Varese, Treviso, Venezia, Cesena, Genova, and Alessandria represent the vertexes of the outer polygon. The full dots denote the cities that were assigned the earthquake because they were located within the polygon. The epicenter, Lanzise, is denoted by a star. After we augment the dataset by means of this criterion, the total number of seismic episodes increases to 274 (of which 151 hit cities before their transition to communes, if any, see Table II).

Epicenter criterion: Consider an earthquake that occurred at time *t* with its epicenter in city *j*. Here we draw a circumference with city *j* at the center and with a radius equal to the distance between city *j* and the farthest city that reports a seismic event with a registered intensity in the DBMI04. We then assign a seismic episode to all the cities located within the circumference. A graphical representation of this criterion is depicted in Figure I.B, where again the empty dots indicate the cities which registered the episode in the DBMI04, the star denotes the epicenter, and the full dots are the cities imputed by the *epicenter* criterion. The total number of seismic events yielded by this criterion is 443 (of which 259 hit cities before their transition to communes, if any).

Circles criterion: We take all the cities for which the occurrence of an earthquake has been reported in the DBMI04 with a registered intensity and draw an equal number of circles with each of those cities as the center and radius equal to 30 km (we also experiment with alternative threshold distances and obtain no significant differences in the results). We then

[12] Since the cities are identified by pairs of geographic coordinates that are points on the plane, in order to include cities that might be located on the line between two vertexes of a polygon, we draw the sides of the polygons using buffers with widths equal to 20 km. The results described in the following sections do not change in any significant way when alternative widths are used. For earthquakes that hit just one city, we draw a circular area around the city with a radius equal to 20 km. When the earthquake hit two cities, we draw a rectangular area that covers the two cities and whose shortest side is 40 km wide (20 km on each side of the city).

FIGURE I. THE EARTHQUAKE OF 1222

FIGURE I.A. (*POLYGON* CRITERION)

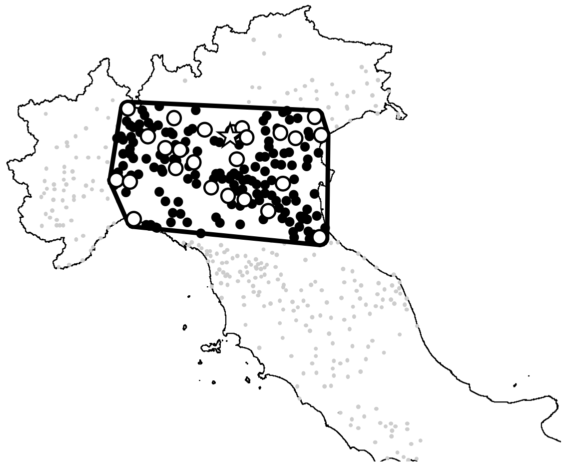
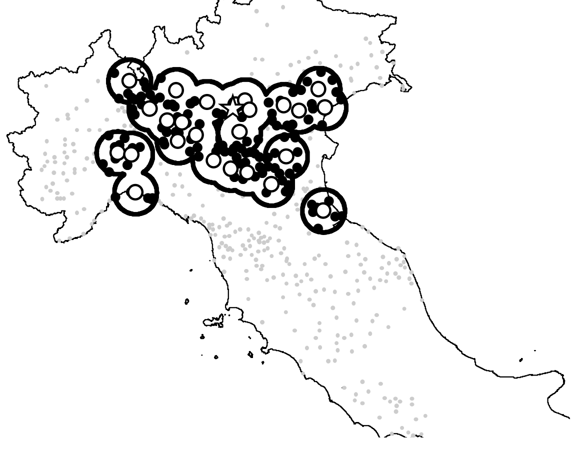


FIGURE I.B. (*EPICENTER* CRITERION)

FIGURE I.C. (*CIRCLES* CRITERION)



Notes. Geographic distribution of the cities hit by the earthquake of 1222. Empty dots represent the cities that reported the earthquake in the DBMI04; full dots denote the cities that were assigned the earthquake by the *polygon*, *epicenter*, or *circles* augmenting criterion, respectively, in Figures I.A, I.B, and I.C. The epicenter is denoted by a star.

assign the earthquake to all the cities within the union of these circles. Figure I.C provides an illustration: the empty dots are the registered episodes in the DBMI04 and the full dots are the events created by the *circles* criterion. The total number of episodes identified by this criterion is 201 (of which 99 hit cities before their transition to communes, if any).

For all the seismic episodes included in the augmented dataset according to one of the above criteria we also impute intensity, and proceed as follows. Consider an earthquake with epicenter in city *i*; we draw around city *i* a circumference with radius equal to the distance between city *i* and its closest city struck by that earthquake with intensity equal to *D*. All the cities included in this circumference are assigned intensity equal to *D*, while all the cities that lie outside this circumference, but are still assigned an earthquake according to one of the three augmenting criteria, report intensity equal to *F*.[13]

Table II shows, for each of the three augmenting criteria explained above, the total number of cities in our sample hit by an earthquake (columns (2)-(4)-(6), respectively) and the number of cities in our sample hit before transition (columns (3)-(5)-(7), respectively), that will be used for the identification of the relevant parameters (see below). Note that in some cases we report earthquakes that were not registered in the cities of our sample but were still detected by our augmenting criteria (for instance, the earthquake that originated in Sansepolcro – not included in our sample – in 1270 was not originally registered in our sample of cities, but was assigned to Arezzo according to the *circles* criterion). In what follows we will refer to the *polygon* criterion as our preferred augmenting methodology.

IV. EMPIRICAL STRATEGY AND RESULTS

IV.A. Identification Strategy

To analyze the effect of an earthquake on the probability of transition to commune, we start by considering the following regression model:

---

[13] With this criterion, we assign *F* intensity to a larger number of cities than *D* intensity. For instance, for the *polygon* criterion, we assign *F* to 200 cities and *D* to 74 cities. We believe this criterion to be valid for the following reason. On average, the distance from the epicenter for cities that registered destructive seismic episodes is larger than that for cities that felt only a tremor without reporting any damage. Hence, we assign *D* to cities inside the circumference and *F* to those outside it. Since earthquakes do not necessarily spread concentrically, however, in some cases low intensity tremors (that would fall in the *F* category) in the DBMI04 may be registered closer to the epicenter than destructive episodes. This is why we adopt as a radius of the circumference the minimum distance of a *D* episode from the epicenter. Note that alternative criteria would not change our conclusions. Finally, the seismic events registered in the original dataset - DBMI04 - with intensity *D* or *F* retain the registered intensity.

$$transition_{it} = \alpha_i + \tau_t + \delta_i \cdot t + \sum_{j=0}^{19} \beta_j \cdot quake_{it-j} + \sum_{j=0}^{19} \gamma_j \cdot bishop_i \cdot quake_{it-j} + \varepsilon_{it}, \quad (1)$$

where i denotes the city and t indicates the year. The dependent variable, $transition_{it}$, captures the event of an institutional transition: it is equal to one if city i became a commune in year t and is equal to zero otherwise. Since the transition from communal institutions back to the feudal regime was not an option for historical reasons, for a city i which transited to a commune in year t, time is not defined after t.[14] This means that the transition to communal institutions is an absorbing state: after becoming a commune, the city drops out of the sample. As a consequence, our dataset is an unbalanced panel. $Quake_{it}$ is a dummy variable that is equal to one if a seismic event occurred in city i and in year t (according to our augmented dataset) and is equal to zero otherwise. $Bishop_i$ is also a dummy variable and equals one if city i was the seat of a bishop at time t=1000 and zero otherwise.

The β-coefficients capture the effect of a seismic event on the transition probability for non-Episcopal see cities, while the γ-coefficients indicate the differential effect between Episcopal and non-Episcopal see cities. α_i, τ_t , and $\delta_i \cdot t$ are respectively the city fixed effects, the year fixed effects, and the city-specific time trends. Finally, ε_{it} is the error term. We are primarily interested in the γs. Under the assumption of common trends, we expect the differential effect between Episcopal and non-Episcopal see cities to be the result of the overlap between political and religious authorities in the former group of cities. This observation is at the core of our diff-in-diff strategy.

In our model specification, city fixed effects take account of the fact that cities may be different in many important permanent unobservable characteristics, which are likely correlated with both the city's seismicity and its probability of an institutional transition (for example, the city's altitude might affect the perception of the earth's tremor and is also a proxy for the city's strategic position and capacity to repel enemies). Time fixed effects absorb any potential event contemporaneous with the earthquake for all the cities (e.g. a famine) that may affect the probability of a transition. Time fixed effects ensure that

[14] In the fourteenth century (hence after the end of our sample period) some cities which had previously established communal institutions adopted an authoritarian form of government ruled by the *signore* (the Lord) and were accordingly named *signoria*. This transition process was highly heterogeneous across cities, and it related to two phenomena: the emergence of a wealthy class of individuals who took control of the city institutions (e.g. the Medicis in Florence) and the territorial expansion of some communes, which conquered the neighboring cities and established regional states. Consequently, since many cities were governed by the same lord (e.g. Bergamo and Cremona were conquered by Milan under the *signoria* of the Visconti family), the number of established *signorie* was remarkably smaller than the number of communes.

identification is obtained conditional on shocks common to cities with and without earthquakes in each single year. Finally, the city-specific time trends account for possible slow-moving social and cultural variables (e.g. civic and human capital accumulation) specific to each city in the sample and which are correlated with both a city's probability of becoming a commune and its probability of registering an earthquake. In fact, in our data, both probabilities are positive functions of time (see, respectively, Table I and Table II). Importantly, these trends may vary from city to city because, for instance, cities experiencing increases in education and civic capital accumulation steadily enhance their ability to register earthquakes. The omission of one or both sets of fixed effects or of the city-specific trends would lead to a potential bias in the coefficients of interest. Their inclusion allows us to exploit the random nature of the timing of the seismic episodes that is the central feature of our design.

We explore the dynamic treatment effects by including lagged earthquake variables because we are interested not only in the contemporaneous effect but also in its duration.[15] We consider lagged quake variables up to 20 years because we expect our effect of interest to develop in a relatively short run period. As we will show, this expectation is confirmed by the data.

Given the large number of fixed effects included, model (1) and its modifications are estimated adopting a linear probability model (LPM hereafter). The limitations of this approach and alternative functional forms are discussed in Section IV.F. To take account of potential spatial correlation of the error terms in an unknown form, we employ Conley's method (Conley, 1999) to compute the standard errors, in which the spatial dependence between two observations in two different cities decreases with the distance between the cities. This method requires a threshold distance after which the dependence disappears. Our preferred threshold is 100 km, meaning that error spatial dependence decreases linearly between zero and 100 km and disappears for longer distances. This is justified by the fact that, for earthquakes registered by multiple cities in the original dataset, the average distance between the epicenter and the farthest city with a registered intensity is about 100. In our analysis, we will also present standard errors clustered at the city level and Conley's standard errors obtained with alternative threshold distances (200 km or 500 km).

[15] Moreover, if the effect of a seismic event on the transition probability lasts for a few years after its occurrence, by omitting the lagged earthquake variable, we would include, mistakenly, in the control group observations treated by the seismic event. The estimated coefficient of the contemporaneous effect would, as a consequence, be biased.

IV.B. Diagnostic Tests and Preliminary Evidence

The three criteria described in Section III.D (*polygon*, *epicenter*, and *circles*) assign possibly missing seismic events to cities by starting from *recorded* earthquakes (respectively, the vertexes of the polygons, the epicenter, the center of the circles). Hence, necessarily, our augmenting procedures cannot take into account earthquakes that were registered in no city according to the DBMI04 because the relative documents were not handed down to the historical sources. This may be important in the presence of pre-trends. For instance, if transitions in Episcopal cities, unlike in non-Episcopal ones, happen during a period of political turmoil or in the presence of other circumstances that influence negatively the probability of registering an earthquake, we would erroneously attribute to a seismic episode a negative impact on the probability of becoming commune, while no true differential effect exists. This, in turn, would imply a negative differential effect of the seismic event between the two groups of cities. If these circumstances last for some years after the transition, we would also observe negative differential effects of the leads of the earthquake variable on the transition. Hence, finding no negative differential effects of the earthquake on past transitions is consistent with the absence of pre-trends.

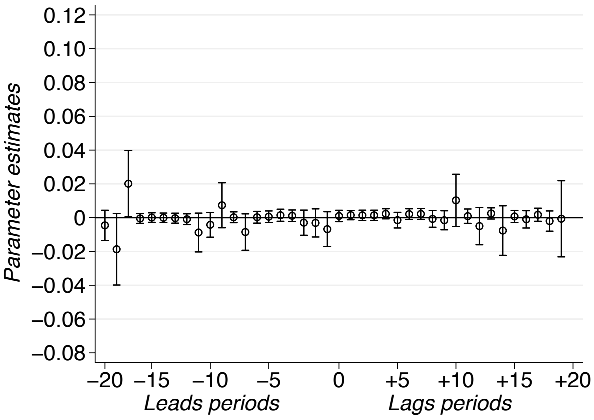
To verify the presence of possible pre-trends and provide preliminary evidence on the differential effects of earthquakes on the transition probability, we estimate model (1) including both lags and leads in the earthquake variable. Since the outcome is an absorbing state, lead and lag effects must be estimated separately. In estimating the coefficients on the leads, we leave the outcome variable equal to one if a transition occurred in city i and at time t and set it equal to zero in the following periods (before t, time is not defined and the city drops).

The results are shown in Figures II, where, for each augmenting criterion, we plot the estimated β- and γ-coefficients from model (1) and the associated confidence intervals according to the estimated Conley's standard errors with 100 km threshold distance. On the left part of the plot, we report coefficients on the leads as they capture a relation between the occurrence of an earthquake in a given period and past transitions. On the right part, we measure the contemporaneous coefficient and coefficients on the lags, reflecting the dynamic treatment effects, as they reveal a relation between an earthquake at time t and future values in the outcome variable.

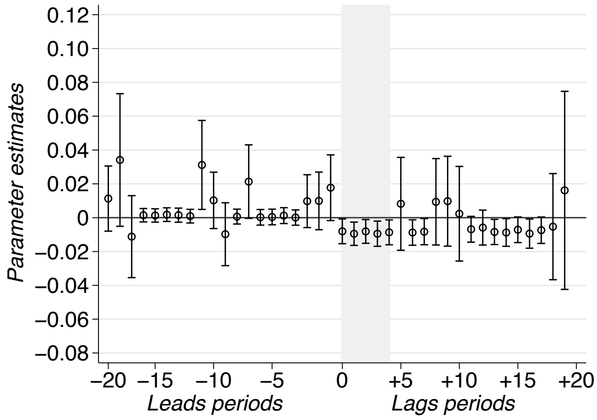
FIGURES II. LEADS AND LAGS (β and γ)

II.A. *POLYGON* CRITERION

Effect on non-Episcopal see cities (β)

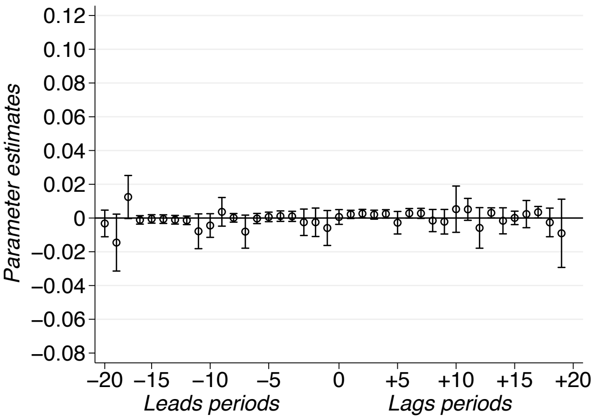


Differential effect on Episcopal see cities (γ)

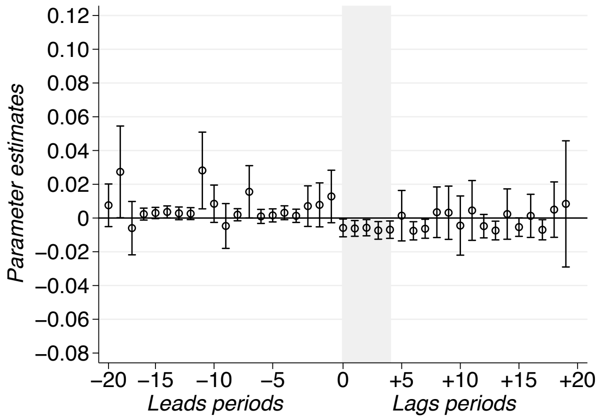


II.B. *EPICENTER* CRITERION

Effect on non-Episcopal see cities (β)

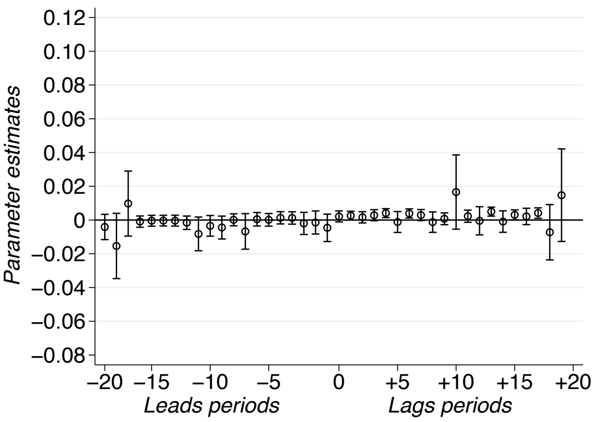


Differential effect on Episcopal see cities (γ)

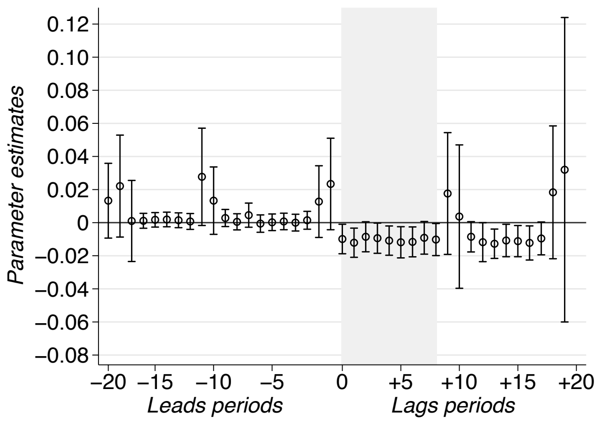


II.C. *CIRCLES* CRITERION

Effect on non-Episcopal see cities (β)



Differential effect on Episcopal see cities (γ)



Notes. Estimated β- and γ-coefficients by OLS of model (1) with 20 leads and lags. Year fixed effects, city fixed effects, and city time trends always included. The dependent variable, *transition*, is =1 if city *i* became a commune at time *t* and =0 otherwise. The independent variable, *quake*, is =1 if an earthquake occurred in city *i* at time *t* and =0 otherwise. The confidence intervals are computed employing Conley's standard errors corrected for spatial dependence with threshold distance of 100 km.

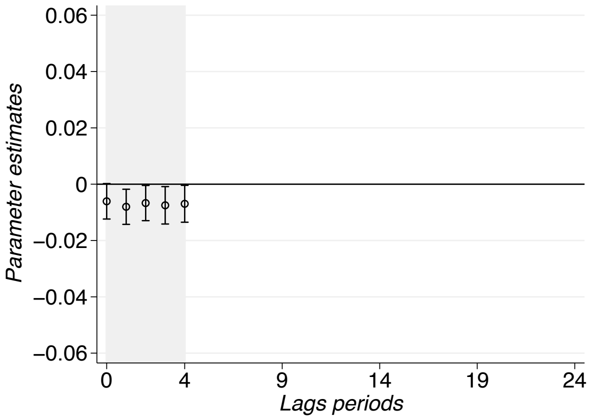
Three empirical patterns are apparent in Figures II. First, while the estimated β-coefficients are close to zero, most of the point estimates of the lagged differential effects between Episcopal and non-Episcopal see cities, the γ-coefficients, are negative, especially in the very short run. These results suggest that the occurrence of an earthquake retards the transition to communal institutions only for Episcopal see cities. The effect appears to last longer when we consider the *circles* augmenting criterion (Figure II.C) and to last for a shorter time when we adopt the other two criteria, *polygon* and *epicenter* (respectively Figures II.A and II.B).[16] Second, no negative pre-trend appears from the plotted lead effects. If anything, the effects are virtually zero with point estimates slightly above zero. Third, the large confidence intervals associated with a number of coefficients suggest that they are quite imprecisely estimated. It is likely that exploiting the annual variability in the earthquake variable generates noise in the estimation. In fact, the latter finding advises us to adopt a model that aggregates the effects of the earthquakes across consecutive years that we report in the following sections.

In Figure III, we show the estimated γ-coefficients from model (1) modified to include up to 25 lagged earthquake dummies (for the *polygon* criterion only, for reasons of space). The p-values computed from a test of joint significance of the lagged differential effects grouped by five-year periods are also reported. They suggest that the differential effect of an earthquake in the first five years following the event is robust to the inclusion of an increasing number of lags. Moreover, as one can see, the effect of an earthquake lasts at most 20 years (i.e. the lagged effects between 20 and 25 years are practically insignificant) and adding a number of lags larger than 20 does not substantially contribute to improving the estimation precision for the coefficients on the previous lags. Consequently, we perform the empirical analysis including lags up to 20 years.

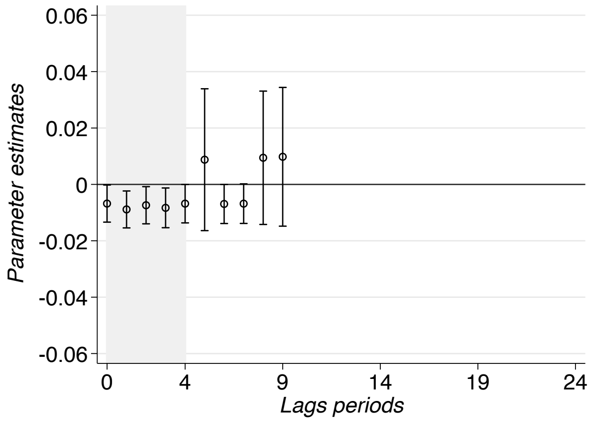
[16] To convey the dynamics better, in the Online Appendix A (Figures A.1), we also report the coefficients on the contemporaneous *quake* variable and its lags up to 40 years. For all the three augmenting criteria, the differential effect of an earthquake is mainly confined to the two decades following the seismic event, being precisely estimated especially in the first five years of the first decade. Starting from the third decade the effect vanishes and most of the coefficients turn out to be not statistically different from zero. This exercise confirms that the effect of the earthquake is confined to the short run.

FIGURES III. LAG STRUCTURE (*POLYGON* CRITERION): DIFFERENTIAL EFFECT (γ)

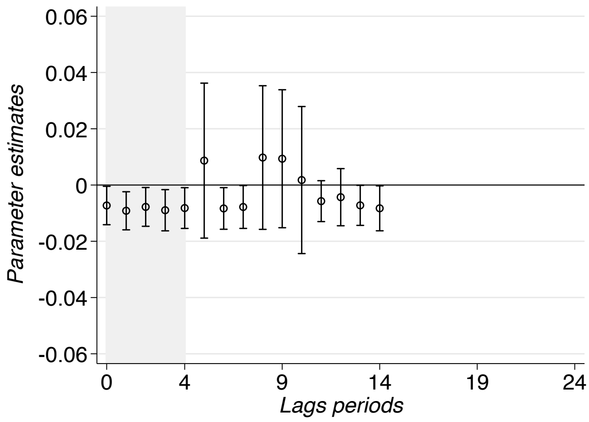
III.A. FIVE LAGS



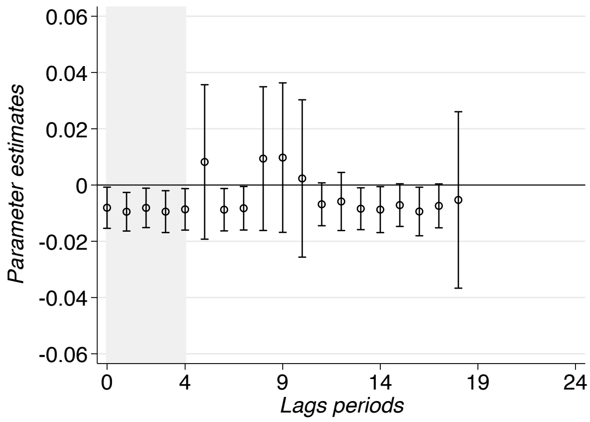
III.B. TEN LAGS



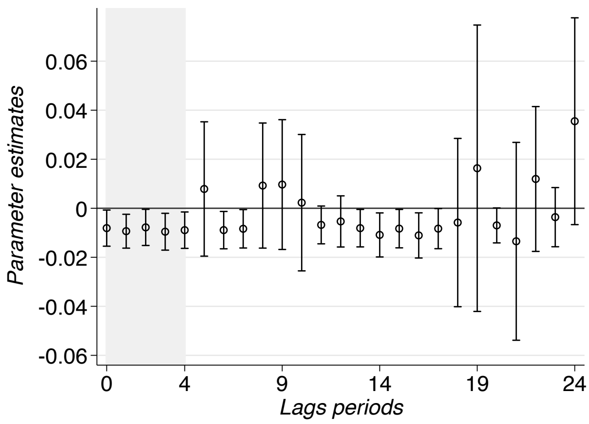
III.C. FIFTEEN LAGS



III.D. TWENTY LAGS



III.E. TWENTY-FIVE LAGS



	P-value				
Null hp.\ Fig.	III.A	III.B	III.C	III.D	III.E
$\Sigma_{j=0\ldots4}\,\gamma_j = 0$	0.162	0.140	0.133	0.102	0.100
$\Sigma_{j=5\ldots9}\,\gamma_j = 0$		0.311	0.278	0.249	0.247
$\Sigma_{j=10\ldots14}\,\gamma_j = 0$			0.476	0.367	0.324
$\Sigma_{j=15\ldots19}\,\gamma_j = 0$				0.431	0.305
$\Sigma_{j=20\ldots24}\,\gamma_j = 0$					0.388

Notes. Estimated γ-coefficients by OLS of model (1) with a variable number of lags. Year fixed effects, city fixed effects, and city time trends always included. The dependent variable, *transition*, is =1 if city i became a commune at time t and =0 otherwise. The independent variable, *quake*, is =1 if an earthquake occurred in city i at time t and =0 otherwise. The confidence intervals are computed employing Conley's standard errors corrected for spatial dependence with threshold distance of 100 km.

IV.C. Aggregate Effects and Intensity

For reasons of tractability and to gain in efficiency, we give more structure to the model and aggregate the effects of earthquakes on the transition probability in five-year effects. We thus estimate the following regression equation:

$$transition_{it} = \alpha_i + \tau_t + \delta_i \cdot t + \sum_{h=0}^{3} \beta_{-5h} \cdot quake_{-5h,it} + \sum_{h=0}^{3} \gamma_{-5h} \cdot bishop_i \cdot quake_{-5h,it} + \varepsilon_{it} , \quad (2)$$

where $quake_{0,it}$, $quake_{-5,it}$, $quake_{-10,it}$, and $quake_{-15,it}$ are equal to one, respectively, in the first, second, third, and fourth five-year interval following the earthquake, and to zero otherwise (note that while data are annual, the effects are aggregated every five years).

The estimated coefficients in this model represent the average effect of an earthquake over each five-year period. Table III presents the results. For each augmenting criterion, we report the estimated β- and γ-coefficients. Columns (1)-(2)-(3) of Table III show the results from regression (2) on adopting, respectively, the *polygon*, the *epicenter*, and the *circles* criterion. Columns (4)-(5)-(6) report the corresponding results but obtained on employing only destructive earthquakes, i.e. seismic episodes with intensity greater than 5 (intensity class *D*). Conley's standard errors corrected for spatial dependence with thresholds distance of 100 km and standard errors clustered at the city level are reported in round and square brackets, respectively. Statistical significance is indicated employing Conley's standard errors, which in most cases are very similar to clustered standard errors.

Our results suggest that the occurrence of an earthquake has always a negative and statistically significant differential effect between Episcopal and non-Episcopal see cities in the first five years following the event. In particular, within the five years after the earthquake, the difference in the change of the probability of transition between the two groups of cities (γ_0 in column (1)) is equal to -0.85 percentage points when we consider our preferred augmenting criterion (*polygon*). Taking into account the corresponding estimated β-coefficient, these estimates imply that an earthquake pushes the probability of transition to zero for Episcopal see cities. Similar conclusions are drawn when we consider the *epicenter* and the *circles* criteria (columns (2) and (3)). The results reported in columns (4)-(5)-(6) are consistent with those presented in columns (1)-(2)-(3) but suggest a somewhat larger effect.

We employ a similar modeling strategy to exploit information on the intensity of seismic events. Here we distinguish between earthquakes that were only felt by the population but did not cause any damage (with intensity in MCS scale greater than 2 and smaller than or equal to 5; *F*), denoted by $fquake_{it}$, and destructive earthquakes (with intensity greater than 5; *D*),

TABLE III. MAIN RESULTS

	All earthquakes			*Only destructive earthquakes*		
	Polygon	*Epicenter*	*Circles*	*Polygon*	*Epicenter*	*Circles*
	(1)	(2)	(3)	(4)	(5)	(6)
$Quake_{0,it}$ (β_0)	0.0015	0.0017	0.0026**	0.0025*	0.0043***	0.0022*
	(0.0011)	(0.0012)	(0.0010)	(0.0015)	(0.0015)	(0.0012)
	[0.0009]	[0.0010]	[0.0009]	[0.0013]	[0.0014]	[0.0011]
$Quake_{0,it} \times bishop_{0,it}$ (γ_0)	-0.0085***	-0.0062***	-0.0099***	-0.0158***	-0.0092***	-0.0121***
	(0.0028)	(0.0019)	(0.0034)	(0.0054)	(0.0029)	(0.0041)
	[0.0023]	[0.0016]	[0.0027]	[0.0031]	[0.0025]	[0.0028]
$Quake_{-5,it}$ (β_{-5})	0.0001	-0.0003	0.0011	0.0007	0.0035*	0.0009
	(0.0016)	(0.0018)	(0.0015)	(0.0022)	(0.0020)	(0.0016)
	[0.0015]	[0.0018]	[0.0015]	[0.0020]	[0.0018]	[0.0015]
$Quake_{-5,it} \times bishop_{-5,it}$ (γ_{-5})	0.0023	-0.0011	-0.0049	0.0034	0.0036	-0.0053
	(0.0062)	(0.0037)	(0.0057)	(0.0141)	(0.0074)	(0.0072)
	[0.0065]	[0.0037]	[0.0058]	[0.0151]	[0.0078]	[0.0073]
$Quake_{-10,it}$ (β_{-10})	0.0001	0.0009	0.0043	0.0041	0.0024	0.0049
	(0.0032)	(0.0027)	(0.0033)	(0.0046)	(0.0047)	(0.0041)
	[0.0036]	[0.0032]	[0.0038]	[0.0041]	[0.0054]	[0.0047]
$Quake_{-10,it} \times bishop_{-10,it}$ (γ_{-10})	-0.0049	-0.0014	-0.0066	-0.0058	-0.0057	-0.0084
	(0.0046)	(0.0037)	(0.0066)	(0.0118)	(0.0060)	(0.0085)
	[0.0048]	[0.0040]	[0.0073]	[0.0130]	[0.0064]	[0.0094]
$Quake_{-15,it}$ (β_{-15})	-0.0001	-0.0010	0.0034	0.0031	0.0126**	0.0046
	(0.0031)	(0.0029)	(0.0039)	(0.0057)	(0.0049)	(0.0049)
	[0.0037]	[0.0028]	[0.0035]	[0.0051]	[0.0054]	[0.0044]
$Quake_{-15,it} \times bishop_{-15,it}$ (γ_{-15})	-0.0026	0.0005	0.0031	0.0126	0.0072	0.0053
	(0.0079)	(0.0052)	(0.0120)	(0.0219)	(0.0113)	(0.0158)
	[0.0070]	[0.0053]	[0.0102]	[0.0187]	[0.0115]	[0.0132]
R-squared	0.054	0.054	0.054	0.054	0.055	0.054

Notes. Estimation by OLS of model (2). Year fixed effects, city fixed effects, and city time trends always included. Number of observations = 23,972; number of cities = 121. The dependent variable, *transition*, is =1 if city *i* became a commune at time *t* and =0 otherwise. The independent variable, *quake*, is =1 if an earthquake occurred in city *i* at time *t* and =0 otherwise. The subscripts "0", "-5", "-10", "-15" refer to the five-year lag (respectively: "from *t* to *t*-4", "from *t*-5 to *t*-9", "from *t*-10 to *t*-14", from "*t*-15 to *t*-19"). Conley's standard errors corrected for spatial dependence with threshold distance of 100 km are reported in round brackets; standard errors clustered at the city level are in squared brackets. *** = significant at 1%; ** = significant at 5%; * = significant at 10%. Statistical significance is indicated employing the Conley's standard errors.

TABLE IV. INTENSITY

	Polygon			*Epicenter*			*Circles*		
	Damage	*Felt*	*F-test* (*P-value*)	*Damage*	*Felt*	*F-test* (*P-value*)	*Damage*	*Felt*	*F-test* (*P-value*)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$Quake_{0,it}$ (β_0)	0.0006	0.0017		0.0006	0.0019		0.0017*	0.0026**	
	(0.0009)	(0.0013)		(0.0009)	(0.0012)		(0.0010)	(0.0011)	
	[0.0010]	[0.0011]		[0.0010]	[0.0011]		[0.0016]	[0.0010]	
$Quake_{0,it} \times bishop_{0,it}$ (γ_0)	-0.0156**	-0.0070**		-0.0155**	-0.0053***		-0.0163**	-0.0073**	
	(0.0067)	(0.0028)	(0.200)	(0.0066)	(0.0018)	(0.121)	(0.0068)	(0.0033)	(0.188)
	[0.0044]	[0.0024]	[0.076]	[0.0043]	[0.0016]	[0.024]	[0.0043]	[0.0029]	[0.086]
$Quake_{-5,it}$ (β_{-5})	0.0002	0.0001		-0.0008	-0.0003		0.0010	0.0011	
	(0.0010)	(0.0019)		(0.0010)	(0.0020)		(0.0011)	(0.0016)	
	[0.0009]	[0.0018]		[0.0009]	[0.0020]		[0.0012]	[0.0016]	
$Quake_{-5,it} \times bishop_{-5,it}$ (γ_{-5})	0.0018	0.0023		0.0018	-0.0015		0.0000	-0.0071**	
	(0.0185)	(0.0064)	(0.979)	(0.0184)	(0.0036)	(0.861)	(0.0188)	(0.0034)	(0.710)
	[0.0187]	[0.0068]	[0.980]	[0.0186]	[0.0037]	[0.862]	[0.0190]	[0.0032]	[0.710]
$Quake_{-10,it}$ (β_{-10})	0.0005	0.0001		0.0000	0.0010		0.0015	0.0046	
	(0.0012)	(0.0037)		(0.0014)	(0.0030)		(0.0012)	(0.0037)	
	[0.0012]	[0.0042]		[0.0014]	[0.0035]		[0.0014]	[0.0042]	
$Quake_{-10,it} \times bishop_{-10,it}$ (γ_{-10})	-0.0151*	-0.0030		-0.0133	-0.0005		-0.0151*	-0.0029	
	(0.0086)	(0.0054)	(0.270)	(0.0087)	(0.0041)	(0.206)	(0.0086)	(0.0088)	(0.370)
	[0.0069]	[0.0057]	[0.625]	[0.0069]	[0.0044]	[0.128]	[0.0067]	[0.0096]	[0.304]
$Quake_{-15,it}$ (β_{-15})	-0.0049	0.0009		-0.0050	-0.0003		-0.0028	0.0043	
	(0.0051)	(0.0033)		(0.0045)	(0.0032)		(0.0047)	(0.0043)	
	[0.0044]	[0.0043]		[0.0037]	[0.0033]		[0.0038]	[0.0039]	
$Quake_{-15,it} \times bishop_{-15,it}$ (γ_{-15})	0.0034	-0.0038		0.0038	-0.0001		0.0026	0.0045	
	(0.0169)	(0.0073)	(0.625)	(0.0169)	(0.0046)	(0.796)	(0.0172)	(0.0119)	(0.900)
	[0.0197]	[0.0075]	[0.730]	[0.0197]	[0.0054]	[0.845]	[0.0198]	[0.0116]	[0.936]
R-squared		0.054			0.054			0.054	

Notes. Estimation by OLS of model (3). Year fixed effects, city fixed effects, and city time trends always included. Number of observations = 23,972; number of cities = 121. The dependent variable, *transition*, is =1 if city *i* became a commune at time *t* and =0 otherwise. The independent variable, *quake*, is =1 if an earthquake occurred in city *i* at time *t* and =0 otherwise. *Damage* indicates earthquakes with intensity between 6 and 10 (physical damage to people or objects); *felt* denotes events with intensity between 2 and 5 (no physical damage). The subscripts "0", "-5", "-10", "-15" refer to the five-year lag (respectively: "from *t* to *t*-4", "from *t*-5 to *t*-9", "from *t*-10 to *t*-14", from "*t*-15 to *t*-19"). Conley's standard errors corrected for spatial dependence with threshold distance of 100 km are reported in round brackets; standard errors clustered at the city level are in squared brackets. *** = significant at 1%; ** = significant at 5%; * = significant at 10%. Statistical significance is indicated employing the Conley's standard errors. In columns (3)-(6)-(9) we report the *p*-values for the *F*-test that $\gamma^D=\gamma^F$ (null hp) computed employing Conley's (clustered) standard errors in round (squared) brackets.

denoted by $dquake_{it}$, and estimate the following model:

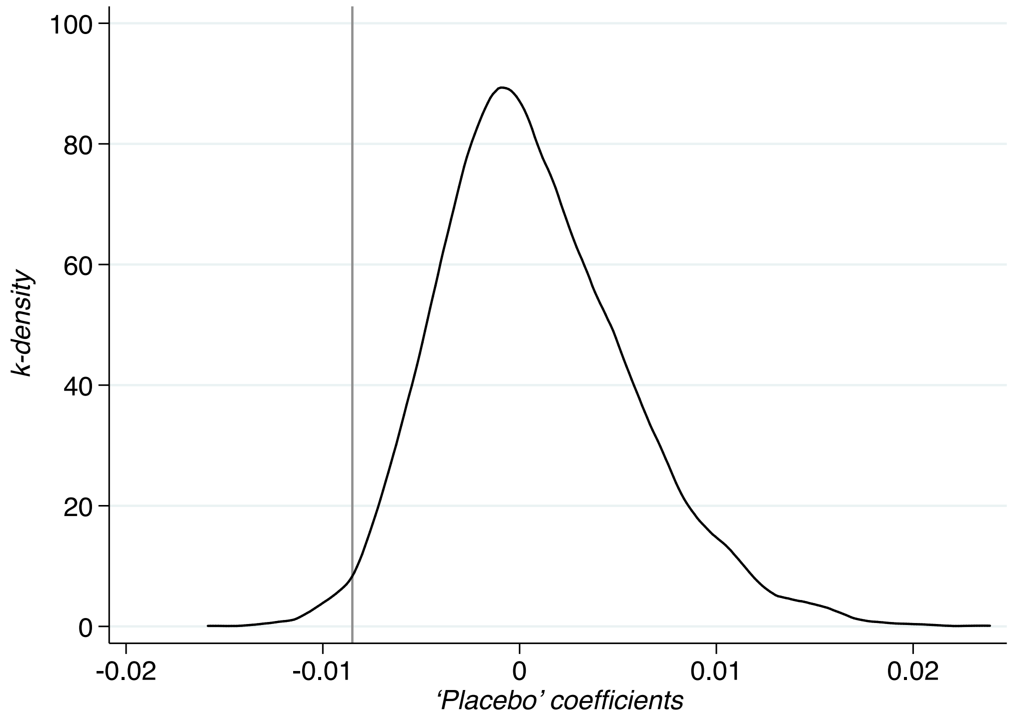
$$transition_{it} = \alpha_i + \tau_t + \delta_i \cdot t + \sum_{h=0}^{3} \beta_{-5h}^{D} \cdot dquake_{-5h,it} + \sum_{h=0}^{3} \beta_{-5h}^{F} \cdot fquake_{-5h,it} + \\ + \sum_{h=0}^{3} \gamma_{-5h}^{D} \cdot bishop_i \cdot dquake_{-5h,it} + \sum_{h=0}^{3} \gamma_{-5h}^{F} \cdot bishop_i \cdot fquake_{-5h,it} + \varepsilon_{it} \cdot \quad (3)$$

The results are shown in Table IV. Specifically, columns (1)-(4)-(7) report, respectively for the three criteria, the effect of an earthquake with *D* intensity in non-Episcopal see cities (β^D) and the differential effect between Episcopal and non-Episcopal see cities (γ^D). The corresponding coefficients for seismic events with *F* intensity (β^F and γ^F) are shown in columns (2)-(5)-(8). In columns (3)-(6)-(9), we also list our results of an *F*-test of equality of the γ-coefficients on destructive and non-destructive earthquakes. We find that both *D* and *F* seismic events always have a negative differential effect on the transition probability in the first five years after the earthquake. The point estimate for a seismic event with intensity *D* is larger, in absolute value, than that associated with intensity *F*; however, when we use Conley's standard errors, the *F*-test never rejects the null hypothesis that the two coefficients are equal. Overall, the results in Table IV suggest that we cannot exclude that earthquakes only felt by the population with no physical damage to people or objects also retarded the establishment of communal institutions in Episcopal see cities.

IV.D. Placebo Test

To check the robustness of our results, we implement a placebo test in the spirit of Chetty, Looney, and Kroft (2009) adopting our preferred augmenting criterion (*polygon*). In our sample of years and cities, 28 earthquakes took place in northern-central Italy, which (according to the *polygon* criterion) generated 274 city-episodes (the total number of seismic events reported in Table II). We then produce 28 'placebo' earthquakes occurring in 28 random years and assign them to random cities for a total of 274 events. Whilst randomly assigned, the 'placebo' earthquakes reflect the true time and space clustering of the real data.

FIGURE IV. PLACEBO TEST (γ_0)



Notes. Probability density function of the differential coefficients on the first five years following a seismic event (γ_0) obtained by estimating regression (2) with the 'placebo' earthquake dummy as independent variable, as explained in Section IV.D, and iterating 10,000 times. The vertical line indicates our 'true' point-estimate (-0.0085), which is reported in column (1) of Table III (*polygon* criterion).

The time clustering is obtained every 50 years: for instance, we generate six 'placebo' earthquakes between 1150 and 1200, which mimic, in random cities and years, the earthquakes that really occurred in 1168 (three cities), 1170 (one city), 1182 (one city), 1194 (seven cities), 1196 (two cities), and 1197 (one city). The space clustering is produced within circular areas around the real epicenter with radius equal to 100 km: for instance, to mimic the earthquake that originated in Arezzo in 1005, we generate a 'placebo' earthquake that is assigned in a random year between 1000 and 1050 to six random cities located within 100 km distance from Arezzo; those cities must be different from the six cities that were really hit by this earthquake in 1005 according to the *polygon* criterion.[17] Hence, we build the 'placebo' earthquake dummy variable and estimate model (2) including it in the place of the real one. We repeat this procedure 10,000 times (employing alternative numbers of replications do not affect our results in any significant way) and save the estimated coefficients. The results, presented in Figure IV, show the probability density function of the 10,000 'placebo' point-

[17] The space clustering is not imposed when we mimic the earthquakes that occurred in 1117 and 1222 because they covered very large areas.

estimates of the γ_0-coefficient, a vertical line indicating our 'true' point-estimate for the differential effect in the first five years after an earthquake (equal to -0.0085, reported in column (1) of Table III).

The purpose of this test is to check how many times these randomly generated 'placebo' point-estimates happen to be smaller or too close to our 'true' point-estimate. If in our main results we were erroneously rejecting the null hypothesis that our coefficient of interest is equal to zero (i.e. we were attributing to earthquakes a negative effect that does not exist in reality), we should have observed 'placebo' coefficients very close to our 'true' estimate. As can be seen from Figure IV, the point-estimates generated in the falsification test are almost always to the right of (meaning larger in value than) the 'true' estimated coefficients. This does not obtain in only 1.23% of cases: moreover, in the 0.92% (0.4%) of cases the 'fake' estimated coefficient is larger than the 'true' one and statistically significant at the 5% (1%) level.[18] Overall, this exercise offers considerable evidence that our results are not an artifact of a small number of 'treated' cities in the dataset and the potentially correlated nature of the error terms.

IV.E. Further Analysis and Robustness Checks

As is clear from Table II, a large fraction of the seismic events considered in our exercise are generated by the earthquake that struck northern-central Italy in 1117. In order to verify whether this or other particular episodes were crucial for obtaining our estimation results, we re-estimate model (2) by excluding earthquakes one-by-one. Adopting our preferred imputation criterion, we perform 20 different regressions (20 is the number of events that, according to the *polygon* criterion, hit at least one city before transition to a commune, if any: this corresponds to the number of non-zero cells in column (3) of Table II). In Table V, we report our coefficients of interest, namely the differential effects estimated in the first five years following the seismic event. The estimated γ_0-coefficients vary across regressions in most of the cases, suggesting that all the earthquakes contribute to estimating the effect under study, though admittedly these changes are very small. When we exclude the earthquake which struck northern-central Italy in 1117 (this earthquake hit 92 out of 121 cities), the point estimate on the *quake* variable in the first five-year interval for the Episcopal cities remains negative (-0.0026 with a *t*-statistics equal to -1.33), indicating that the 1117 earthquake is a

[18] On employing the other two augmenting criteria, *epicenter* and *circles*, the conclusions do not change in any relevant way.

TABLE V. ESTIMATES WHEN DROPPING EARTHQUAKES ONE-BY-ONE (γ_0)

	Polygon						
	Baseline	1005	1005bis	1065	1117	1148	1168
$Quake_{0,it} \times bishop_{0,it}$ (γ_0)	-0.0085***	-0.0086***	-0.0084***	-0.0080***	-0.0026	-0.0086***	-0.0086***
	(0.0028)	(0.0028)	(0.0028)	(0.0029)	(0.0020)	(0.0028)	(0.0028)
	[0.0023]	[0.0023]	[0.0023]	[0.0024]	[0.0018]	[0.0023]	[0.0023]
	1170	1194	1222	1231	1249	1268	1269
$Quake_{0,it} \times bishop_{0,it}$ (γ_0)	-0.0085***	-0.0086***	-0.0090***	-0.0085***	-0.0085***	-0.0086***	-0.0086***
	(0.0028)	(0.0029)	(0.0030)	(0.0029)	(0.0028)	(0.0029)	(0.0029)
	[0.0023]	[0.0023]	[0.0023]	[0.0024]	[0.0023]	[0.0023]	[0.0023]
	1276	1279	1279bis	1279ter	1285	1295	1298
$Quake_{0,it} \times bishop_{0,it}$ (γ_0)	-0.0087***	-0.0089***	-0.0085***	-0.0090***	-0.0085***	-0.0087***	-0.0087***
	(0.0029)	(0.0029)	(0.0028)	(0.0030)	[0.0023]	(0.0028)	(0.0029)
	[0.0023]	[0.0024]	[0.0023]	[0.0024]	(0.0029)	[0.0023]	[0.0023]

Notes. Estimation by OLS of model (2) obtained on dropping earthquakes one-by-one and on adopting the *polygon* criterion. Year fixed effects, city fixed effects, and city time trends always included. Number of observations = 23,972; number of cities = 121. The dependent variable, *transition*, is =1 if city i became a commune at time t and =0 otherwise. The independent variable, *quake*, is =1 if an earthquake occurred in city i at time t and =0 otherwise. Conley's standard errors corrected for spatial dependence with threshold distance of 100 km are reported in round brackets; standard errors clustered at the city level are in squared brackets. *** = significant at 1%; ** = significant at 5%; * = significant at 10%. Statistical significance is indicated employing the Conley's standard errors.

strong driver of our results, although it is not the only episode that generates the regression output.[19]

Finally, we perform some robustness checks. First, we run our regressions on employing an augmented dataset (three criteria) that also includes earthquakes with unreported intensity (results are reported in Table A.1 of the Online Appendix A): our conclusions are not altered in any relevant way. Second, to show how sensitive our estimated standard errors are to the thresholds of 100 km employed in the Conley's correction, we compute the spatially corrected standard errors obtained by adopting thresholds of 200 and 500 km (estimation output is shown in Table A.2 and Table A.3 for model (2) and model (3), respectively); the results are substantially the same as before. Finally, we investigate whether our findings are robust after we drop cities one-by-one (this set of 121 regressions is available upon request). No compelling evidence suggests that the results change on the exclusion of some cities in any significant way.

[19] On the other hand, if we estimate our regression considering only the earthquake of 1117, we obtain a negative differential effect equal to -0.0120 with a t-statistics of -2.81, which is quite different from that obtained when we employ the full dataset (equal to -0.0085 with a t-statistics of -3.03, reported in Table III). Moreover, the estimated effect on the non-Episcopal group when we only use the earthquake of 1117 is positive and not precisely estimated (equal to 0.0015 with a t-statistics of 0.61).

IV.F. Alternative Functional Forms

One potential concern with using a LPM is that this estimation method could provide an imprecise approximation of the marginal effects, especially when there is a mass of zeroes in the dependent variable as in our design.[20] Alternative functional forms are the conditional logit model and duration analysis. We will consider them in turn.

A conditional logic model, in our case, suffers from two substantial limitations. First, this method leads us to discard all the information from cities that never transited to communes and does not reach convergence when year fixed effects and city-specific time trends are included.[21] Second, differential effects in non-linear models, such as the conditional logit, are difficult to interpret (Ai and Norton, 2003). Nonetheless, a logic model conditional on city fixed effects allows estimation of the parameters of interest and may prove useful for verifying whether or not the implied negative and statistically significant effect of earthquakes on the transition probability for Episcopal cities is confirmed in a non-linear model. In fact, reassuringly, the conditional logit model yields results qualitatively similar to those provided by the LPM for Episcopal see cities (results are in Table A.4 of Appendix A).

A duration model would not be appropriate in our context either. Indeed, a Cox model with no time varying covariates would ignore the panel structure of the data, whereas a Cox model with time varying covariates (i.e. the earthquakes) could not accommodate time fixed effects, city-specific time trends, and city fixed effects (which are important in our analysis to exploit the plausible randomness in the occurrence of the seismic events, as explained in Section IV.A). Moreover, the Cox model incurs the same estimation problems as a standard logit whenever the independent variable perfectly predicts the outcomes (see footnote 20). This makes estimation of the dynamics of the effects of earthquakes not feasible when the outcome variable (transition) is always equal to zero in correspondence to the earthquake variable, or its lags, equal to one. Finally, a duration model (with or without time varying

[20] Alternative models, such as logit or probit, present serious limitations in our design. In particular, the inclusion of (city or year) fixed effects would be problematic: first, a large set of fixed effects (as in our case) would yield inconsistent slope estimates due to the incidental parameter problem (Wooldrige, 2002); second, including city and year fixed effects would lead to the loss of all the information related to cities that were hit by earthquakes but never experienced a transition and years in which we do not observe a transition. More generally, all the observations for which the independent variable perfectly predicts the transition outcome would be dropped from the analysis (see Zorn, 2005).

[21] These limitations are not minor. Cities that never transited to communes contribute to the identification of our effect of interest as long as they are hit by an earthquake. Year fixed effects and city-specific time trends are also important in our design, as explained in Section IV.A. The problem of convergence with a large set of fixed effects is common in maximum likelihood estimations (Greene, 2004).

covariates) would make it difficult to distinguish between short and long run effects of (possibly multiple) earthquakes on the transition probability. To conclude, the LPM seems the most appropriate model in our design to exploit the random nature of the timing of earthquakes. This is especially the case when considering the more serious limitations of alternative models (conditional logit or Cox model).

V. Earthquakes and Religious Buildings

V.A. Anecdotal Evidence

Our interpretation of the previous results holds under the assumption, supported by the narrative historical evidence reported in Section II, that an earthquake represented a shock to people's religiosity and that the bishop was able to take advantage of it in terms of his political and religious power. Providing empirical test of this hypothesis is no simple exercise, given the absence of systematic data in the medieval period and the impediments to appraising religious beliefs directly. Yet, an indirect measure of the intensity of the religious feelings in a given city in a certain period could be given by the number of constructions and ornamentations of religious buildings. Indeed, according to the Catholic religion, churches and cathedrals are not only the houses of God where people celebrate rituals: they are also important manifestations of people's faith in God.

Medieval history furnishes several cases in which people reacted to the dread and consternation caused by a seismic event with an increase in votive offerings and enrichments of religious buildings. These were powerful means to please God and to seek reconciliation after a crisis. One example is provided by the history of Bergamo. The year 1117 was crucial for the monastery of Santo Sepolcro in Astino (located near the city of Bergamo): immediately after the earthquake that shook northern-central Italy, substantial offerings were given by two consuls (officials) of Bergamo to the monks of Astino. As testified in a document written in January 1117, the offerings were made in the name and upon request of the citizens ("*per parabolam et consensum fere omnium civium Pergamensium*") for the salvation of their souls (*pro remedio animarum nostrarum et omnium vicinourm masculini et feminini sexus*) (Bartoli Langeli, 2015). Yet, besides saving the citizens' souls, it turned out that the offerings represented building blocks for the economic, religious, and political enhancement of the monastery and constituted an official and definitive endorsement of its political and religious influence over the surrounding region.

Further examples are suggested by the history of Verona. In that city, after 1117, the bishop Bernardo promoted the reconstruction of several ecclesiastic buildings in the city. This undertaking has been scrutinized by historians and archeologists because of its importance for the city's urban structure (Coden, 2010). The bishop was able to take advantage of the earthquake's occurrence not only by investing resources in the construction and ornamentation of the ecclesiastic buildings of Verona but also by enlarging the size of the ecclesiastic properties under his direct control. In 1122 he transformed the Benedictine monastery of San Giorgio – which, like any monastery, was independent from the Episcopal authority – into an *ecclesia* by replacing the abbot (the head of the monastery elected by the monks) with a *prepositus* nominated by the bishop himself (Passuello, 2015). Finally, an anecdote reported by Guidoboni and Poirier (2004) illuminates the effects of earthquakes on citizens' deference to the Church. In Verona, a nobleman, named Rodolfo, used to exact (sometimes with the use of violence) payment of a tithe by the priest of a local church. Immediately after the tremor which hit Verona in 1117, Rodolfo was so scared for his life and soul that decided to renounce the tithe (Galli, 2005; Guidoboni and Poirier, 2004).

In light of the historical episodes described above, in the remainder of this section we offer econometric evidence that – in our sample of cities and years – the occurrence of a seismic event has a positive differential effect between Episcopal see and non-Episcopal see cities in the construction of religious buildings and the maintenance of their magnificence. All other factors being equal, this differential effect between the two groups of cities is likely to be the consequence of the bishop's ability to exploit his religious and political role and to take advantage from the occurrence of an earthquake, in order to boost the citizens' religiosity and deference to the Church.

V.B. Data Description

To run the exercise above described, we assemble an original dataset on religious buildings' construction and related ornamentation in the 1000-1300 period. We start by considering the data collected by the National Office for Ecclesiastical Cultural Assets and Information Services of the Association of Italian Catholic bishops (CEI - Conferenza Episcopale Italiana), which lists, for all the Italian cities, the existing churches and, for a number of them, registers the year in which the church was built and, possibly, renovated. In regard to northern-central Italy and the historical period under analysis, after uncertain dates of construction are discarded, this information is available for 194 events (146 in Episcopal see cities and 48 in non-Episcopal see cities). Since the CEI project is still ongoing and proceeds at different speeds for different dioceses and different cities, these data may be incomplete. Consequently, we augment the original database and proceed as follows. Starting from the list of churches provided by CEI, in the case of those for which the date of construction or further ornamentation was not reported, we obtain this information (whenever possible) from history books, journal articles, encyclopedia references, and other sources.[22] This effort enables us to augment the CEI dataset to including 663 additional church events (545 and 118 Episcopal see and non-Episcopal see cities, respectively). However, it might happen that a given city was reported as having no church by the CEI database because of slow registration or data collection by the local ecclesiastic administration. Hence, our analysis considers only the sub-sample of cities that, according to CEI, have at least one church. These cities number 97 (out of 121): 61 Episcopal see cities and 36 non-Episcopal see cities. Finally, for Episcopal see cities, we also collect data on the history of each cathedral from historical books and encyclopedias, and annotate its year of construction and further ornamentation (if any). Considering cathedrals, our extended dataset includes information on 681 events (563 and 118, respectively in the two groups of cities). Hence, we have three datasets of interest: the CEI dataset, the extended dataset (CEI and additional sources) that comprises only churches, and the extended dataset (CEI and additional sources) that includes both churches and cathedrals.[23]

V.C. Estimation and Results

To minimize noise in the annual data and provide evidence consistent with the main empirical patterns presented in previous sections, we adopt the aggregated version of our model (model (2); results reported in Table III). The model estimated differs only in the dependent variable, here capturing the religious building constructions and renovations, as we explain in greater detail below. Therefore, our regression model becomes:

$$religious\ buildings_{it} = \alpha_i + \tau_t + \delta_i \cdot t + \sum_{h=0}^{3} \beta_{-5h} \cdot quake_{-5h,it} + \sum_{h=0}^{3} \gamma_{-5h} \cdot bishop_i \cdot quake_{-5h,it} + \varepsilon_{it}, \quad (4)$$

where *religious buildings*$_{it}$ equals one if a new church (or cathedral) was registered or a substantial improvement of an existing church (or cathedral) was carried out in city i and at time t. The other variables are already known from model (2). Since we are interested in estimating the differential effect of an earthquake on religiosity (and the bishop's ability to

[22] Detailed sources are available from the authors upon request.

[23] Before transitions, the average numbers of religious building events (including churches and cathedrals) are 0.017 and 0.006 in Episcopal and non-Episcopal see cities, respectively. In the first five years following an earthquake these averages become, respectively in Episcopal and non-Episcopal see cities, 0.029 and 0.002 (*polygon* criterion), 0.025 and 0.005 (*epicenter* criterion), and 0.026 and 0.003 (*circles* criterion).

TABLE VI. EARTHQUAKES AND RELIGIOUS BUILDINGS

	CEI dataset: churches			*Extended dataset: churches*			*Extended dataset: churches and cathedrals*		
	Polygon	*Epicenter*	*Circles*	*Polygon*	*Epicenter*	*Circles*	*Polygon*	*Epicenter*	*Circles*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$Quake_{0,it}$ (β_0)	-0.0075**	-0.0028	-0.0070**	-0.0238***	-0.0150*	-0.0166***	-0.0237***	-0.0151*	-0.0165***
	(0.0030)	(0.0054)	(0.0032)	(0.0062)	(0.0084)	(0.0048)	(0.0062)	(0.0084)	(0.0048)
	[0.0034]	[0.0060]	[0.0051]	[0.0065]	[0.0076]	[0.0059]	[0.0065]	[0.0076]	[0.0059]
$Quake_{0,it} \times bishop_{0,it}$ (γ_0)	0.0124*	0.0041	0.0172*	0.0237*	0.0192*	0.0193	0.0237*	0.0188*	0.0194
	(0.0064)	(0.0056)	(0.0100)	(0.0132)	(0.0105)	(0.0190)	(0.0130)	(0.0105)	(0.0190)
	[0.0075]	[0.0047]	[0.0137]	[0.0133]	[0.0120]	[0.0166]	[0.0132]	[0.0120]	[0.0166]
$Quake_{-5,it}$ (β_{-5})	0.0008	-0.0015	-0.0003	-0.0114	-0.0157*	0.0007	-0.0113	-0.0159*	0.0008
	(0.0048)	(0.0042)	(0.0067)	(0.0073)	(0.0087)	(0.0104)	(0.0073)	(0.0087)	(0.0104)
	[0.0032]	[0.0028]	[0.0025]	[0.0061]	[0.0076]	[0.0066]	[0.0061]	[0.0076]	[0.0066]
$Quake_{-5,it} \times bishop_{-5,it}$ (γ_{-5})	-0.0016	-0.0019	0.0093	0.0019	-0.0023	0.0044	0.0018	-0.0026	0.0046
	(0.0072)	(0.0054)	(0.0070)	(0.0092)	(0.0073)	(0.0114)	(0.0092)	(0.0073)	(0.0114)
	[0.0080]	[0.0068]	[0.0107]	[0.0111]	[0.0090]	[0.0146]	[0.0112]	[0.0091]	[0.0146]
$Quake_{-10,it}$ (β_{-10})	-0.0025	-0.0012	-0.0013	-0.0119	-0.0142**	-0.0075	-0.0119	-0.0145**	-0.0075
	(0.0064)	(0.0046)	(0.0065)	(0.0077)	(0.0062)	(0.0074)	(0.0078)	(0.0062)	(0.0074)
	[0.0062]	[0.0042]	[0.0039]	[0.0073]	[0.0057]	[0.0049]	[0.0073]	[0.0057]	[0.0048]
$Quake_{-10,it} \times bishop_{-10,it}$ (γ_{-10})	0.0147	0.0116	0.0197	0.0232*	0.0209**	0.0279*	0.0229*	0.0203**	0.0281*
	(0.0097)	(0.0074)	(0.0147)	(0.0119)	(0.0095)	(0.0165)	(0.0120)	(0.0095)	(0.0165)
	[0.0100]	[0.0103]	[0.0140]	[0.0125]	[0.0110]	[0.0172]	[0.0125]	[0.0110]	[0.0172]
$Quake_{-15,it}$ (β_{-15})	-0.0009	0.0001	-0.0021	-0.0019	-0.0017	-0.0073*	-0.0020	-0.0000	-0.0072*
	(0.0017)	(0.0020)	(0.0026)	(0.0078)	(0.0059)	(0.0038)	(0.0078)	(0.0060)	(0.0038)
	[0.0029]	[0.0023]	[0.0048]	[0.0081]	[0.0066]	[0.0047]	[0.0081]	[0.0071]	[0.0047]
$Quake_{-15,it} \times bishop_{-15,it}$ (γ_{-15})	-0.0048*	-0.0073***	-0.0047	-0.0145	-0.0134*	0.0034	-0.0147	-0.0116	0.0033
	(0.0027)	(0.0021)	(0.0038)	(0.0093)	(0.0071)	(0.0114)	(0.0093)	(0.0074)	(0.0115)
	[0.0039]	[0.0041]	[0.0055]	[0.0111]	[0.0085]	[0.0115]	[0.0111]	[0.0092]	[0.0113]
R-squared	0.069	0.074	0.074	0.080	0.080	0.079	0.080	0.080	0.079

Notes. Estimation by OLS of model (4). Year fixed effects, city fixed effects, and city time trends always included. Number of observations = 17,852; number of cities = 97. The dependent variable, *religious buildings*, is =1 if in city *i* at time *t* a new religious building was registered or substantial renovation was carried out and =0 otherwise. The independent variable, *quake*, is =1 if an earthquake occurred in city *i* at time *t* and =0 otherwise. The subscripts "0", "-5", "-10", "-15" refer to the five-year lag (respectively: "from *t* to *t*-4", "from *t*-5 to *t*-9", "from *t*-10 to *t*-14", from "*t*-15 to *t*-19"). Conley's standard errors corrected for spatial dependence with threshold distance of 100 km are reported in round brackets; standard errors clustered at the city level are in squared brackets. *** = significant at 1%; ** = significant at 5%; * = significant at 10%. Statistical significance is indicated employing the Conley's standard errors.

take advantage of it) in the sample used in our previous regressions, we only use cities in the period preceding their transition to a commune (if any).[24]

The results are reported in Table VI for the three augmenting criteria, *polygon*, *epicenter*, and *circles*. Columns (1)-(2)-(3) refer to the CEI dataset, columns (4)-(5)-(6) consider the extended dataset for churches, and columns (7)-(8)-(9) show our output obtained on adopting the extended dataset for churches and cathedrals.

The interpretation of the estimated coefficients is similar to that given for Table III: the

[24] Note that our main results reported in Table III are robust when we only include the 97 cities employed in the estimation in this section.

β-coefficients refer to the effect of a seismic event on church building/ornamentation for the entire sample (Episcopal and non-Episcopal see cities), while the γ-coefficients capture the differential effect in Episcopal see cities. Our results are consistent across datasets and imputation criteria. As will be seen, controlling for year fixed effects, city fixed effects, and city specific time trends, in the first five years after an earthquake the β-coefficient is negative and (with only one exception) statistically significant at conventional levels, suggesting that the earthquake tends to retard or hinder the opening of new construction sites of religious buildings. One explanation is that a seismic event, besides influencing the religious beliefs, is likely to cause shocks to income or expectations on future streams of income, retarding the construction or the renovation of churches (and cathedrals). Importantly for our design, however, the estimated interaction effect between earthquake and bishop dummies in the first five years after an earthquake, the γ_0 coefficient, is positive and (most of the times) statistically significant, suggesting that in Episcopal see cities the effect is of lesser magnitude with respect to cities that were not seats of a bishop. Furthermore, the estimated coefficient on the interaction term points to an effect of earthquakes on religious building events for Episcopal see cities that is (with the opposite sign) equal to or greater than that for the non-Episcopal cities. In the Online Appendix A we also report our results obtained on using only data referring to entire buildings' constructions and excluding minor renovation works (Table A.5). Our conclusions remain substantially unchanged.

VI. Concluding Remarks

In this paper, we have documented that earthquakes retarded the transition to communal institutions in Italian cities ruled by religious-political leaders. We did not find such an effect for Italian cities ruled by feudal lords. Our explanation of these results hinges on the role of the religious leader in dealing with disorder after the crisis. In the Middle Ages, the Earth's tremors were mysterious and frightening events: they provoked panic, consternation, and disorder among the population. In a context of scant civic capital and substantial coordination problems, social order could only be restored by a strong leader. In the Episcopal cities, the seismic events fortified the power of the bishops, who were simultaneously political and religious leaders. Since, in our period of interest, earthquakes were perceived by the population as manifestations of God's wrath against men, they can be interpreted as shocks to people's religiosity that reinforced the authority of the incumbent religious-political leaders and, consequently, hampered institutional change. Our interpretation is supported by ancillary evidence, also presented in the paper, that points to a positive impact of earthquakes on religious beliefs. Alternative explanations of our findings seem not to be particularly compelling (from both an empirical and historical point of view).

For example, an alternative explanation for the negative effect of earthquakes on the probability of transition to communal institutions is that, after a seismic event, people devoted their time to rebuilding their properties, thus diverting resources from the process of institutional change. Although plausible, in our case this interpretation would not be consistent with two facts: first, the impact of an earthquake on the probability of an institutional transition to a commune holds for Episcopal cities but not for cities that were not seats of a bishop; second, this effect operated even if the earthquake was only felt by people without causing any physical damage or deaths.

Our findings highlight the important role played by cultural factors, such as religiosity, in affecting institutional change, and they account for the observation that political institutions controlled by religiously connected leaders have historically proven to be stable. For instance, Ancient Egypt under the rule of the pharaohs, China under the Han dynasty, the Roman Empire, the Papal State in central Italy until the late nineteenth century, the Meiji empire in Japan, and the ayatollah's supreme leadership in Iran were all long-lasting regimes in which the political leader and the religious leader were one and the same person. Some scholars have maintained that religion plays a crucial role in the resilience of political regimes (e.g. North, Wallis, and Weingast, 2009). Niccolo Machiavelli (1532) argued that religiosity is able to support political stability and ensure social order. On discussing how the sovereign can ensure his power, Machiavelli drew a distinction between ecclesiastical and other principates: in the former, he stated, power is relatively easier to maintain, since the prince can rely on popular support based on religious feelings.

Whilst our paper has focused on a particular historical episode, the mechanisms uncovered may prove important in other historical contexts as well, and their implications call for further investigation in broader settings. Of course, our contribution cannot shed full light on such vast phenomena, nor does it have any ambition to do so. Nonetheless, the findings presented in this paper point to the existence of mechanisms that, to the best of our knowledge, are still largely unexplored in the economic literature and have implications that warrant further exploration.

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Online Appendix A

Table A.1. Including Earthquakes with Unreported Intensity

	Earthquakes with reported intensity (Main results - Table 3)			*Earthquakes with reported and unreported intensity*		
	Polygon	*Epicenter*	*Circles*	*Polygon*	*Epicenter*	*Circles*
	(1)	(2)	(3)	(4)	(5)	(6)
$Quake_{0,it}$ (β_0)	0.0015	0.0017	0.0026**	-0.0001	-0.0003	0.0014
	(0.0011)	(0.0012)	(0.0010)	(0.0013)	(0.0013)	(0.0013)
	[0.0009]	[0.0010]	[0.0009]	[0.0011]	[0.0012]	[0.0010]
$Quake_{0,it} \times bishop_{0,it}$ (γ_0)	-0.0085***	-0.0062***	-0.0099***	-0.0076***	-0.0057***	-0.0083***
	(0.0028)	(0.0019)	(0.0034)	(0.0024)	(0.0018)	(0.0031)
	[0.0023]	[0.0016]	[0.0027]	[0.0020]	[0.0016]	[0.0025]
$Quake_{-5,it}$ (β_{-5})	0.0001	-0.0003	0.0011	-0.0011	-0.0021	-0.0003
	(0.0016)	(0.0018)	(0.0015)	(0.0019)	(0.0021)	(0.0019)
	[0.0015]	[0.0018]	[0.0015]	[0.0015]	[0.0018]	[0.0016]
$Quake_{-5,it} \times bishop_{-5,it}$ (γ_{-5})	0.0023	-0.0011	-0.0049	-0.0008	-0.0017	-0.0050
	(0.0062)	(0.0037)	(0.0057)	(0.0046)	(0.0033)	(0.0049)
	[0.0065]	[0.0037]	[0.0058]	[0.0046]	[0.0032]	[0.0048]
$Quake_{-10,it}$ (β_{-10})	0.0001	0.0009	0.0043	-0.0002	-0.0006	0.0024
	(0.0032)	(0.0027)	(0.0033)	(0.0020)	(0.0020)	(0.0024)
	[0.0036]	[0.0032]	[0.0038]	[0.0022]	[0.0023]	[0.0026]
$Quake_{-10,it} \times bishop_{-10,it}$ (γ_{-10})	-0.0049	-0.0014	-0.0066	-0.0046	-0.0026	-0.0063
	(0.0046)	(0.0037)	(0.0066)	(0.0041)	(0.0033)	(0.0053)
	[0.0048]	[0.0040]	[0.0073]	[0.0041]	[0.0034]	[0.0055]
$Quake_{-15,it}$ (β_{-15})	-0.0001	-0.0010	0.0034	-0.0001	-0.0008	0.0020
	(0.0031)	(0.0029)	(0.0039)	(0.0023)	(0.0023)	(0.0032)
	[0.0037]	[0.0028]	[0.0035]	[0.0026]	[0.0021]	[0.0027]
$Quake_{-15,it} \times bishop_{-15,it}$ (γ_{-15})	-0.0026	0.0005	0.0031	-0.0025	0.0004	0.0053
	(0.0079)	(0.0052)	(0.0120)	(0.0061)	(0.0047)	(0.0098)
	[0.0070]	[0.0053]	[0.0102]	[0.0057]	[0.0048]	[0.0089]
R-squared	0.054	0.054	0.054	0.054	0.054	0.054

Notes. Estimation by OLS of model (2). Year fixed effects, city fixed effects, and city time trends always included. Number of observations = 23,972; number of cities = 121. The dependent variable, *transition*, is =1 if city *i* became a commune at time *t* and =0 otherwise. The independent variable, *quake*, is =1 if an earthquake occurred in city *i* at time *t* and =0 otherwise. The subscripts "0", "-5", "-10", "-15" refer to the five-year lag (respectively: "from *t* to *t*-4", "from *t*-5 to *t*-9", "from *t*-10 to *t*-14", from "*t*-15 to *t*-19"). Conley's standard errors corrected for spatial dependence with threshold distance of 100 km are reported in round brackets; standard errors clustered at the city level are in squared brackets. *** = significant at 1%; ** = significant at 5%; * = significant at 10%. Statistical significance is indicated employing the Conley's standard errors. Columns (1)-(2)-(3) report results from Table III in the paper. Columns (4)-(5)-(6) report estimation output on employing an augmented dataset (three criteria) that also includes earthquakes with unreported intensity.

TABLE A.2. ALTERNATIVE THRESHOLD DISTANCE FOR CONLEY'S S.E.

	All earthquakes			*Only destructive earthquakes*		
	Polygon	*Epicenter*	*Circles*	*Polygon*	*Epicenter*	*Circles*
	(1)	(2)	(3)	(4)	(5)	(6)
$Quake_{0,it}$ (β_0)	0.0015	0.0017	0.0026***	0.0025*	0.0043***	0.0022**
	(0.0012)	(0.0012)	(0.0009)	(0.0014)	(0.0016)	(0.0011)
	[0.0009]	[0.0011]	[0.0010]	[0.0014]	[0.0016]	[0.0011]
$Quake_{0,it} \times bishop_{0,it}$ (γ_0)	-0.0085***	-0.0062***	-0.0099***	-0.0158***	-0.0092***	-0.0121***
	(0.0029)	(0.0020)	(0.0027)	(0.0056)	(0.0030)	(0.0044)
	[0.0025]	[0.0017]	[0.0034]	[0.0058]	[0.0030]	[0.0045]
$Quake_{-5,it}$ (β_{-5})	0.0001	-0.0003	0.0011	0.0007	0.0035*	0.0009
	(0.0014)	(0.0017)	(0.0015)	(0.0019)	(0.0021)	(0.0015)
	[0.0012]	[0.0014]	[0.0015]	[0.0017]	[0.0018]	[0.0012]
$Quake_{-5,it} \times bishop_{-5,it}$ (γ_{-5})	0.0023	-0.0011	-0.0049	0.0034	0.0036	-0.0053
	(0.0054)	(0.0032)	(0.0058)	(0.0126)	(0.0065)	(0.0068)
	[0.0045]	[0.0028]	[0.0057]	[0.0119]	[0.0054]	[0.0068]
$Quake_{-10,it}$ (β_{-10})	0.0001	0.0009	0.0043	0.0041	0.0024	0.0049
	(0.0033)	(0.0026)	(0.0038)	(0.0046)	(0.0043)	(0.0040)
	[0.0035]	[0.0028]	[0.0033]	[0.0051]	[0.0051]	[0.0043]
$Quake_{-10,it} \times bishop_{-10,it}$ (γ_{-10})	-0.0049	-0.0014	-0.0066	-0.0058	-0.0057	-0.0084
	(0.0044)	(0.0037)	(0.0073)	(0.0111)	(0.0057)	(0.0080)
	[0.0044]	[0.0035]	[0.0066]	[0.0114]	[0.0060]	[0.0082]
$Quake_{-15,it}$ (β_{-15})	-0.0001	-0.0010	0.0034	0.0031	0.0126***	0.0046
	(0.0027)	(0.0021)	(0.0035)	(0.0055)	(0.0048)	(0.0042)
	[0.0017]	[0.0019]	[0.0039]	[0.0047]	[0.0042]	[0.0040]
$Quake_{-15,it} \times bishop_{-15,it}$ (γ_{-15})	-0.0026	0.0005	0.0031	0.0126	0.0072	0.0053
	(0.0034)	(0.0038)	(0.0102)	(0.0165)	(0.0079)	(0.0107)
	[0.0041]	[0.0036]	[0.0120]	[0.0160]	[0.0079]	[0.0104]
R-squared	0.054	0.054	0.054	0.054	0.055	0.054

Notes: Estimation by OLS of model (2). Year fixed effects, city fixed effects, and city time trends always included. Number of observations = 23,972; number of cities = 121. The dependent variable, *transition*, is =1 if city *i* became a commune at time *t* and =0 otherwise. The independent variable, *quake*, is =1 if an earthquake occurred in city *i* at time *t* and =0 otherwise. The subscripts "0", "-5", "-10", "-15" refer to the five-year lag (respectively: "from *t* to *t*-4", "from *t*-5 to *t*-9", "from *t*-10 to *t*-14", from "*t*-15 to *t*-19"). Conley's standard errors corrected for spatial dependence with threshold distance of 200 (500) km are reported in round (squared) brackets. *** = significant at 1%; ** = significant at 5%; * = significant at 10%. Statistical significance is indicated employing the Conley's standard errors with threshold distance of 200 km.

TABLE A.3. ALTERNATIVE THRESHOLD DISTANCE FOR CONLEY'S S.E. – INTENSITY

	Polygon			*Epicenter*			*Circles*		
	Damage	*Felt*	*F-test* (*P-value*)	*Damage*	*Felt*	*F-test* (*P-value*)	*Damage*	*Felt*	*F-test* (*P-value*)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$Quake_{0,it}$ (β_0)	0.0006	0.0017		0.0006	0.0019		0.0017*	0.0026**	
	(0.0008)	(0.0013)		(0.0008)	(0.0013)		(0.0009)	(0.0011)	
	[0.0007]	[0.0011]		[0.0010]	[0.0011]		[0.0008]	[0.0011]	
$Quake_{0,it} \times bishop_{0,it}$ (γ_0)	-0.0156**	-0.0070***		-0.0155**	-0.0053***		-0.0163**	-0.0073**	
	(0.0069)	(0.0027)	(0.203)	(0.0068)	(0.0019)	(0.127)	(0.0070)	(0.0032)	(0.191)
	[0.0070]	[0.0024]	[0.220]	[0.0069]	[0.0017]	[0.137]	[0.0072]	[0.0030]	[0.193]
$Quake_{-5,it}$ (β_{-5})	0.0002	0.0001		-0.0008	-0.0003		0.0010	0.0011	
	(0.0009)	(0.0017)		(0.0010)	(0.0018)		(0.0010)	(0.0015)	
	[0.0007]	[0.0014]		[0.0009]	[0.0020]		[0.0008]	[0.0012]	
$Quake_{-5,it} \times bishop_{-5,it}$ (γ_{-5})	0.0018	0.0023		0.0018	-0.0015		0.0000	-0.0071**	
	(0.0174)	(0.0060)	(0.979)	(0.0174)	(0.0034)	(0.857)	(0.0178)	(0.0033)	(0.694)
	[0.0171]	[0.0053]	[0.979]	[0.0171]	[0.0031]	[0.857]	[0.0175]	[0.0033]	[0.688]
$Quake_{-10,it}$ (β_{-10})	0.0005	0.0001		0.0000	0.0010		0.0015	0.0046	
	(0.0011)	(0.0037)		(0.0013)	(0.0029)		(0.0011)	(0.0036)	
	[0.0009]	[0.0040]		[0.0014]	[0.0035]		[0.0009]	[0.0039]	
$Quake_{-10,it} \times bishop_{-10,it}$ (γ_{-10})	-0.0151*	-0.0030		-0.0133	-0.0005		-0.0151*	-0.0029	
	(0.0089)	(0.0053)	(0.285)	(0.0091)	(0.0041)	(0.220)	(0.0090)	(0.0084)	(0.381)
	[0.0090]	[0.0052]	[0.625]	[0.0091]	[0.0039]	[0.228]	[0.0091]	[0.0086]	[0.378]
$Quake_{-15,it}$ (β_{-15})	-0.0049	0.0009		-0.0050	-0.0003		-0.0028	0.0043	
	(0.0043)	(0.0029)		(0.0038)	(0.0024)		(0.0039)	(0.0039)	
	[0.0040]	[0.0015]		[0.0037]	[0.0033]		[0.0035]	[0.0036]	
$Quake_{-15,it} \times bishop_{-15,it}$ (γ_{-15})	0.0034	-0.0038*		0.0038	-0.0001		0.0026	0.0045	
	(0.0164)	(0.0023)	(0.658)	(0.0164)	(0.0037)	(0.815)	(0.0166)	(0.0085)	(0.920)
	[0.0174]	[0.0028]	[0.672]	[0.0173]	[0.0035]	[0.824]	[0.0175]	[0.0081]	[0.919]
R-squared		0.054			0.054			0.054	

Notes: Estimation by OLS of model (3). Year fixed effects, city fixed effects, and city time trends always included. Number of observations = 23,972; number of cities = 121. The dependent variable, *transition*, is =1 if city *i* became a commune at time *t* and =0 otherwise. The independent variable, *quake*, is =1 if an earthquake occurred in city *i* at time *t* and =0 otherwise. *Damage* indicates earthquakes with intensity between 6 and 10 (physical damage to people or objects); *felt* denotes events with intensity between 2 and 5 (no physical damage). The subscripts "0", "-5", "-10", "-15" refer to the five-year lag (respectively: "from *t* to *t*-4", "from *t*-5 to *t*-9", "from *t*-10 to *t*-14", from "*t*-15 to *t*-19"). Conley's standard errors corrected for spatial dependence with threshold distance of 200 (500) km are reported in round (squared) brackets. *** = significant at 1%; ** = significant at 5%; * = significant at 10%. Statistical significance is indicated employing the Conley's standard errors with threshold distance of 200 km. In columns (3)-(6)-(9) we report the *p*-values for the *F*-test that $\gamma^P=\gamma^F$ (null hp) computed employing Conley's (clustered) standard errors in round (squared) brackets.

TABLE A.4. CONDITIONAL LOGIT

	Episcopal see cities			*non-Episcopal see cities*		
	Polygon	*Epicenter*	*Circles*	*Polygon*	*Epicenter*	*Circles*
	(1)	(2)	(3)	(4)	(5)	(6)
$Quake_{0,it}$	-12.5595***	-13.5681***	-12.5526***	-13.7522***	-13.6544***	-12.0687***
	(0.2392)	(0.1965)	(0.3535)	(0.3076)	(0.2628)	(0.7507)
$Quake_{-5,it}$	1.3016*	0.8542	0.7971	-13.7522***	-13.6544***	-12.0687***
	(0.6700)	(0.6287)	(1.0928)	(0.3076)	(0.2628)	(0.7507)
$Quake_{-10,it}$	0.1699	0.6762	0.7721	0.6376	0.2591	3.1049*
	(1.0334)	(0.6346)	(1.0752)	(1.0991)	(1.0468)	(1.6263)
$Quake_{-15,it}$	1.2854**	1.2611**	1.9000**	1.3553*	0.9697	3.1573**
	(0.6526)	(0.5367)	(0.7407)	(0.8011)	(0.7862)	(1.5420)
Observations	6,067	6,067	6,067	3,319	3,319	3,319
R-squared	0.017	0.021	0.015	0.023	0.020	0.033
Cities	50	50	50	20	20	20

Notes: Estimation by conditional logit (grouped by cities) of model (2) in the paper. The dependent variable, *transition*, is =1 if city *i* became a commune at time *t* and =0 otherwise. The independent variable, *quake*, is =1 if an earthquake occurred in city *i* at time *t* and =0 otherwise. Standard errors clustered at the city level are reported in parentheses. *** significant at 1%; ** significant at 5%; * significant at 10%. Model (2) is here estimated separately for Episcopal and non-Episcopal cities in order to avoid interaction terms, since the estimated coefficients on interaction terms in non-linear models may turn out biased (Ai and Norton, 2003). The table reports coefficients from the conditional logit model and not the marginal effects, since estimation of the latter would be problematic (see Wooldridge, 2002). Finally, it is worth noting that the results for non-Episcopal cities are based on 20 cities and suggest a negative effect of the earthquake on the transition probability. These findings are driven by the absence of year fixed effects, since for this group of cities we observe many periods in which an earthquake hit most of the cities and no transition occurred. Furthermore, the point estimates cannot be compared across groups of cities without information on the distribution of the fixed effects (Wooldridge, 2002).

TABLE A.5. EARTHQUAKES AND RELIGIOUS BUILDINGS (NO ORNAMENTATIONS)

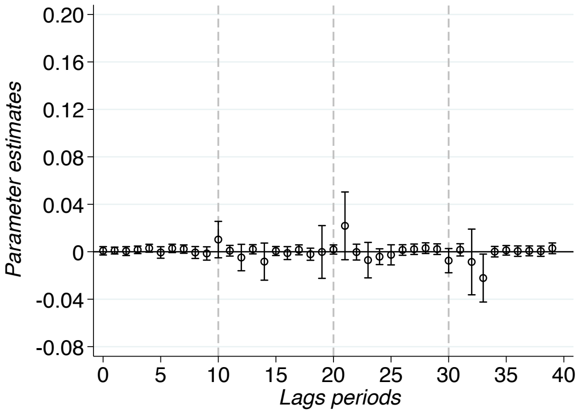
	CEI dataset: churches			*Extended dataset: churches*			*Extended dataset: churches and cathedrals*		
	Polygon	*Epicenter*	*Circles*	*Polygon*	*Epicenter*	*Circles*	*Polygon*	*Epicenter*	*Circles*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$Quake_{0,it}$ (β_0)	-0.0076**	-0.0028	-0.0070**	-0.0229***	-0.0133*	-0.0161***	-0.0229***	-0.0133*	-0.0162***
	(0.0030)	(0.0054)	(0.0032)	(0.0057)	(0.0079)	(0.0046)	(0.0057)	(0.0079)	(0.0046)
	[0.0035]	[0.0060]	[0.0051]	[0.0065]	[0.0075]	[0.0058]	[0.0065]	[0.0075]	[0.0058]
$Quake_{0,it} \times bishop_{0,it}$ (γ_0)	0.0127**	0.0044	0.0177*	0.0215**	0.0188**	0.0137	0.0211**	0.0187**	0.0136
	(0.0064)	(0.0056)	(0.0100)	(0.0106)	(0.0093)	(0.0141)	(0.0106)	(0.0093)	(0.0141)
	[0.0077]	[0.0049]	[0.0140]	[0.0129]	[0.0119]	[0.0157]	[0.0129]	[0.0119]	[0.0157]
$Quake_{-5,it}$ (β_{-5})	0.0008	-0.0014	-0.0004	-0.0116	-0.0153**	0.0004	-0.0116	-0.0153*	0.0004
	(0.0048)	(0.0043)	(0.0067)	(0.0072)	(0.0086)	(0.0103)	(0.0072)	(0.0086)	(0.0103)
	[0.0032]	[0.0028]	[0.0025]	[0.0060]	[0.0076]	[0.0065]	[0.0060]	[0.0076]	[0.0065]
$Quake_{-5,it} \times bishop_{-5,it}$ (γ_{-5})	-0.0012	-0.0015	0.0098	0.0034	-0.0001	0.0054	0.0031	-0.0002	0.0053
	(0.0072)	(0.0054)	(0.0070)	(0.0092)	(0.0072)	(0.0113)	(0.0092)	(0.0072)	(0.0113)
	[0.0083]	[0.0072]	[0.0112]	[0.0111]	[0.0092]	[0.0147]	[0.0111]	[0.0092]	[0.0147]
$Quake_{-10,it}$ (β_{-10})	-0.0015	0.0003	-0.0010	-0.0108	-0.0138**	-0.0061	-0.0112	-0.0144**	-0.0063
	(0.0064)	(0.0045)	(0.0065)	(0.0072)	(0.0059)	(0.0070)	(0.0072)	(0.0060)	(0.0070)
	[0.0060]	[0.0034]	[0.0039]	[0.0071]	[0.0052]	[0.0049]	[0.0071]	[0.0052]	[0.0049]
$Quake_{-10,it} \times bishop_{-10,it}$ (γ_{-10})	0.0111	0.0094	0.0136	0.0154	0.0145*	0.0141	0.0146	0.0142*	0.0139
	(0.0095)	(0.0073)	(0.0143)	(0.0115)	(0.0084)	(0.0159)	(0.0115)	(0.0084)	(0.0159)
	[0.0085]	[0.0100]	[0.0109]	[0.0112]	[0.0110]	[0.0146]	[0.0113]	[0.0110]	[0.0146]
$Quake_{-15,it}$ (β_{-15})	-0.0011	0.0001	-0.0021	-0.0016	-0.0014	-0.0071*	-0.0018	-0.0015	-0.0070*
	(0.0017)	(0.0019)	(0.0026)	(0.0078)	(0.0058)	(0.0038)	(0.0078)	(0.0058)	(0.0038)
	[0.0029]	[0.0023]	[0.0048]	[0.0080]	[0.0066]	[0.0048]	[0.0080]	[0.0066]	[0.0048]
$Quake_{-15,it} \times bishop_{-15,it}$ (γ_{-15})	-0.0044*	-0.0068***	-0.0042	-0.0133	-0.0118*	0.0036	-0.0138	-0.0120*	0.0034
	(0.0026)	(0.0021)	(0.0036)	(0.0093)	(0.0071)	(0.0113)	(0.0093)	(0.0071)	(0.0112)
	[0.0036]	[0.0038]	[0.0051]	[0.0107]	[0.0082]	[0.0111]	[0.0107]	[0.0082]	[0.0111]
R-squared	0.071	0.071	0.071	0.075	0.075	0.073	0.076	0.076	0.075

Notes: Estimation by OLS of model (4). Year fixed effects, city fixed effects, and city time trends always included. Number of observations = 17,852; number of cities = 97. The dependent variable, *religious buildings*, is =1 if in city *i* at time *t* a new religious building was registered and =0 otherwise. The independent variable, *quake*, is =1 if an earthquake occurred in city *i* at time *t* and =0 otherwise. The subscripts "0", "-5", "-10", "-15" refer to the five-year lag (respectively: "from *t* to *t*-4", "from *t*-5 to *t*-9", "from *t*-10 to *t*-14", from "*t*-15 to *t*-19"). Conley's standard errors corrected for spatial dependence with threshold distance of 100 km are reported in round brackets; standard errors clustered at the city level are in squared brackets. *** = significant at 1%; ** = significant at 5%; * = significant at 10%. Statistical significance is indicated employing the Conley's standard errors.

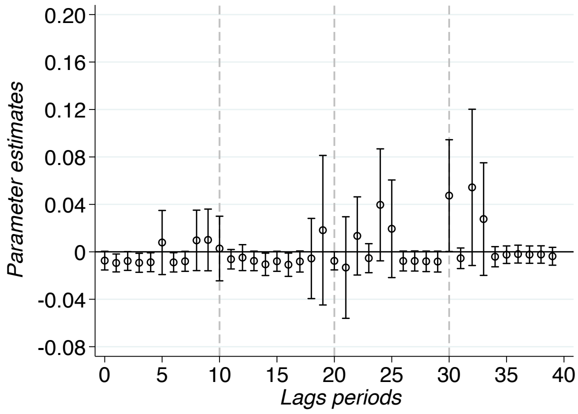
FIGURES A.1. LAGS (40 YEARS)

A.1A. *POLYGON* CRITERION

Effect on non-Episcopal see cities (β)

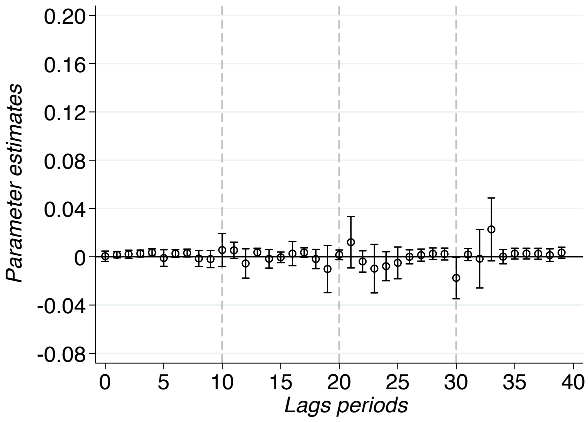


Differential effect on Episcopal see cities (γ)

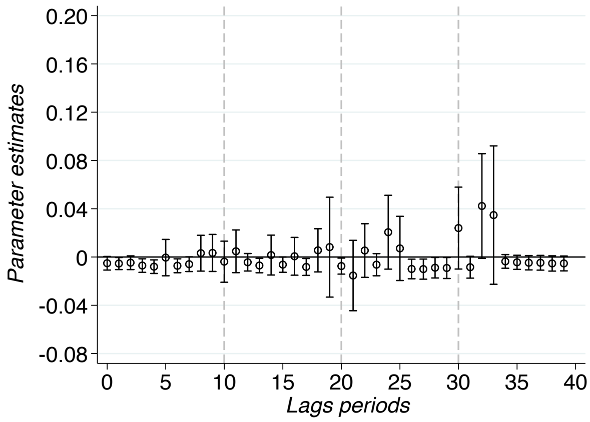


A.1B. *EPICENTER* CRITERION

Effect on non-Episcopal see cities (β)

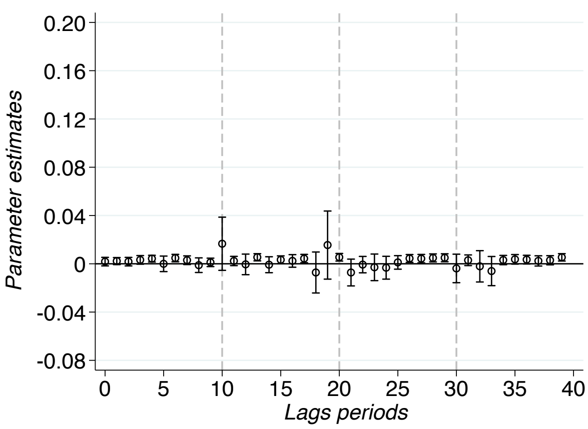


Differential effect on Episcopal see cities (γ)

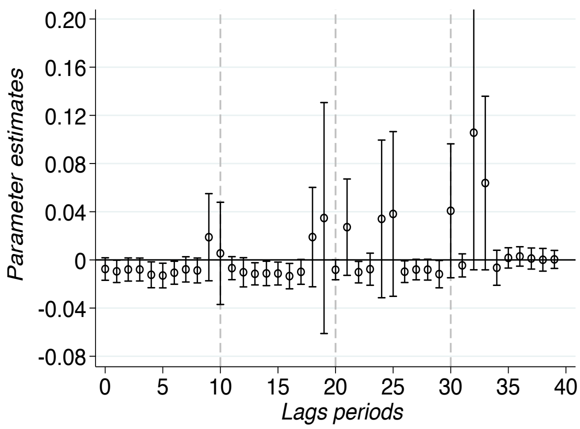


A.1C. *CIRCLES* CRITERION

Effect on non-Episcopal see cities (β)



Differential effect on Episcopal see cities (γ)



Notes: Estimated β- and γ-coefficients by OLS of model (1) with 40 lags. Year fixed effects, city fixed effects, and city time trends always included. The dependent variable, *transition*, is =1 if city *i* became a commune at time *t* and =0 otherwise. The independent variable, *quake*, is =1 if an earthquake occurred in city *i* at time *t* and =0 otherwise. The confidence intervals are computed employing Conley's standard errors corrected for spatial dependence with threshold distance of 100 km.