Earthquakes, Religion, and Institutional Change: Evidence from a Historical Experiment[*]

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Abstract

For a panel of 60 Episcopal see cities (governed by a bishop) over 300 years in the medieval northern-central Italy, we document that occurrence of an earthquake retarded transition from feudal regime to commune. This evidence is consistent with the idea that shocks heightening people's religiosity, by temporarily increasing the fixed cost of an uprising for those contesting the *status quo* regime, retard institutional change when the incumbent political leader is also the religious authority. This interpretation is corroborated by the historical evidence and by a number of additional empirical findings. First, the negative effect of the earthquake is independent of the earthquake's intensity. Second, it holds even if the earthquake did not result in any physical damage to people or buildings but was simply felt by the population. Third, the negative impact of earthquakes on transitions is not observed in the group of non-Episcopal cities, where the communal movement was also under way in the period considered.

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1. Introduction

The relation between religion and politics has historically played a key role in shaping the evolution of political regimes and their stability. Ancient Egypt under the rule of the pharaohs, China under the Han dynasty, the State of the Church in central Italy up to the late 19th century and Khomeini's Supreme leadership in Iran are all regimes in which political leaders and religious leaders coincide. Even when the political and religious authorities are formally distinct, religion can affect political regimes (e.g. Barro, 1999; Chaney, 2011). In particular, close connection between religious and political leaders may support political stability. This view is maintained, for instance, by Niccolo Machiavelli ("The Prince" (2005 (1532), ch. 11) who, discussing how the sovereign can ensure his power, makes a distinction between the Ecclesiastical and the other principates. Once the former are founded, he states, power is relatively easy to maintain, since the prince can count on popular support based on religious feelings.[1] From this insight it follows that, *ceteris paribus*, regimes governed by political-religious leaders should be more difficult to overturn in the consequence of shocks that heighten people's religiosity.

Testing this conjecture, and disentangling the channels along which the above mechanisms may work, is of course challenging. In the ideal experiment, we would observe political regimes characterized by a correspondence between political and religious authorities in a period of potential institutional change, in which the incumbent leaders are threatened and possibly overturned by the secular elites. We would also observe exogenous shocks affecting the people's religiosity and assess whether or not these shocks, in turn, strengthen the *status quo* political regime.

The ideal setting outlined above is to be seen in northern and central Italy between the 11th and the 13th centuries. In this period, Italian cities witnessed a process of profound change in political and institutional configurations, known as the communal movement, in which the power of the incumbent feudal leaders was challenged and, often replaced, by the bourgeois elite. In the *status quo* feudal regime, the political leader was either the bishop, in the Episcopal see cities, or the feudal lord, in the non-Episcopal see cities. In the former, the bishops were at the same time political leaders, monopolists in the provision of religious services and the supreme religious authorities. In the *status quo* regime they ruled, *de facto* and *de jure*, free of checks and balances. The transition from the feudal regime to the emergence of the commune represented a

[1] "It only remains now to speak of ecclesiastical principalities […]. These princes alone have states and do not defend them, they have subjects and do not rule them; and the states, although unguarded, are not taken from them, and the subjects, although not ruled, do not care, and they have neither the desire nor the ability to alienate themselves. Such principalities only are secure and happy." Machiavelli, *The Prince*, Ch. 11.

remarkable improvement in political and economic institutions. In the communal system, the political power was checked by constitutional limitations and representative assemblies. Hence, the process conducing to the birth of a commune implied the emergence of tension between the bishop and the new urban elite contesting the *status quo* regime and pursuing institutional change. As we document in section 3 with historical evidence, this tension resulted in a potential conflict between the incumbent political and religious leader and the emerging bourgeoisie.

The exogenous shock to the people's religiosity is offered in our context by the occurrence of an earthquake. During the Middle Ages, in Western Europe and in Italy in particular, the earthquake represented a mysterious and unforeseeable event men could only account for as a manifestation of God's wrath. This conviction was widespread and was maintained at least until the Enlightenment (Guidoboni, 2000; Guidoboni and Poirier, 2004; Nur and Borgess, 2008; Schenk, 2010). After an earthquake, the peoples' common reaction was panic, consternation, and an immediate urge for reconciliation with God. As amply documented in the following sections, this resulted in a sudden increase in participation in (and thus an increase in the demand for) religious services, such as collective prayers and fasts. Consistent with the idea that earthquakes represent a shock to religiosity, we document (subsection 3.6) that in the Italian cities the number of existing churches today (including all the churches built in the past up to nowadays) positively correlates with the number of earthquakes that occurred in the medieval period, controlling for the number of earthquakes that occurred in different periods, population and regional fixed effects.

Our analysis is conducted on a unique large panel dataset, specially constructed for the purpose. Starting from the sample of the largest cities in northern-central Italy for which reliable historical documents on the communal experience are available, we collected (various sources) information on the cities that were seat of a bishop (Episcopal see cities) before 1000, their political regime (either feudal or communal), the year when the change to communal institutions (if any) occurred and other city characteristics, such as whether or not it was on the sea and whether or not it was an Etruscan city. The transition to a commune is dated to the publication of the *statutum* and/or when the presence of the *consules* is testified by the historical sources (as explained in greater detail in section 3). These data are matched with information on the earthquakes (epicenter, time, intensity at the epicenter and at the locality in Mercalli-Cancani-Sieberg scale) that occurred in Italian cities in the period studied provided by the DBMI04 dataset (Database Macro Sismico Italiano, 2004), collected by researchers at the Italian National Institute for Geophysics and Volcanology (Stucchi et al., 2007). In particular, we work on seismic events reported in 105 locations between 1000 and 1300, and are able to distinguish between earthquakes for which physical damage to people, natural objects, buildings and other

man-made objects and the Earth's surface were reported, and earthquakes that did not result in material damage but were still felt by the population (this distinction is crucial, as will be evident shortly). In order to address potential concerns about possible unreported earthquakes due to missing or inaccurate historical sources, in the robustness checks we augment the dataset by assigning an earthquake to all the cities in the neighborhood of a city for which historical records were available documenting that an earthquake took place (subsection 4.4).

Exploiting the panel structure of the data, we document a strong negative empirical relationship between the occurrence of an earthquake and transition to commune status in the group of Episcopal see cities. An earthquake brings the probability of transition down to zero in the 10 and 20 years following the event. Our interpretation runs as follows. According to the Catholic tradition the bishop was a successor to the apostles and head of the local church (see, e.g., Benvenuti, 2010). In Episcopal see cities, the leader who held absolute political power in the city was, at the same time, the monopolist in the provision of religious services, the demand for which increased after the earthquake, and the intermediary between God and the people, who could possibly threaten the *status quo* political regime. In the case of potential conflict between the bishop and the classes attempting to upset the *status quo* political power, the occurrence of an earthquake may be interpreted as an exogenous shock affecting the people's religiosity and/or the demand for religious services, provision of which comes under the bishop's monopoly. This was likely to result in an increase in the cost of contesting the incumbent political power that was also held by the bishop.

A first potential concern to consider in the interpretation of our findings is that our results might be driven by the fact that an earthquake may be associated not only with a shock to religiosity but also with an income shock. This possibility is ruled out by the fact that the effect of an earthquake is independent of its intensity and of the amount of damage (if any) caused by it, meaning that its destructive power makes no difference. This suggests that the negative effect of an earthquake on the probability of transition should not depend on the material damage, increase in poverty, deaths or differential material impact it has on the social classes involved in the political transition. Furthermore, to corroborate our interpretation we produce evidence to show that earthquakes that did not result in physical damage to people or buildings, but were nevertheless felt by the population, also delayed institutional transition to the commune system. Figure 1 gives a graphical intuition of our key econometric findings. The average probability of transition to commune taking place in any decade within the sample period is higher for cities never hit by an earthquake before transition (if any) than for cities hit by at least one (*any*). The difference between average probabilities for the two groups of cities is practically the same should we consider earthquakes only felt by the population without causing any physical damage

(*just felt*) or destructive earthquakes (*damage*). This rough evidence is confirmed by the fixed effects regression analysis.

FIGURE 1 ABOUT HERE

Although this evidence tends to rule out the possibility that the effects of the earthquakes are driven by material factors, it is still possible that our findings are related to other non-religious factors such as fear or need to maintain the *status quo* in periods of potential catastrophe for reasons not related to religion. To exclude this possibility, we collect the same information included in the main dataset for the sample of the largest northern and central Italian cities that were not seats of bishops. In the medieval period, non-Episcopal see cities were normally governed by secular leaders (counts and marquises) and thus, in these cities, there was no correspondence between political and religious leaders. Our results show that an earthquake does not retard transitions to communal institutions when non-Episcopal see cities are considered. The effect is not statistically significant and very close to zero in magnitude.

Our interpretation that an earthquake, by causing a positive shock to religiosity, decreases the probability of the institutional change for cities ruled by a bishop is widely supported by the historical records. First, we document the existence of potential conflict between an incumbent bishop and those benefiting from the emergence of communal institutions. Second, we document the fact that in the Middle Ages God was considered the ultimate cause of earthquakes and other natural disasters, which were interpreted as manifestations of divine judgment. Moreover, we provide references to the central role of the bishop as the religious authority to protect the 'flock', and report several historical episodes that document an increase in demand for religious services following an earthquake or a natural disaster. Finally, we discuss a number of alternative explanations involving other factors possibly driving our results and find no compelling and consistent evidence (either historical or empirical) to support them.

The paper is structured as follows. Section 2 offers reference to the relevant literature, whereas section 3 describes the historical background. Section 4 provides data description. In section 5 we report the empirical strategy, results and a number of robustness checks. In section 6 we discuss our preferred interpretation of the results and evaluate possible alternative explanations. Section 7 concludes the paper. We also provide an appendix explaining the sample restriction and the data in greater detail.

2. Related Literature

There is increasing interest among economists in the role of religion[2] in affecting economic outcomes and political institutions. With regard to the former relation (religion and economic outcomes), Barro and McCleary (2003) and McCleary and Barro (2006) investigate the effects of country differences in religious beliefs and religion adherence on economic growth, while Becker and Woessman (2009) focus on the positive effects of Protestantism on economic prosperity, working through higher education. With regard to the latter relation (religion and institutional settings), Barro (1999) studies the relation between the primary religious affiliation of a country and its electoral rights indicator, interpreted as a degree of democracy; whereas Barro and McCleary (2005) adopt a political economy approach to study the determinants of the differences across nations in the probability of having state religion. Murphy and Shleifer (2004) point out the role of core issues (such as religious beliefs) in building social networks (such as political parties or religious coalitions) and, indirectly passing through the social network, in creating popular support for political leaders. We contribute to this literature by exploring how religion and correspondence between religious and political leaders account for the probability of institutional change and the stability of political regimes in the medieval period.

The relevance of our findings in the economic literature is also reinforced by historical research and economic studies (Coleman, 1999; Tabacco, 1989; Jones, 1997; Menant, 2005; DeLong and Shleifer, 1993) documenting that cities adopting communal institutions reached higher levels of urbanization and rates of growth than the cities governed by despotic political leaders. Furthermore, recent research suggests that communal institutions had a long-term impact on trust and social capital (Guiso, Sapienza and Zingales, 2008). More in general, Roland (2004), Tabellini (2008) and Greif and Tabellini (2010) point out the complementarity between values and beliefs (slow moving institutions in Roland's terminology), on the one hand, and political institutions (fast moving), on the other. This complementarity is key to an understanding of institutional dynamics. In our framework the stability and functioning of the political regime is rooted in the religious beliefs that support it. Exogenous shocks that strengthen religious convictions or, correspondingly, increase participation in religious services can impede or retard the institutional change that would otherwise be triggered by an ongoing process of institutional evolution (for discussion of the role of beliefs (culture) as a determinant of institutional persistence see also Nunn, 2012).

Chaney (2011), investigating the effects of economic and other shocks on the political power of religious leaders, seems to be the paper closest to ours. Using historical data, the author finds

[2] On the economics of religion see, among others, Iannaccone (1991) and Ekelund, and Tollison (2011).

that the probability of change in Egypt's most powerful religious authority decreased during deviant Nile floods. Based on historical records and empirical evidence on the construction of religious buildings (taken as a proxy of religious leaders' preferred policies), he argues that his main findings are consistent with the view that deviant Nile floods altered the balance of power in favor of the religious authority, whose political influence was rooted in their control of popular support. Unlike Chaney (2011), we are unable to provide a proxy measure of the popularity of the religious leaders (which, as we only infer from our empirical findings and the collected historical records, increases with the occurrence of natural disaster), but we are able to measure the impact of the shock on the actual institutional change, which is the outcome of particular interest to us. The historical experiment in this paper provides, to the best of our knowledge, the first suggestive example of how religion may interfere with political and institutional change.

Our findings also relate to the recent empirical literature on the effects of economic shocks on institutional change. For instance, Brückner and Ciccone (2011) find that negative rainfall shocks are followed by a significant improvement in democratic institutions in contemporary Sub-Saharan African countries. This result is consistent with the view that transitory negative shocks can open a window of opportunity for democratic improvement (Acemoglu and Robinson, 2001, 2006) since they decrease the opportunity-cost of an uprising for citizens contesting the *status quo* regime. Our findings show that the mechanism implied by the window of opportunity theory may even work in a more general context, in that the opportunity-cost of contesting the *status quo* for those excluded from political power can also be altered by further transitory shocks besides those affecting only material incentives. A natural disaster such as an earthquake is arguably a negative shock to income. However, since earthquakes temporarily also induce a positive shock to religiosity, rather than favoring a change in the current political regime they tend to favor the *status quo* by increasing the cost of contesting the political-religious leader.

3. Historical Background

3.1 *The Emergence of the Commune*

The process leading to the creation of the commune has been of much interest to economists, historians, and social and political scientists alike. By analyzing it we may further our understanding not only of the communal period but also of the general mechanisms underlying institutional change. The process started at the beginning of the 11th century in northern-central Italian cities that were formally part of the Holy Roman-German Empire. Cities in the empire

were governed by feudal lords or bishops. While in the 10th century feudal lords were officials appointed by and dependent on the emperors,[3] between 1000 and 1300 they became increasingly autonomous. In fact, a crucial characteristic of this period is the decline in the political influence of the German emperors' central authority on the fringes of the empire. As a consequence, the feudal lords' power over their territory came to encompass the social, political, judicial, and economic spheres (Bloch, 1961; Ascheri, 2009). The increasing importance of the feudal lords was favored by the establishment of a system of hereditary rules over the land allocated.[4] Seeking to limit to some extent their progressive loss of control over the Italian territory to the local feudal lords, the emperors clashed with the Pope to control the process of electing bishops in Episcopal see cities.[5] Bishops in Episcopal see cities filled the same role as feudal lords in non-Episcopal cities, and in fact came from the most important noble families of the cities. Formally, they were chosen by the local churches, but the elections were actually influenced by the emperors. Once elected, they were then appointed to local political and judicial offices. Unlike the non-religious feudal lords (counts or marquises), the bishops did not have the right to transfer their temporal power to their heirs. Thus, by controlling the nomination of bishops, emperors were able to appoint people they could trust and who could not transfer their power to their heirs.

At the local level, this period was also characterized by potential conflict emerging between political and economic actors. Starting from the 10th century, the northern and central Italian cities saw an increase in urbanization rates and in their economic importance. It was from this background that a *bourgeoisie* emerged. Despite their social and economic importance, before the birth of the commune, the members of this urban elite were excluded from the *de jure* power. Hence a potential conflict emerged between the *status quo* political leaders (local feudal lords or bishops), who wielded *de jure* power, and those belonging to the disenfranchised new-born urban elite, who started *de facto* to play a growing role in the life of the city. This historical setting fits in with the analytical framework presented by Galor, Moav and Vollrath (2009), in which an established elite faces the threat of an emerging entrepreneurial one.

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[3] Under the Carolingian empire, which preceded the Holy Roman-German Empire in the 10th century, feudal lords such as counts or marquises were officials appointed by the emperor. They were in charge of representing the emperor locally and benefitted from the rents on the allocated lands. After the end of Carolingian rule, the feudal lords began to secure a system of hereditary rule over their allocated land.

[4] With the *Quierzy Capitulary* in 877, the emperor Charles II assigned to the most important feudal lords the right to transfer their feuds to their heirs. In 1037 this right was extended to all feudal lords.

[5] Episcopal sees were mostly established during the 3rd and 4th centuries AD, following the spread of Christianity through the Roman Empire.

It was in this context that some members of the urban elite started to form groups of individuals who agreed in a *patto giurato* (sworn pact) to provide mutual help and cooperate on issues of common interest. Gradually, more stable institutions started to emerge and the citizens signing the pact began to become involved in government of the city.

This increase in the citizens' involvement in the political affairs of the city changed the institutional set-up of city government. The shift from the rule of the bishops or feudal lords to the commune implied a dramatic improvement in terms of citizen participation in the political sphere and the emergence of constitutional checks and balances. Government was exercised by the representatives of the commune in the name of all the citizens. In particular, city government was based on a general council of 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).[6] 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 contained some checks and balances as in contemporary democracies.

The commune represented the institutional evolution of a society of citizens that aimed at regulating their economic and social relations but were (before the transition to a commune) excluded from the *de jure power* of the city. It was in fact governed by both the *bourgeois* elite and the nobles living in the city, who had their main interests in the countryside. A peculiar characteristic of the Italian commune is the fact that, unlike free cities in Flanders and Germany, Italian cities became true city-states including territory extending beyond the city walls. Once constituted, the commune started imposing its rules on the countryside. Thus feudal lords owning lands in the territory of a communal city became subject to the city's law. Historians use the term 'conquest of the *contado*' (the territory surrounding the city) to describe this event (Coleman, 1999). The objective of the subjugation of the territory surrounding the communal city was to secure its trade routes, exploit its manpower for tax collection and military service, and extract its production for urban markets. In fact, the subjugation of the *contado* changed the balance of

[6] The *statuta* of the *consules* of the commune of Pistoia (1117) are the oldest documents of this kind that have reached modern times in their original form (whereas only copies of other similar documents have been handed down to the modern period), and offer an idea of the content of these constitutional documents. http://www.societapistoiesestoriapatria.it/P_ListaPagine.aspx?IDLibro=d6d732c6-095b-4e2d-9e7e-150d6a561901

power between the cities' commercial elites and the feudal aristocracy. Although they retained their private property, the feudal lords began to be taxed by the city.[7]

3.2 *The Bishop*

The bishop held religious power, and managed – and benefitted for life from – the property of the Cathedral (the church that was formally his see). He could also benefit from the exercise of local fiscal power and the rents on lands and other resources (Ascheri, 2009; Tabacco, 1987). Formally the bishop was elected by the local churches, but the elections were actually influenced by the emperors. In many circumstances bishops acted as officials of the Empire in northern-central Italy. The emperor granted them rights and power previously wielded by secular rulers (counts, marquises). The bishop came to serve as an advisor, judge, warlord and messenger of the emperor and was thus at the same time the head of the local church and the supreme political authority. This fact merits particular emphasis since (in northern-central Italy as in the rest of western Europe) the Catholic Church was in turn the monopolist in religion. There was no actual 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 without an Episcopal see, political power and religious services were more clearly separated, the former being held by feudal lords, the latter provided by several local representatives of the Catholic Church (e.g. parish priests or monks).

3.3 *The Bishop and the Commune*

The transition from Episcopal or feudal power to commune in the various cities followed different patterns. In some cities the transition was peaceful. For example, in Milan at the beginning of the commune period the bishop and the *consules* ruled the city together (Ascheri, 2009). In other cases the transition entailed a an explicit conflict, as in Mantua, where the emerging commune had to fight the powerful Marquises of Canossa, or in Cremona, where conflict broke out between the commune and the bishop from the very outset (Ascheri, 2009; Tabacco, 1987).

It is worth noting that, even in cases in which there was apparent cooperation between the incumbent feudal leaders and the emerging urban elite is calling for establishment of the

[7] With the conquest of the *contado* we thus observe an evolution in the balance of power in favour of the *bourgeoisie*. After the conquest of the *contado,* the commune acquired the power to tax the rural private property of the nobles. This (r)evolution was quantitatively very important: as Epstein (1993) records, for example, in the second half of the 14th century rural taxpayers were paying taxes from 2 to 4 times as much per capita as urban dwellers, which constituted a redistribution of wealth from country to town (Molho, 1971).

commune, the institutional change triggered potential conflict. The very fact of sharing the management of justice and the government of the city with the *consules* and the existence of a set of rules registered in the *statutum* implied severe limitation of the former leaders' power. Hence, the emergence of the commune entailed a loss of executive and judicial power for the bishop. This loss of power, however, was not limited to the public sphere but also involved the private domain: in fact, with the establishment and consolidation of the power of the communes, the cities started administering justice also over the lands privately owned by the bishop (Pellegrini, 2009; Nobili, 2011). Thus, with the establishment of the commune the bishop lost not only judicial and executive power over the city but also over those villages and lands surrounding the city that were private property of the cathedral and over which the bishop (like any feudal lord over his own lands) had absolute power. All in all the conflict between bishop and commune developed in two directions: control over the city and control, ancillary to the former, over the *contado* (Guyotjeannin, 1985).

The conflict over the administration of justice often resulted in formal juridical debate. In several cases the conflict was violent (Pellegrini, 2009). An example is offered by Cremona, one of the most important northern Italian cities at that time. During the 11th century the citizens of Cremona rose up against the bishop several times to expropriate the bishop of his judicial and fiscal power. A revolt is documented in 1035 in a letter of the Emperor Corradus II, who intervened in the dispute re-establishing the bishop's power. A further revolt led by the urban elite in the second half of the century was, however, successful, and the bishop was obliged to leave the city (Pellegrini, 2009). The first document identifying the presence of a free commune in Cremona is registered soon after in 1098.

Our second example is offered by Parma, where the conflict between the bishop and the commune is one of the best documented thanks to an intact document dating back to 1218. The document drawn up by the bishop's officials assembled the people's testimony for evidence in a judicial trial that the commune was illegally exercising judicial power over the bishop's private lands. The bishop, in particular, aimed to show that the commune was expropriating his rights over the management of waters and streets and his property rights over all the personal belongings of the people who died on his lands, including pilgrims (Albini, 2005; Guyotjeannin, 1985). In order to gain the upper hand in the conflict with the commune, the bishop resorted to his power to suspend religious services. Thus, Obizzo, the bishop of Parma, prohibited all clergymen of the city from blessing the *carroccio*[8] (Albini, 2005). A similar conflict over the exercise of judiciary power between the bishop and the commune occurred in Vercelli, as is

[8] The *carroccio* was a large vehicle bearing the city standard and used by Italian free cities as symbol of their independence during wars.

documented in a letter by Pope Gregory IX in 1235. As a consequence of this dispute, the bishop decided to excommunicate the council members of the commune (Baietto, 2002).

A further important element of conflict was of a fiscal nature. In fact, the commune started levying and collecting taxes, a prerogative that was previously held by the bishop who consequently lost an important source of revenue (Menziger, 2005, and Baietto, 2008). In 1280 in Reggio Emilia the commune established that people were no longer obliged to pay duties to the church, which had previously been collecting a ten percent income tax. Also in this case, the bishop reacted by excommunicating the members of the city council (Corradini, 1997). In 1219 the city of Ivrea witnessed a fierce dispute between the bishop and the commune over the right to raise the *salaria* (a sort of customs tax). The tension was such that the bishop asked the emperor to intervene and take a judicial decision (Baietto, 2002).

Overall, these episodes confirm the existence of tension that could potentially break out in violent conflict between bishops holding the *status quo* power and the urban elites newly admitted to the exercise of it over the city and the surrounding territory.

3.4 *Natural Disasters and Religiosity in the Middle Ages*

In this section we provide historical and empirical evidence suggesting the presence of the widespread belief that natural events were controlled by God and consistent with the idea that earthquakes caused an exogenous positive shock to religiosity (possibly associated with increasing participation in religious services) and further empowerment for the bishops.

In the Middle Ages, the belief that God is the ultimate cause of natural events (Le Goff, 1982) was rooted in biblical references to earthquakes, suggesting that such calamities were the result of God's pleasure or displeasure with men. This view was supported by popular thinkers among the early fathers of the Church. For example, Philastrius, bishop of Brescia in the 4th 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*".[9] Isidore of Seville, in his work "*De rerum natura*" maintained that earthquakes were originated by the spirit of God (*spirito oris Dei*) judging sinners (*iudicium peccatores*).[10] Thomas Aquinas, who represented the summation of medieval Christian philosophy, recognized God as the

[9] Authors' translation from: *Philastrius, De haeresibus liber*, in Banterle, G. (1991) *Delle varie eresie/San Filastrio Di Brescia. Trattati/San Gaudenzio di Brescia*, Citta Nuova, Roma.

[10] Isidore de Séville (1969), *Traité de la Nature*, in J. Fontaine, Bordeaux, Bibliothèque de l'École des Hautes Études Hispaniques, 28.

ultimate cause of earthquakes and, in line with Aristotle's thought, the wind driving into the earth as the physical means causing them.[11]

Saba Malaspina, a priest writing in the *Curia* of Pope Martin IV in the year 1280, described earthquakes as a sign of God's wrath (Schenk, 2010). Even in the *corpus iuris civilis*, the collection of legal rules written under the emperor Justinian, earthquakes are described as consequences of sins against God, such as blasphemy.[12]

The view that earthquakes were caused by God was confirmed in the Catholic liturgy. This was particularly true during the rogation days, the three days before Ascension Day, when people took part in processions and fasts and sang litanies praying God to protect them from plagues and earthquakes. These rogation days were introduced in 463 AD by Mamertus, bishop of Vienne, in France subsequent to an earthquake, and were extended to all the Catholic Church by the council of Orleans in 511 AD (Geary, 2010).

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 Ottonis, bishop of Bamberg in Germany, reports that in 1117 an earthquake occurred because of the people's sins and that the Earth was fighting for God against the 'unwise'.[13] This view persisted in Europe at least up to the Enlightenment. A breaking point came with the earthquake that almost totally destroyed Lisbon in 1755. This event was still seen by some as a manifestation of divine judgment,[14] but most thinkers started to reject such an idea.[15]

3.5 *The Peoples' Reaction After an Earthquake*

Given this widespread belief, the peoples' common reaction after an earthquake was panic. Significantly, people were also frightened by earthquakes that did not cause physical damage. For example, the chronicles report that in 1279 an earthquake with epicenter in the Umbria-

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[11] See Guidoboni and Poirier (2004).

[12] Rudolf Schoell (1895) ed., *Corpus iuris civilis* vol. III, in *Novellae*, Berolini, Weidmann.

[13] Ebbo, P.J. (1869) *Ebonis Vita Ottonis Episcopi Bambergensis*, Berolini: Apud Weidmannos.

[14] "*Will you say, in seeing this mass of victims: "God is revenged, their death is the price for their crimes?" What crime, what error did these children, Crushed and bloody on their mothers' breasts, commit? Did Lisbon, which is no more, have more vices Than London and Paris immersed in their pleasures? Lisbon is destroyed, and they dance in Paris!*" Voltaire: Poem on the Lisbon Disaster, 1755, in *Candide, and Related Texts*, trans. David Wootton (Indianapolis: Hackett, 2000).

[15] See for instance Rousseau's response to Voltaire: *The Dialogue between Voltaire and Rousseau on the Lisbon Earthquake: The Emergence of a Social Science View*. Russell Rowe Dynes (University of Delaware: Disaster Research Center, 1999).

Marche region was felt to some extent in Rome. When the earthquake shook the Earth, the Pope was at dinner and his table and the whole palace moved "miraculously", and all the people believed that this heralded God's judgment.[16]

After the immediate panic there was an urge for reconciliation and an increase in the demand for religious services and, in particular, processions. Many medieval chronicles refer to processions as the very first public act in a city after an earthquake.[17] These had the aim of purifying the city land and were conceived as a first step in the restoration of public order. Both religious and political leaders took part in the procession, and the structure of this ritual in which all the citizens participated was conceived to show that the authority of the leaders was still strong, despite the damage to palaces and cathedrals occasionally caused by earthquakes (Guidoboni and Poirier, 2004). For example, in the period covered in our dataset, on the 25th of December 1222 a violent earthquake hit the city of Modena (in our dataset registered with 7 degrees MCS in magnitude). The historical records report 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.[18] The same happened in Pistoia in 1293, where the chronicles report that after the earthquake (8 degrees MCS) that repeatedly hit the city for eight days, all the citizens (including the children) participated in a number of processions.[19]

Even after the communes had been constituted, their political leaders depended on the religious power of the bishops to cope with these unforeseeable natural events. A chronicle reports that in the city of Siena in 1320, just after an earthquake, the governors of the city begged the bishop to order a procession. From the description in the chronicle it is clear that the symbols of political power were subordinate to the religious power during the procession. The chronicle concludes the description of the event by saying that the processions, which lasted for three days, brought about the end of the earth tremor.[20] The role of the religious leaders was therefore crucial after an earthquake: the bishops in fact held the power to provide (or restrain the provision of) all religious services and were generally recognized as the intermediary between God and his 'flock'.

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[16] *Chronica S. Petri Erfordensis moderna (1072-1335)* cited in *Earthquake of 30 April 1279 Umbria and Marche Apennines*, *Annali di Geofisica* 43(4), August, 2000: Appendix A.

[17] Processions took place even when earthquakes did not cause physical damage (see Riera Melis, 2010).

[18] The episode is recorded in *Codice Capitolare Duomo di Modena* (0 III, n.13) and reported in A. Dondi (1895), *Notizie Storiche ed Artistiche del Duomo di Modena, Coll'Elenco dei Codici Capitolari*, Modena.

[19] *Storie Pistoresi* [MCCC-MCCCXLVIII], in S. Adrasto Barbi (1907-1927) ed., Città di Castello Tipi della Casa Editrice S. Lapi (RIS2, XI/V): p. 3.

[20] *Cronaca Senese dall'Anno 1202 al 1362, con Aggiunte Posteriori fino al 1391*, in A. Lisini and F. Iacometti (1939) ed., *Cronache senesi*, Rerum Italicarum Scriptores, XV/6, Bologna: p. 118.

The increase in the power of the bishops after an earthquake was such that even in the 15th century, when Italian city-states turned into monarchies controlled by the *signore* (the city lord), the bishop had the power to order the political leader to participate in a ritual. For example, after the earthquake that struck Florence in September 1453, the archbishop ordered four days of processions in which the *signore* and all his court also took part (Guidoboni and Poirier, 2004). These episodes and the general increase in religious participation after a seismic event were not limited to northern-central Italy in the Middle Ages but were a common phenomenon throughout Europe at least until the end of the 18th century.[21]

The role of the bishops was crucial, 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 intermediary between God and his 'flock', the bishops held an apotropaic power and could actually influence natural events. An example is offered 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).[22]

3.6 *Churches and Natural Disasters*

Providing empirical support to the historical evidence discussed in the previous subsections is no simple exercise given the absence of systematic data in the medieval period. A possibility is offered by observing that the number of churches in a given city is likely to capture the demand for religious services and may represent a measure of the degree of religiosity characterizing the population of residents. Indeed, according to the Catholic religion, churches are not only the houses of God where people celebrate rituals but also among the main manifestations of faith in God.[23]

While it is not possible to have precise data on the number of churches built in our period (1000-1300), we were able to ascertain the current number of churches in each city. The data were obtained from the National Office for Ecclesiastical Cultural Assets and Information Services of the Association of Italian Catholic bishops (Conferenza Episcopale Italiana).[24] In this

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[21] Nur and Borgess (2008) offer a description of the earthquake in Lisbon in 1755 in which, before the physical reconstruction of the city, the church led fasts, processions and other penitential rituals.

[22] As reported in Benvenuti (2010), the bishop's order was "*Pado, precipio tibi in nomine Ihesu Christi Domini ut de alveo tuo in locis istis ulterius non exeas, nec terras aeccesiae ledere praesumas*" ("*Pado, I order you in the name of Jesus Christ not to abandon your flood towards these lands, so that the lands protected by the Church be not destroyed*").

[23] See "Catechismo della Chiesa Cattolica", (2004) Section 2 Ch. 2., Libreria Editrice Vaticana.

[24] The data are in the public domain and available at http://www.chieseitaliane.chiesacattolica.it/chieseitaliane/.

exercise, we regress the current number of churches on the number of earthquakes that occurred in each Episcopal see city in the sample between 1000 and 1300 (data details in subsection 4.3). Of course, for each city the stock also includes the churches built in our period (11^{th}-13^{th} centuries), as well as in the previous and subsequent periods. For this reason, we also control for the number of earthquakes before the 11^{th} century and the number of earthquakes after the 13^{th} century. We also include regional fixed effects in order to control for variation in seismicity across regions, which is constant over time, and for the logarithm of the current population (data from ISTAT, 2001).

Figure 2 plots the residuals obtained from the above-mentioned equation regression on the number of earthquakes that occurred in our period. As can be seen, there is a positive and statistically significant correlation (coeff. 16.497, s.e. 2.880) between the number of churches in each city and the number of earthquakes that struck the city between 1000 and 1300, after controlling for regional fixed effects, number of earthquakes in different periods and the logarithm of the city population today.

FIGURE 2 ABOUT HERE

4. Data Description

4.1 Sample

The northern-central Italian cities at the beginning of the XIth century were a heterogeneous sample as regards historical and political background, size, and other characteristics, and cannot be seen *a priori* as all potentially capable to become communes. This observation is particularly important in our context and crucial for the sample selection. Accordingly, we must ensure our sample to consist of cities that were founded before 1000 and that at the beginning of the XIth century were large enough to ever experience the communal movement. Unfortunately, as a selection criterion, we cannot employ the city's population because the first available data on the number of inhabitants in Italian cities dates back at the earliest to the XIVth century (Malanima, 2005), whereas other data (Bairoch, Batou, and Chevre, 1988) covering the XIth century are limited to 8 cities only. According to historical sources (Ermini, Stasolla, and Magister, 2002), differently from cities governed by the secular feudal lords, the group of cities governed by the bishop present common characteristics as regards to size and political structure. The institution of Episcopal sees is dated back to the Council of Sardica in the IV^{th} century A.D. where it was

established that Episcopal seats could only be set in the roman *urbes*, which were the administrative and religious centers of the Ancient Roman Empire.[25] A relevant implication is that this rule guaranteed that the Episcopal see cities were the most important and largest cities of the time. Most of the cities that eventually become communes in the northern-central Italy were indeed Episcopal sees (Guiso, Sapienza, and Zingales, 2008).

These considerations motivate our choice of employing in our empirical analysis only the 61 northern-central Italian cities that were founded before 1000 and were ruled by a bishop. For each of them, we collected information on whether or not it became a commune during the sample period and (if so) the year in which the institutional transition occurred (as we explain in subsection 3.2), the year in which it experienced an earthquake (if any), the earthquake's intensity and other related information (as we explain in subsection 3.3 in greater detail) and further information on the distance from universities in the period following 1088 (section 3.4).

4.2 Transition to Commune

Following the historiography (Ascheri, 2006), we identified as date of transition to commune the first year for which the historical sources offer evidence of the presence of the *consules* or the *statutum* was registered. Since these dates are not systematically available from uniform data sources, we adopted the following criterion. We first tracked down academic medieval history books, encyclopedic references (i.e. the Enciclopedia Treccani, which is the main Italian encyclopedic reference) and the documents conserved in the local national archives mentioning the first date that *consules* were present in the city or the *statutum* was registered. When no date for the birth of the commune could be established on the evidence of these initial sources, we combed through a number of books on the histories of each city and Wikipedia.[26] Whenever we found discordance between two sources, we tracked down a third source and opted for a date recorded in at least two out of the three sources. When this criterion was not satisfied, we left the date of the birth of the commune as missing data point. This procedure left us with 61 cities; city names are listed in Table 1 where we also report, for the cities that became communes in the sample period, the year of transition. Note that most of the Episcopal see cities eventually became communes in the sample period. This is not a problem because we exploit the panel

[25] "Non licere autem simpliciter Episcopum constituere in aliquo pago vel parva urbe, cui vel unus Presbyter sufficit" in Synodorum Generalium ac Provincialium Decreta et Canones, scholiis, notis ac historicâ actorum dissertatione illustrati; studio et labore Christiani Lupi (1673).

[26] The whole series of sources is available upon request.

structure of the dataset.

TABLE 1 ABOUT HERE

In the empirical analysis, we also employed a panel dataset over the same sample period, only including non-Episcopal see cities. Likewise, for this group of cities we collected information on the year of transition to commune (if any), as above described, and on earthquakes experienced in the span of time considered, as explained in the next subsection. This sample, which we then employed in the placebo test (subsection 5.4), consists of 279 cities (names not reported for reasons of space).

4.3 Earthquakes

The data on earthquakes were drawn from the DBMI04 dataset[27] (Database Macrosismico Italiano 2004), 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 fruit of a branch of seismology called historical seismology (Vogt, 1989). Historical seismology is a multidisciplinary project, which uses historical sources to identify the occurrence and effects of seismic events, even in the remote past (Guidoboni, 2002; Stucchi, 1993), and processes historical information into macroseismic parameters, such as time, epicentral location, and intensity (Gasperini and Ferrari, 2000). 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) which the seismic events left behind (Guidoboni and Ebel, 2009). In the past three decades, the meticulous approach followed by the historical seismologists has led to a dramatic improvement in the quality of the investigation and 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 for Italy (Boschi et. Al., 2000; Guidoboni, 2002; Guidoboni and Ferrari, 1989). 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, 2002). For instance, critical historical investigation making use of accounts by monks, notaries and the Pope's chancellery has revealed with greater precision the effects of the earthquake that hit Brescia and the surrounding territory

[27] The data are in the public domain and can be accessed at: http://emidius.mi.ingv.it/DBMI04/

on the 25th of December 1222, which was long transmitted as a legendary event (Guidoboni, 1986, and Guidoboni and Comaschi, 2005; see also Stucchi et al., 2008, and references therein). The archaeoseismological information and critical and comparative analysis of a significant number (about 94) of different sources have revealed with fair approximation the location and the considerable amount of damage provoked by the earthquake that hit the Verona area on the 3rd of January 1117 (for an assessment see Guidoboni et al. 2005; see also Stucchi et al., 2008, and references therein).

For each Italian locality the DBMI04 gives the identification number of the earthquake that struck the locality, the time (day, month, year, exact time), the site that registered the most serious damage, its epicenter, the greatest macroseismic intensity on the Mercalli-Cancani-Sieberg (MCS hereafter) scale, the intensity registered at the epicenter and that registered at the locality, and finally the latitude and longitude of the epicenter, of the site that registered the maximum intensity and of the locality. The main source for the geographical references is the ENEL-ISTAT catalogue of Italian localities (ENEL, 1978) and updates. In most cases the locality coincides with a city, but sometimes it refers to a broader geographical area (such as a region). In our analysis we only considered earthquakes for which it was possible to track down clear correspondence between a locality in the DBMI04 and a city in our sample. Figure 3 shows the number of earthquakes that occurred in the northern-central Italy by city between 1000-1300.

FIGURE 3 ABOUT HERE

The intensity (*I*, hereafter) of the earthquake is registered on the MCS 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. The scale goes from 1 to 12: when *I* stands at 1 it 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 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* 11 indicates catastrophic destruction; and *I* 12 total (apocalyptic) destruction. In our analysis we only considered earthquakes for which the effects could be registered in terms of macroseismic intensity (dropping all the cases for which the intensity is unreported).

In the period (1000-1300) and geographical area (northern-central Italy) considered in this paper, 105 earthquakes occurred. Of these, 68 caused damage to buildings or people ($I \geq 5$; hereafter denoted by F), while 37 were felt by people but did not cause any physical damage ($I < 5$; hereafter denoted by D). Table 2 lists the names of the cities that were struck by an earthquake in the sample period. In the table, we also indicate the year in which the earthquake occurred and its intensity (in MCS scale). Note that this table shows all the earthquakes

registered by the DBMI04 for all the cities, both Episcopal and non-Episcopal in the period under study since all these earthquakes were used to construct the augmented dataset as explained below (subsection 4.4).

TABLE 2 ABOUT HERE

As can be seen, the most violent (*I* above 8) earthquakes were registered in Verona in 1117 (intensity 9) and in Camerino in 1279 (intensity 8-9). Intensities above 9 do not occur in our sample: earthquakes with *I*=10 were observed only in the south of Italy during the time period here considered; the first earthquake with *I*=11 was registered in 1456; finally, earthquakes with intensity 12 have never occurred in Italy.

4.4 An Augmented Dataset of Earthquakes

A possible concern with these data is that not all the earthquakes that occurred are recorded in the data, due to missing or inaccurate historical sources. Adopting the mild hypothesis that this form of measurement error is constant over time within a city, this might not be a concern since the panel structure of the dataset allows for this type of error to be absorbed by the fixed effects in our regressions. However, taking this concern more seriously, we will also use in our regressions a dataset augmented in the following way. Let us assume that city *i* at time *t* was struck by an earthquake but that the historical sources were not handed down to the most recent periods so that the earthquake was not registered in the baseline dataset. It still remains possible that the earthquake that hit city *i* but turns out unreported in the dataset for that city was instead recorded in some neighboring cities. Hence we impute an earthquake as occurring in city *i* at time *t* if the neighboring (within some threshold distance) city *j* recorded an earthquake in that given year. As threshold distances we consider 20, 25 or 30 km from city *i*. In this way, we increase the number of earthquakes resulting in material damage in the original dataset from 68 to 154, 238, and 327 when the threshold distance is 20, 25, and 30 km respectively, and the number of earthquakes felt but not causing destruction and deaths from 37 to 107, 157, and 200. Note that, central-northern Italy being a territory with a high density of cities, a threshold of 30 km is pretty large. To perform this exercise, we exploit all the available information on the reported earthquakes that occurred in the period considered, even when reference is to cities not included in our sample.

5. Empirical Strategy and Results

5.1 Regression Analysis

Our baseline regression equation is as follows:

$$transition_{it} = \alpha_i + \beta_t + \gamma \times earthquake_{it} + \varepsilon_{it}, \quad (1)$$

where *i* is the city and *t* is a 10-year interval. The dependent variable, *transition*, captures an institutional transition to a commune, and is equal to 1 if city *i* became a commune at time *t* (i.e. if the year of independence is 1005, *transition* is equal to 1 in 1010, meaning in the time interval between 1001 and 1010) and 0 otherwise. The independent variable involved, *earthquake* is a dummy that is equal to 1 if an earthquake occurred in city *i* and at time *t* (in the time interval as explained above) and 0 otherwise. Finally, α_i and β_t are respectively the city and the time fixed effects. Given our design, a number of issues are worth pointing out.

First, in our dataset the time dimension is defined every 10 years. The reason for this choice is that the number of years needed for the effects of an earthquake (if any) to materialize may vary from one city to another and may take more than one year. Imposing that the potential effects of an earthquake on the process of institutional change must occur within one year (and so adopting a one-year time dimensional framework) would be very restrictive and would probably rule out *a priori* a number of potential cases. By adopting the 10-year interval framework we opt for a more conservative scenario in which, potentially, the effects of an earthquake on transition can materialize up to 10 years after its occurrence. Of course, we are using an approximation, since we are not discriminating between situations in which a transition has occurred, say, two years after an earthquake and situations in which the former event follows the latter by nine years. Let us emphasize, however, that in the sample period transition to commune never occurs within the 10 years after the earthquake struck the city.

Second, since we are interested in studying the effects of an earthquake on the transition to a commune, if a transition occurred at time *t* in city *i*, no time after *t* is defined for that city.

Third, in some cases it may happen that in decade *t* both an earthquake and transition to commune took place, but the former event followed the latter, so that no causal relation can, of course, be inferred between them. For instance, Mantua was struck by an earthquake in 1117 and became a commune in 1115, both occurrences thus taking place in the decade between 1110 and 1120. In order to prevent such cases from affecting our inferences, we set the earthquake dummy to 0 in the decade in which the institutional shift occurred. Since the time is not defined for that city afterwards (see above), the occurrence of these earthquakes plays no role in our analysis.

Finally, in our dataset the year associated with the transition of the city to a commune is the one in which the transition was finalized. Clearly, the transition process may be slow and start well before the year in which the transition is recorded in the data. Since we cannot observe the exact moment in time when the transition process begins, the outcome to consider cannot but be

the year in which the commune was formally established (date of publication of the *statutum* and/or that on which the presence of the *consules* is testified by the historical sources, as explained in subsection 4.2). It follows that, in our estimation regression, for a given city *i* hit by an earthquake at time *t*, we measure the difference between the probability of the occurrence of the actual outcome (e.g. a commune was established and an earthquake had occurred) and the probability of the potential outcome had the city not experienced the earthquake (a commune was established and no earthquake had occurred).

5.2 Main Results

We start our analysis presenting our findings on the effects earthquakes had on transition to commune for Episcopal see cities. Our regression model (1) and variations of it are estimated with a linear probability model. Standard errors are consistently clustered at the city level. Table 3 reports the basic results. In column 1, we include as a regressor a dummy variable (*earthquake*) equal to 1 if an earthquake of any intensity (including both earthquakes resulting in material damage and deaths and earthquakes only felt by people) occurred. We obtain that the effect is negative and statistically significant at the one percent level. To address potential concerns with the 10-year interval choice, in column 2 we also include the lagged dummy on the earthquake and it turns out that the effect is still negative. In the other columns we include results obtained by employing also the earthquakes from the augmented dataset, namely by imputing earthquakes to cities which had a nearby city hit by an earthquake. We do so applying thresholds of 20, 25 and 30 km. The results are essentially the same, but the effects are on a larger scale. The mean of the dependent variable in our sample is 0.037. Therefore, the point estimate on the earthquake resulting in damage brings the probability of transition down to zero. These results, together with the evidence discussed in section 3, are consistent with our interpretation: by causing a shock to people's religiosity, earthquakes increased the popularity of the incumbent religious leader (the bishop) and therefore delayed transition to commune.

TABLE 3 ABOUT HERE

5.3 Results – The Intensity of the Earthquakes

One major concern with the interpretation of the previous results is that earthquakes may delay transition to commune for reasons other than a shock to religiosity. In fact, earthquakes are also associated with physical destruction, deaths, and income shocks. All these factors could potentially also play a role in delaying transition. To explore whether this conjecture finds support from the data, we exploit detailed information on the intensity of each earthquake. The

results are given in Table 4. We first (columns 1 and 2) use only earthquakes causing physical damage (greater than 5) and distinguish between weak earthquakes (intensity between 6 and 7, extremes included) and strong earthquakes (intensity between 8 and 9). The results are consistent with those reported in the previous tables: earthquakes delay institutional transitions. Moreover, there is no compelling evidence that the effect of an earthquake in this respect increases with its intensity. In the last two columns of Table 4, we use all the earthquakes in the original dataset and distinguish between earthquakes that were felt by the population but caused no damage (intensity below or equal to 5), and earthquakes associated with physical damage (intensity above 5). Again, there is no evidence that earthquakes resulting in greater damage have greater effect. Alternative specifications with the augmented dataset go in the same direction of no differential effect with respect to intensity. Taken together, these findings suggest ruling out the hypothesis that the effects of earthquakes on transition probability depend on the extent of the material damage and number of deaths caused.

TABLE 4 ABOUT HERE

5.4 Non-Episcopal See Cities

Although the previous results tend to rule out the hypothesis that the effects of the earthquakes are driven by material factors, it is still possible that the previous findings be driven by other non-religious factors, such as dread, and by the need to maintain the *status quo* political regime in periods when some natural catastrophe (regardless of its possible relation with God's will) upsets everyday life. The historical context we consider in this paper offers the possibility to take this aspect into account. If our conjecture is correct, an earthquake delayed transition to commune because it increased people's religiosity and so raised the cost of contesting the *status quo* regime. Hence, acting an earthquake enhanced the (political and religious) power of the incumbent political leader who, in the sample of Episcopal see cities, was the bishop. As a consequence, if our hypothesis is correct, the negative effect of the earthquake should not be found in non-Episcopal see cities that were governed by secular leaders (counts and marquises).

As a placebo test for our previous findings, we estimate regression (1) and its variation using the sample of cities that were not seats of bishops. Since the number of earthquakes documented for these cities is scanty, we employ the augmented datasets (20, 25 and 30 km respectively). The results are shown in Table 5. Columns 1-3 replicate the regressions shown in Table 3 but for non-Episcopal see cities, while columns 3-6 replicate the regression shown in Table 4 column 2, respectively using the 20, 25 and 30 km augmented datasets. The point estimates on the earthquakes are much smaller in absolute value and never statistically significant. In some cases

they are even positive.

TABLE 5 ABOUT HERE

In column 7 we set out the results drawn from the entire sample of cities (both Episcopal and non-Episcopal see cities) and look at the interaction term between the dummy for the earthquake and a dummy for the Episcopal see city. As expected, this interaction term is negative and statistically significant. Finally, for robustness, we also include other interaction terms between earthquakes and fixed characteristics of the city: whether or not it was on the sea and whether or not it was an Etruscan city. The results, given in columns 8-9, show that the interaction terms between earthquakes and Episcopal see city remain negative suggesting that the presence of a bishop in the city reduces the probability of transition following an earthquake even after controlling for other time constant characteristics of the cities related to their (possibly strategic) location or their proximity to the sea.

5.5 Robustness Checks

To challenge the robustness of our results, we implement a permutation test. The underlying idea of this test was taken up from DellaVigna and La Ferrara (2010) and Gagliarducci and Nannicini (2010). For 800 times, we randomly impute to Episcopal see cities and 10-year time intervals the number of earthquakes (105) that hit cities in our sample according to the augmented dataset (30 km). We then run the regression including, as independent variables, two dummy variables, one for the 'fake' event and one for its lag. Since the fake event is created 800 times (800 dummy variables), we in fact run 800 regressions (employing alternative numbers of replications does not affect our results in any significant way), and save the estimated coefficients. In Figures 4.a and 4.b we show the cumulative density function of the 800 point-estimates and with a vertical line indicate our 'true' point-estimates (respectively -0.060 and -0.064, reported in column (5) of Table 3). The idea of this test is to check how many times these randomly generated point-estimates prove close to our 'true' point-estimates. If our estimations are correct, we should not observe coefficients close to our estimates. As can be seen from Figures 4.a and 4.b, the point-estimates generated in the permutation test are almost always on the right (meaning larger in value) of the 'true' estimated coefficients (this does not obtain in only two out of 800 cases when we consider the coefficient on the contemporaneous variable and always obtains when the coefficient of the lagged variable is taken into account). This is the case whether or not we randomly allocate these earthquakes to cities and time intervals by stratifying the real number of earthquakes by century. On the whole, this exercise offers considerable evidence suggesting that our results are not an artifact of a small number of cities 'treated' in the dataset.

FIGURE 4 ABOUT HERE

In another test we restrict the sample to those cities for which data on the population in the medieval era have been collected. These data are from Malanima (2005) and apply to cities with at least 1,000 inhabitants in 1300 (earlier data are not available). The aim of this exercise is to show that our findings hold even if we only consider cities that were more likely to be densely populated and for which more accurate historical records are likely to be available. The results (not reported here) are essentially identical to the main results.

To increase the ratio between the number of earthquakes and the number of observations, we check if the results remain unchanged when we organize the data taking as temporal unit a time interval of 20 instead of 10 years. Again, not surprisingly, by rescaling the coefficients for the alternative time intervals, the results (not reported here) remain essentially unchanged.

7. Discussion and Alternative Explanations

The results described in the previous section point to two facts: *a*) the negative relationship between the occurrence of an earthquake and the institutional transition holds for Episcopal see cities only, and *b*) the relationship does not depend on the amount of damage caused by the earthquake; earthquakes that do not cause physical damage also have negative impact on the emergence of communes.

Taken together, both these findings and the historical arguments are consistent with the interpretation that the negative relationship between earthquakes and the institutional transition to a commune may be accounted for with the fact that earthquakes increased the cost of contesting the *status quo* political power in Episcopal see cities. The argument runs as follows. The earthquake was a dreadful and unforeseeable natural event generally interpreted as a sign of God's wrath with men and was likely to provoke a strong urge for reconciliation. This urge may be equivalent to an exogenous increase in religiosity. Since the bishop was, on the one hand, the mediator between men and God and, on the other, the political leader in the city, the earthquake resulted in an exogenous increase in the cost of conflict with the *status quo* political institutions.

This interpretation is also consistent with a possible second channel leading to the same result. In Episcopal see cities, the bishop was also the monopolist in the provision of religious services, the demand for which increased subsequent to the earthquake (especially processions, as we have seen) as means to gratify God and invoke forgiveness for men's sins. Hence, in this view, in Episcopal see cities where the bishop was both the political and religious leader, the increase in the cost of an uprising may have had two (not mutually exclusive, but rather mutually

reinforcing) components: *a*) the earthquake was followed by fright and immediate need for reconciliation with God and, as a consequence, increased the cost of contesting the power of God's mediator with men, the bishop; *b*) the earthquake caused a direct increase in the utility that people derived from religious services, the provision of which was totally controlled by the religious and political leader of the city, the bishop. Note that these two effects did not only (or did not necessarily) work through those directly contesting the *status quo* political institutions, i.e. the emerging economic urban elite, as they could be (and most probably also were) working through the other citizens whose support was needed by the new-born elite (thereby, again, raising the cost of an uprising). Since these two components have observationally equivalent implications and since we do not have data on participation in religious services in the historical period considered, our analysis cannot tell apart the relative importance of the two potential channels.

An alternative interpretation of our findings relates to the costs of contesting the *status quo* leaders. If rising up against the feudal or bishops' power is a coordinated activity, the negative relationship between earthquakes and transitions toward a commune could in principle be explained by the fact that natural catastrophes caused an increase in coordination costs for those contesting the *status quo* power. In this case, the effort of reconstruction could account for our overall results. Nonetheless, in such a case the effect would be expected to be increasing with the intensity of earthquakes (greater intensity resulting in greater coordination and reconstruction costs), and this is not in line with the fact that our findings do not depend on earthquake intensity.

A further potential alternative explanation is that earthquakes caused a permanent negative shock to income and thus hampered the process of institutional transition. This view would be consistent with the modernization hypothesis (Lipset, 1959), which predicts that permanent increases in income per capita trigger institutional improvements (for a critical assessment see Acemoglu et al., 2009). However, as we have already pointed out, both the historical evidence and the fact that our empirical results found no role for the intensity of the earthquake are inconsistent with this interpretation. Moreover, the literature on the long-run effects of earthquakes seems to suggest that there is no compelling evidence that earthquakes cause permanent reductions in income (Cavallo and Noy, 2009; Cavallo et al., 2010). Finally, our effect is found in the short-run, whereas the modernization hypothesis develops over the long term.

An alternative interpretation relates to the possibility that, after a natural catastrophe, people may prefer to have a more centralized and authoritarian government (by bishops or feudal lords) expecting such a government to be more effective in reconstruction. However, this hypothesis,

too, is inconsistent with the evidence given in the previous sections showing that also earthquakes not resulting in material damage have an impact on the probability of emergence of a commune. In order to be consistent with our results, an explanation based on the greater effectiveness of the feudal leaders in the reconstruction process with respect to the communal institutions would require that: *a*) bishops, compared to secular lords, were more effective in the reconstruction and thus received more support from the citizens, and *b*) the people's support for the existing authoritarian leaders increased also after an earthquake that caused no damage and so required no reconstruction. In this case support for the authoritarian political leaders would be an insurance device and such support would be greater for bishops than for feudal lords. Although we cannot directly test this explanation, historical research (Guidoboni and Poirier, 2004; Guidoboni and Ebel, 2009) indicates that there was no difference between Episcopal see cities and other cities as far as financing reconstruction in the period considered is concerned. In all the cases, there were no direct transfers from the political authorities to the citizens, and in general the main financial support for reconstruction lay in tax breaks. Transfers from the government to the citizens are documented only much later, starting with the Medici family which, in the Grand-Duchy of Tuscany in the 16th century, accorded small credits at low interest rates for reconstruction to damaged households (Favier, 2002).

Finally, one further remark is worth making. A view, held by some historians (e.g. Tabacco, 1987) and more recently economists (Guiso, Sapienza and Zingales, 2008), has it that the presence of a bishop favored the emergence of the commune in Episcopal see cities by playing a coordination role in the transition process. Indeed, in some cases, the bishop was even asked to act as a guarantor of the *patto giurato*. This, of course, should not suggest that conflict, at least potential, between the bishop and the communal institutions did not exist. With very few exceptions limited in time (Milano), the transition to a commune implied a loss of political power for the bishop. The conflict could remain potential, and in these cases the transition was peaceful, or become violent, as the reported cases of Parma and Cremona testify (see subsection 3.3). These facts, however, hold no implications for our findings, which show that the effect of the religiosity shock on institutional change works *ceteris paribus* (conditional on being an Episcopal see city).

7. Conclusions

Understanding the determinants of institutional change is one of the thorniest issues in the political economy literature. In particular, empirical investigation of the channels leading to transitions toward more democratic institutions, both in the contemporary world and in the past, has recently proved of much interest to economists. One of the main challenges in this literature

has been finding a way to single out the possible mechanisms working in such a complicated process and to identify the causality. Our effort goes in this direction and focuses on a particular historical episode of institutional change: the birth of communal institutions in the northern and central Italian cities in the Middle Ages.

Our contribution in the present paper focuses on a narrow and precise empirical relation, but with possibly broader implications and stimulus for future work. We study the effects of the occurrence of a natural catastrophe, an earthquake, in a city, and the transition probability for that city to become a commune in the subsequent periods. Our empirical findings show two things. First, the occurrence of an earthquake reduces to a substantial and statistically significant degree such a probability in the decade following the event. Second, this effect is independent of the earthquake's intensity and occurred even if the earthquake was only felt by people without causing any physical damage to buildings or deaths. The negative effect of earthquakes on the institutional transition is present and strong only in Episcopal see cities, while being in practice absent in cities governed by secular feudal leaders. Thus the negative effect of an earthquake on the probability of transition did not necessarily work through material destruction, aggravated poverty, deaths or differential material impact on the social classes involved in the political transition but rather through the consternation caused by an uncontrollable natural event, dread of God's wrath falling upon the people, and urge for reconciliation. Since the bishop was the mediator between men and God and the monopolist in religious services, on the one hand, and the political leader in Episcopal see cities, on the other, the earthquake may be seen as resulting in an increase in the cost of a transition. With the available data we are not able to test this interpretation directly; however, both the historical records and our empirical evidence seem to be consistent with it and, as we argue in the text, alternative interpretations of our findings do not seem particularly compelling.

While our contribution focuses on a particular historical episode, and given that the political economy interpretation proposed in the paper is supported with historical records relevant to that specific period, the mechanisms uncovered may prove important in other historical contexts as well, and their implications call for further investigation in broader circumstances. For instance, the central role of religion is not an exclusive peculiarity of the medieval period. Religious leaders have historically influenced political decisions to the present day. In the very recent history of Italy, the Church has played a crucial role in preventing the extension to *de facto* couples of certain basic civil rights that are currently acquired by people only after marriage. Similarly, the opposition of the Church to extension of the local property tax to commercial activities run by religious institutes, exempted up to 2012, has always been able to rely on the ample support of people and policy-makers. Interestingly, the fiscal exemption was finally

removed by a technical government (presided over by Mario Monti) that did not need political support for elections.[28]

Religion is still important in many other contexts, in democratic and nondemocratic countries as well, though to different degrees. Strikingly, the belief that the governance of natural events is in the hands of God is not that far from the culture of contemporary society in Italy.[29] There is a widespread tendency to look to God, his mediators, or charismatic political leaders for protection in periods of uncertainty and instability which has been seen as playing an important role in a number of historical episodes conducive to the re-emergence of despotic institutions after substantial progress towards democracy. Of course, our contribution cannot bring fully to light such vast phenomena, nor does it have any ambition to do so. Nonetheless the findings presented in this paper point to the existence of possible mechanisms that, to the best of our knowledge, are still largely unexplored in the economic literature and are suggestive of implications that seem worth further exploration.

Appendix – Sample Details

The following cities were excluded from the original sample (Guiso, Sapienza, and Zingales, 2008):

- Cities that did not belong to the Holy Roman Empire: Formia, Amatrice, Itri, Leonessa, Pontecorvo.
- Cities that became communes before 1000 [foundation year in square brackets]: Sezze [956].
- Cities for which the year when the city became a commune is unclear (inconsistent or inaccurate historical sources): Alatri, Amelia, Ancona, Belluno, Borgo San Lorenzo, Cagli, Chieri, Colle Val d'Elsa, Ferentino, Forlì, Genova, Gubbio, Lucca, Pisa, Pontremoli, Todi, Tivoli, Urbino, Venezia.
- Cities that did not exist yet in the medieval era or funded between the XI and XIII century [foundation year in square brackets]: Alfonsine [1464], Cherasco [1242], Firenzuola

[28] http://www.corriere.it/economia/12_febbraio_16/calabro-la-svolta-ici-sulla-chiesa_4c1a85ee-5867-11e1-9269-1668ca0418d4.shtml

[29] Corriere della Sera (one of the current biggest selling Italian daily newspapers) on March the 12th 2012 published an article with the following title: "Another period of drought after March. [Florence's] Cardinal says: pray God for the rain". http://www.corriere.it/cronache/12_marzo_30/caprara-pioggia-caldo-preghiera_08fa616e-7a2a-11e1-aa2f-fa6a0a9a2b72.shtml

[1332], Loreto [1294], Minerbio [1231], Pergola [1234], Pietrasanta [1255], Portogruaro [1140], Russi [1371], Sabbioneta [after 1550].

- Cities with a different denomination in the medieval period or resulting from the union of more than one city: Arcevia, Corridonia, Magione, Mira, Molinella, Peveragno, Potenza Picena, Quarrata, Reggello, Vittorio Veneto.
- Cities that were hit by an earthquake of unreported intensity before the year in which the city became a commune (see section 4.3 in the text): Carpi, Cerea, Legnano, Piacenza, Pieve di Sacco, Trino, Vicenza.

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TABLES AND FIGURES

Table 1. List of cities and transitions to commune

City	Year	City	Year
acqui terme	1135	narni	-
alba	1169	novara	1116
anagni	-	orvieto	1157
arezzo	1098	padova	1138
ascoli piceno	1183	parma	1149
asti	1095	pavia	1106
bergamo	1098	perugia	1139
bologna	1116	pesaro	-
brescia	1127	piacenza	1126
camerino	-	pisa	1081
cesena	1176	pistoia	1105
comacchio	-	ravenna	-
como	1109	reggio nell'emili	1136
cremona	1098	rieti	-
faenza	1141	savona	1191
fano	1114	senigallia	-
feltre	-	siena	1147
fermo	1199	sora	-
ferrara	1105	spoleto	1173
fiesole	-	terni	-
firenze	1125	tortona	1122
foligno	-	trento	-
fondi	-	treviso	1150
forlì	1182	trieste	1295
fossombrone	-	ventimiglia	1149
imola	1084	vercelli	1141
ivrea	1171	veroli	-
lodi	1142	verona	1136
mantova	1115	vicenza	1147
milano	1097	volterra	1170
modena	1135		

Note: Sample period (1000-1300). Year is the year when the commune was formally established (date of the publication of the statutum and/or that in which the presence of consules is testified by the historical sources, as explained in the text). '-' denotes the city never becomes a commune within the sample period.

Table 2. List of earthquakes

City	Year	Intensity	City	Year	Intensity
arezzo	1005	7-8	forlì	1222	NR
pistoia	1005	5	genova	1222	5-6
bologna	1065	NR	lodi	1222	6
brescia	1065	8	mantova	1222	5
genova	1065	NR	milano	1222	6
milano	1065	F	modena	1222	7
verona	1065	NR	padova	1222	6
belluno	1117	F	parma	1222	5-6
bergamo	1117	NR	piacenza	1222	F
bologna	1117	F	reggio nell'emi	1222	5-6
brescia	1117	NR	tortona	1222	5
como	1117	NR	treviso	1222	6-7
cremona	1117	D	ventimiglia	1222	NR
faenza	1117	NR	verona	1222	6
feltre	1117	F	vicenza	1222	NR
ferrara	1117	5-6	bologna	1234	NR
lodi	1117	NR	ferrara	1234	7
lucca	1117	NR	mantova	1234	NR
mantova	1117	F	padova	1234	NR
milano	1117	7	spoleto	1246	7-8
modena	1117	F	bologna	1249	NR
padova	1117	D	modena	1249	7-8
parma	1117	D	parma	1249	NR
pavia	1117	D	reggio nell'emi	1249	5
piacenza	1117	D	feltre	1268	F
pisa	1117	4	padova	1268	5
trento	1117	F	treviso	1268	8
treviso	1117	7	ancona	1269	8
verona	1117	9	genova	1276	5
vicenza	1117	D	lodi	1276	F
firenze	1148	7	milano	1276	NR
pisa	1168	5-6	piacenza	1276	F
genova	1182	6	verona	1276	NR
cesena	1194	6-7	spoleto	1277	8
pistoia	1196	6	cagli	1279	F
bologna	1197	NR	camerino	1279	8-9
brescia	1197	6-7	faenza	1279	6-7
genova	1197	NR	foligno	1279	7-8
lodi	1197	NR	forlì	1279	6-7
milano	1197	NR	ravenna	1279	5
parma	1197	NR	parma	1284	F
piacenza	1197	NR	ferrara	1285	7
verona	1197	NR	padova	1285	NR
genova	1217	5-6	pistoia	1293	8
bergamo	1222	5-6	bergamo	1295	6-7
bologna	1222	6-7	como	1295	F
brescia	1222	8	milano	1295	F
cesena	1222	F	verona	1295	F
como	1222	NR	forlì	1298	F
cremona	1222	7	rieti	1298	8
ferrara	1222	6-7	spoleto	1298	8

Note: Sample period (1000-1300). Year is the year when the earthquake was registered. Intensity is in MCS scale (when intensity was not specified in the original sources, D denotes I=(5,9] and F denotes I=(2,5]).

Table 3. Main results

	(1) Main dataset	(2) Lags - Main dataset	(3) Lags - With unreported	(4) Augmented (20 km)	(5) Augmented (25 km)	(6) Augmented (30 km)
Earthquake	-0.08317***	-0.08661***	-0.09726***	-0.09072***	-0.08928***	-0.08476***
	(0.02775)	(0.03197)	(0.03120)	(0.02827)	(0.02714)	(0.02525)
Lag earthquake		-0.03092	0.00092	-0.00002	-0.00483	-0.01302
		(0.06215)	(0.06150)	(0.05232)	(0.05007)	(0.04552)
Observations	1,138	1,077	1,077	1,077	1,077	1,077
R-squared	0.151	0.155	0.156	0.156	0.156	0.157
Number of cities	61	61	61	61	61	61

Note: Estimation by OLS; standard errors (in parentheses) are clustered at the city level. The dependent variable is a dummy=1 if city *i* became a commune at time *t*, and 0 otherwise. *Earthquake* is a dummy =1 if an earthquake occurred in city *i* at time *t,* and 0 otherwise. *** significant at 1%; ** significant at 5%; * significant at 10%.

Table 4. Intensity

	(1) Damage/ and felt	(2) Damage and felt (lags)	(3) Weak and strong	(4) Weak and strong (lags)
Earthquake (damage/strong)	-0.09959***	-0.10328***	-0.11950***	-0.13310***
	(0.03148)	(0.03487)	(0.04113)	(0.04139)
Earthquake (felt/weak)	-0.05794*	-0.06029	-0.05843**	-0.05515*
	(0.02912)	(0.03671)	(0.02451)	(0.03044)
Lag earthquake (damage/strong)		-0.00591		-0.14823***
		(0.10281)		(0.04476)
Lag earthquake (felt/weak)		-0.06524**		-0.06840**
		(0.03161)		(0.03146)
Observations	1,138	1,077	1,138	1,077
R-squared	0.151	0.153	0.149	0.153
Number of cities	61	61	61	61

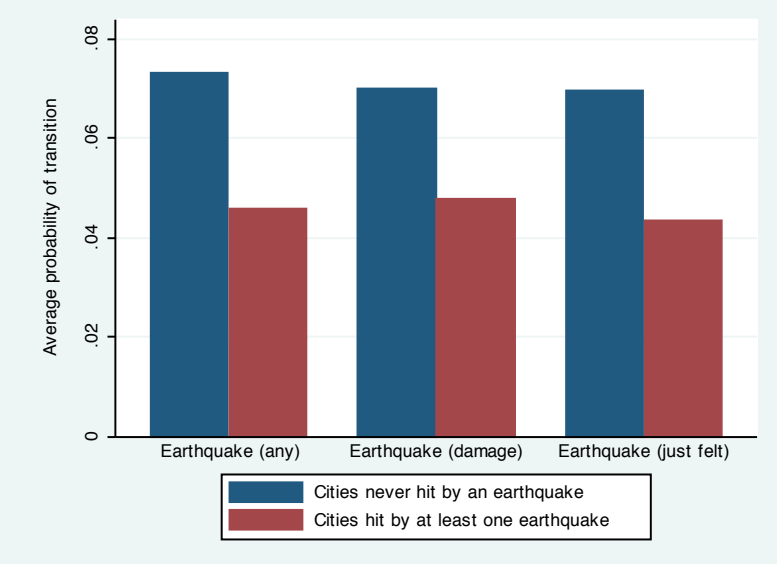
NOTE: Estimation by ordinary least squares; standard errors (in parentheses) are clustered at the city level. The dependent variable, *transition*, is equal to 1 if city *i* became a commune at time *t* and 0 otherwise. *Earthquake* is equal to 1 if an earthquake occurred in city *i* and at time *t* and 0 otherwise. Intensity classes are refined as follows: *Weak earthquake*: *I*=(5,7]; *Strong earthquake*: *I* =(8,10); *Earthquake damage*: *I*=(5,10); *Earthquake felt*: *I*=[2,5]. City and time fixed effects are always included. *** significant at 1%; ** significant at 5%; * significant at 10%.

Table 5 – Robustness

	Non-Episcopal sea cities						Whole sample		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Augmented (20 km)	Augmented (25 km)	Augmented (30 km)	Augmented (20 km)	Augmented (25 km)	Augmented (30 km)	Main - Bishop	Main - Etruscan	Main - Sea
Earthquake	-0.00958	-0.00810	-0.00593				-0.00326	-0.05490**	-0.06476***
	(0.03526)	(0.01104)	(0.00994)				(0.02271)	(0.02127)	(0.02130)
Lag erthquake	-0.00258	-0.00482	-0.00305				-0.00400	-0.05742**	-0.01167
	(0.03529)	(0.01201)	(0.01065)				(0.02183)	(0.02294)	(0.06072)
Earthquake (felt)				-0.01658	-0.00378	-0.00307	-0.06126***	-0.02985	0.06270***
				(0.01519)	(0.01081)	(0.01012)	(0.01927)	(0.03056)	(0.02106)
Earthquake (damage)				-0.00378	-0.01658	-0.01204	-0.00747	0.14011	0.01229
				(0.01081)	(0.01519)	(0.01267)	(0.06523)	(0.16631)	(0.05813)
Observations	1,145	1,145	1,145	1,192	1,192	1,192	2,179	2,179	2,179
R-squared	0.090	0.090	0.090	0.087	0.087	0.087	0.109	0.110	0.109
Number of cities	.	47	47	47	47	47	106	106	106

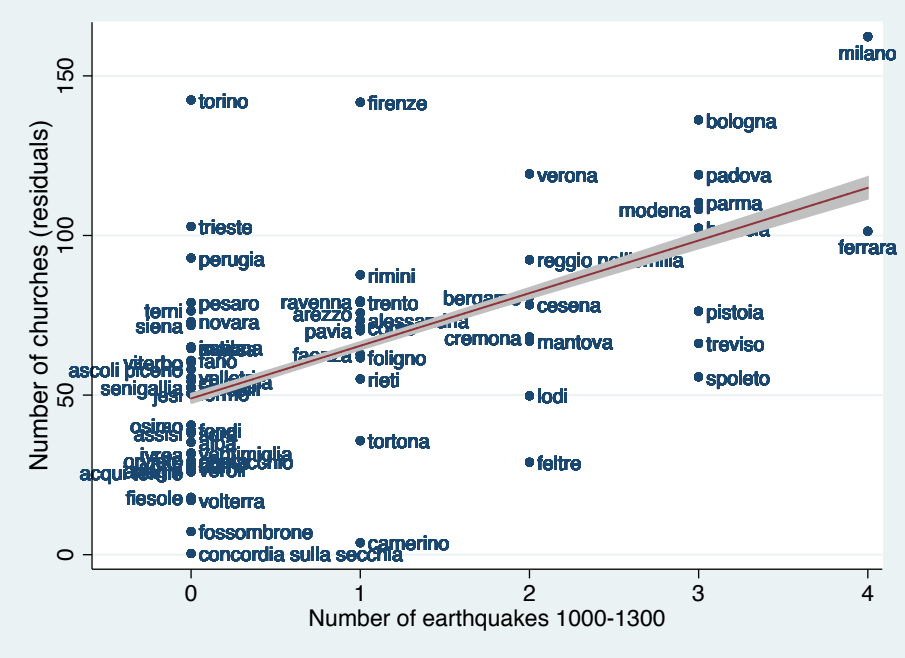
NOTE: Estimation by least squares; standard errors (in parentheses) are clustered at the city level. The dependent variable, *transition*, is equal to 1 if city *i* became a commune at time *t* and 0 otherwise. *Earthquake* is equal to 1 if an earthquake occurred in city *i* and at time *t* and 0 otherwise. *Earthquake n km* is equal to 1 if an earthquake occurred in a neighboring (within *n* km) city *i* and at time *t* and 0 otherwise. *Interaction* is the interaction term between *earthquake* and one of the following: *Etruscan* is equal to 1 if the city was Etruscan and 0 otherwise. *Bishop* is equal to 1 if the city was seat of a bishop before 1000 and 0 otherwise. City and time fixed effects are always included. *** significant at 1%; ** significant at 5%; * significant at 10%.

Figure 1 – Probability of transition between 1000 and 1300



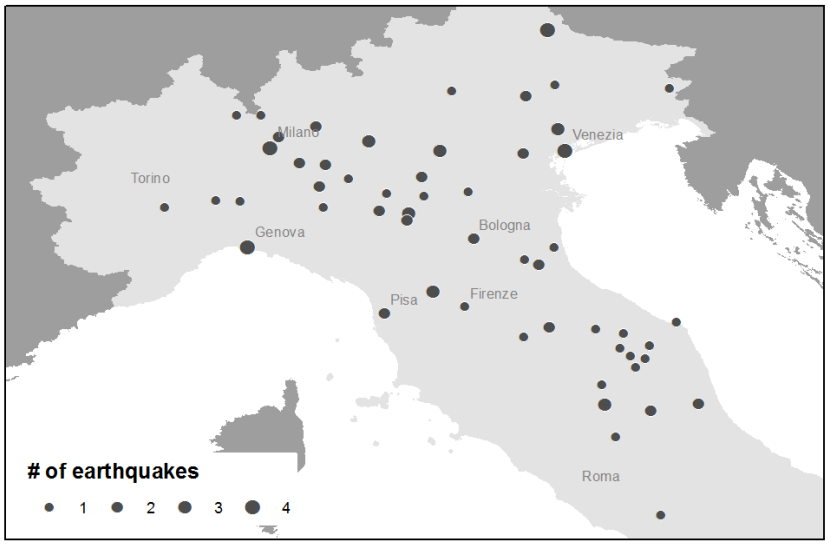
NOTE: The figure reports the average probability that a transition to a commune occurs in any decade in the sample period (1000-1300) for cities hit by an earthquake (any earthquake, an earthquake resulting into physical damage, an earthquake just felt by people, respectively) before the transition (if any) occurs and for cities never hit by an earthquake. The average probability for each group of cities is computed as the average, across cities, of the ratios between 1 and the number of periods taken for the transition (if any) to occur (the time periods for cities that never become commune counting as zeros).

Figure 2 – Churches and earthquakes



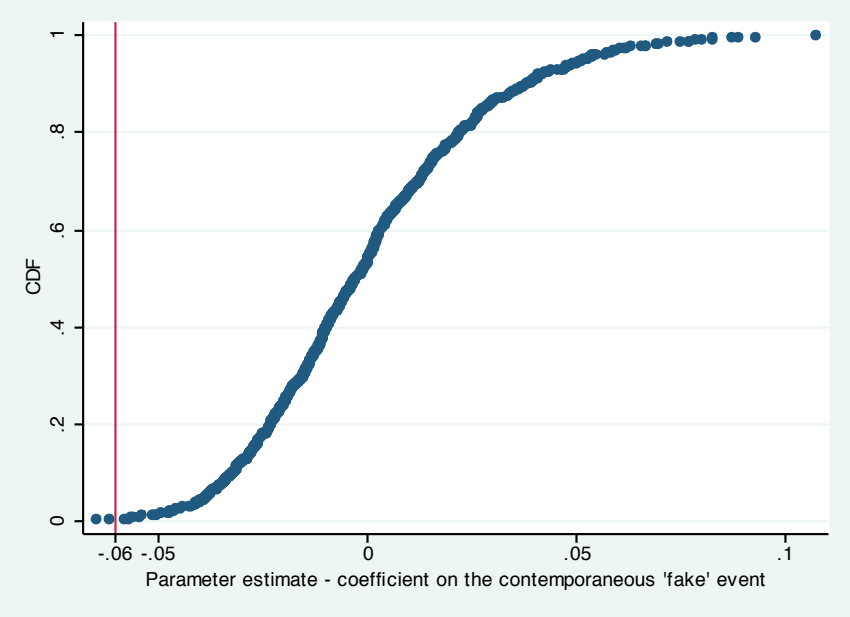
NOTE: The figure reports the linear interpolation (red line) and the confidence interval (grey area) between the number of earthquakes in a city between 1000 and 1300 (x-axis) and the residuals of the number of churches (y-axis) of a regression including as controls regional fixed effects, log-population in 1991 and number of earthquakes before 1000 and after 1300.

Figure 3 – Earthquakes in northern-central Italy between 1000 and 1300



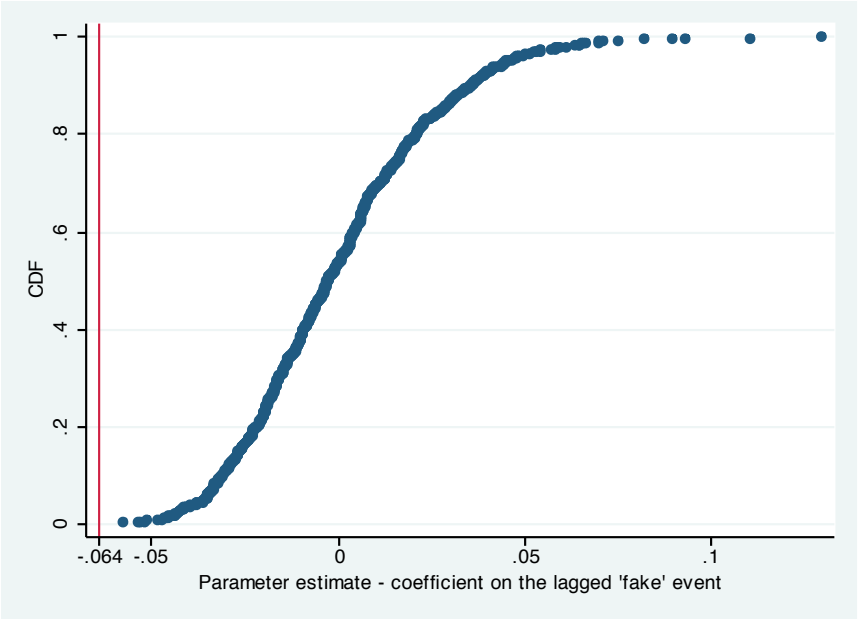
NOTE: Data from the DBMI04 (Database Macro Sismico Italiano, 2004).

Figure 4.a – Distribution of parameter estimate on the contemporaneous 'fake' event



NOTE: The figure reports the cumulative density functions of 800 coefficients on the contemporaneous dummy for the 'fake' earthquake. The procedure creating the fake datasets is described in the text (subsection 5.5). The red vertical line is the true point estimate of the variable *Earthquake* (*t*) reported in column 5 of Table 3.

Figure 4.b – Distribution of parameter estimate on the lagged 'fake' event



NOTES: The figure reports the cumulative density functions of 800 coefficients on the lagged dummy for the 'fake' earthquake. The procedure creating the fake datasets is described in the text (subsection 5.5). The red vertical line is the true point estimate of the variable *Earthquake* (*t*-1) reported in column 5 of Table 3.