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DID SEISMIC ACTIVITY LEAD TO THE RISE OF RELIGIONS?

Jeanet Bentzen and Eric Force

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Abstract

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JEL Classification: E71, Z12, Q54, R11, O43, Z13, D91

Keywords: Religiosity

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Did seismic activity lead to the rise of religions?

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We hypothesize that natural disasters, such as earthquakes, may have facilitated the rise of the major religions of today. To motivate, we combine an empirical literature linking contemporary natural disasters - earthquakes in particular - to religiosity with a qualitative literature observing religious responses to ancient earthquakes. Using modern data from surveys, the first part shows that religiosity has increased in the aftermath of disasters such as earthquakes. As emotional effects can be analytically disentangled from those of physical destruction, religious coping seems the most potent link; people use their religion for comfort and explanation to match the otherworldly aspect of seismic destruction. The second part shows that the major religions of the modern world emerged in a remarkably tight band along seismically active plate-tectonic boundaries, suggesting the persistence of this link. The third part shows that several immediate cultural responses to historic earthquakes have been religious. We conclude that religion may have emerged as a response to the unanswerable questions posed by earthquakes, and as a provider of comfort to survivors. Earthquakes may thus have played a pivotal role for millennia in the emergence and persistence of religion.

Keywords: Religiosity, major religions, coping, natural disasters, earthquakes.

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1. Introduction

For most of our history and throughout most of the globe, religion has played a surprisingly central role in human lives.² Only recently has the importance of religion dwindled in some societies, while it continues to influence most aspects of life in others. A puzzle of the social sciences remains why religion emerged in the first place. A second puzzle is why religion has not declined in importance in most parts of the world today as the secularization hypothesis otherwise suggests.³ This chapter aims to improve our understanding of these puzzles.

To do so, we combine two insights from the literature. First, people across the globe become more religious when earthquakes and other natural disasters hit (Bentzen (2019a), Sibley & Bulbulia (2012)). The reason is that people use religion to cope with the adversity caused by disaster, in keeping with the religious coping hypothesis (Pargament (2001)). Even the corona pandemic has instigated people across the globe to pray (Bentzen (2020)). Second, thousands of years ago, all the major religions emerged particularly close to boundaries between tectonic plates and the majority of past great earthquakes have led to some religious response (Force (2015, 2018)). Residing in areas with much tectonic activity historically most likely instigated a larger need for explaining of the world, compared to living in calmer areas. The belief in God often satisfied this requirement (e.g., Hall (1990), Van De Wetering (1982)). While we do not have detailed data on people's religious beliefs in the past, we instead draw on numerous examples of ancient societies engaging in direct religious responses to earthquakes. For instance, several explanations of earthquakes in the ancient Judaic world built on religion; God's anger in particular.

Combining these two insights leads to our hypothesis that providing comfort and explanation form important reasons for the emergence of the world's major religions and for why they continue to hold such a strong position in most contemporary societies. In particular, we hypothesize that earthquakes (and other natural disasters) may have played a crucial role in the emergence of religion thousands of years ago and at the same time help explain why religion retains center stage in many societies today. While modernization may tend to reduce religiosity, the continued existence of natural disasters may help explain why average global religiosity is not falling. As we shall see, religious coping can also be exploited by rulers with an interest in using religion for power purposes, which further anchors the role of religion in society.

Studies have found correlations between religiosity and various socioeconomic outcomes such as health, fertility choices, gender roles, productivity, labor force participation, and education choices.⁴ Understanding religious origins and continued impact may help understand the socioeconomic consequences of religion.

² E.g., Murdock (1965), Brown (1991), Peoples et al. (2016).

³ The secularization hypothesis predicts that religiosity falls as societies modernize. It has received mixed support, though. Norris & Inglehart (2011) show that while religion has become less important in many Western countries it has increased in importance in other parts of the world, leading to a net- increase in the number of people with traditional religious views during the past fifty years. See also Stark & Finke (2000) and Iannaccone (1998) for discussions and Becker et al. (2017) for an empirical investigation of the influence of education on the secularization process.

⁴ See Guiso et al. (2003), Scheve & Stasavage (2006), McCleary & Barro (2006), Gruber & Hungerman (2008), Campante & Yanagizawa-Drott (2015), and Bentzen and Sperling (2020) for empirical investigations or Iannaccone (1998), Lehrer (2004), and Kimball et al. (2009) for reviews.

2. What explains religion?

In this section, we review existing explanations of differences in religiosity and the emergence of religion. The two are not necessarily intertwined: Factors that led to the emergence of religion thousands of years ago may not be the same factors that makes people more religious today. We argue, though, that some factors may explain both the emergence of religion historically and the differences in religiosity today.

Social scientists have applied microeconomic theory to explain why some individuals, societies, or groups are more religious than others.⁵ By religiosity, we mean both the degree of participation in religious activities and the strength of beliefs in religious concepts. The notion of religiosity is to be distinguished from types of religious denominations, such as Christianity versus Islam. The work explaining why some are more religious than others began with the model by Azzi & Ehrenberg (1975), where individuals allocate their time and goods among religious and secular commodities to maximize their lifetime and afterlife utility. Within this framework, the reasons for differences in religiosity can be grouped into demand and supply side factors (e.g., Finke & Stark (2005)).

One supply-side explanation of differences in religiosity is that religious congregations compete for followers, thus increasing the quality and quantity of the religious services provided. The larger supply in turn would improve the match-rate between potential follower and religion, thus increasing the likelihood that people take up religion (e.g., Finke & Stark (2005), Olson (2011)). Bryan et al. (2020) collaborated with an evangelical Protestant anti-poverty organization to randomly offer poor households in the Philippines an education program based on “theology and values”. In support of the supply-driven explanation of religiosity, the researchers found significant increases in religiosity in areas “treated” with the religious program. Across Africa, Nunn (2010) found that descendants of people who experienced greater missionary contact are more likely to identify themselves as Christians today. In a modern Western country, the USA, Bentzen and Sperling (2020) exploited the faith-based initiatives as quasi-exogenous shocks to the supply of religious organizations. They found that the initiatives led to an increase in the number of religious organizations and a rise in churchgoing and strengthened religious beliefs. Instead of competing with other religious congregations, a potentially important competitor from the viewpoint of the particular congregation could be secular organizations (e.g., Hungerman (2010) and Hungerman (2005)). In support, Gruber & Hungerman (2008) show that the legalization of retail activity on Sundays led to lower church attendance and church donations across US states.

The supply-side theories are arguably not that great at explaining the emergence of religion, as they assume the prior existence of religion and from that explain differences in religiosity by differences in the availability of this religion.

Turning to the demand-side, demand-side explanations of differences in religiosity emphasize factors that elevate the demand for religion, in turn increasing the extent of religious engagement (e.g., Norris & Inglehart (2011)). One demand-side theory that has received widespread empirical support is the idea that individuals use their religion to cope with stress, uncertainty, and events that are otherwise difficult to explain. This is termed the religious coping hypothesis, a theory to which we will return in Sections 3, 4, and 5. Another demand-side theory is the secularization hypothesis, which claims that religion will die out as countries develop. This, however, has received

⁵ See reviews by Iannaccone (1998) and Iyer (2016).

mixed support in the data.⁶

The demand-side explanations of differences in the degree of religiosity can plausibly also contribute to our understanding of the emergence of religion: Religion would be more likely to emerge when the demand for religion is higher. This would be the case when the particular population demands comfort and explanation to a larger extent, for instance.

The model by Azzi and Ehrenberg (1975) views differences in religiosity as a product of the supply and demand for religion seen from the viewpoint of the populace. An important part of the literature instead views differences in religiosity and religious institutions as products of the *rulers'* demand for religion. In particular, a line of research focuses on the use of religion for power legitimacy and social control. This research goes far back, at least to Marx (1844), including a list of research within political science (e.g., Djupe & Calfano (2013), Hertzke et al. (2018), Jelen (2006)) and economics (Belloc et al. (2016), Bentzen & Gokmen (2020), Chaney (2013), Kuran (2012), Platteau (2017), Rubin (2017)). Belloc et al. (2016) document that transition to democracy across Medieval Italian cities was less likely when an earthquake had recently hit, but only in cities, where the political and religious leader was the same person. They argue that the earthquake increased religiosity due to religious coping, which could be exploited by the religious ruler who would then have a higher chance to withstand the movement towards democracy. Across 1265 societies spread across the globe, Bentzen & Gokmen (2020) document that all types of societies have used religion for power legitimization at some point. In fact, certain types of gods, Big Gods, were more likely to develop in societies that could benefit more from religious power legitimacy. They further document that these societies are more likely to remain autocracies today, have a larger share of current state laws that are religious laws, and are more religious. This theory thus potentially explains both differences in contemporary religiosity and the emergence of religion historically. The theory also illustrates how religious coping can be exploited by rulers to entrench their powers.

One may conjecture that differences in religiosity arise due to differences in the type of religious affiliation.⁷ For instance, Muslims are more religious than Protestants, on average. In turns out, though, that this explains only a rather small share of differences in religiosity. Bentzen (2019b) finds that differences in terms of religious denominations explain a miniscule part of differences in religiosity in a sample of nearly 500,000 individuals across the globe. This also means that theories explaining the differential emergence of Islam or Protestantism do not explain contemporary differences in religiosity (something which they do not claim to do either).

Turning to theories aiming specifically at explaining the emergence of religion, evolutionary theories dominate. One important theory states that religion evolved as a solution to large-scale cooperation problems (e.g., Norenzayan (2013)). According to this theory, beliefs in an almighty punishing god solved the problem of free-riding in pre-modern societies; God was believed to punish deviants, thus inducing cooperation. Inhabitants in societies that developed punishing gods were better able to cooperate, and thus more likely to survive and multiply. Eventually, evolution selected societies that held beliefs in punishing gods. As time went by, the invention of formal policing institutions reduced the need for God as such an institution, thus reducing the importance of

⁶ Rather, religion seems to be on the rise in many societies, which some see as a rejection of the secularization hypothesis (e.g., Iannaccone (1998); Finke & Stark (2005); Norris & Inglehart (2011)). Some scholars have viewed rising religiosity in the US as a counter example of the secularization hypothesis. However, Voas & Chaves (2016) document that religiosity in the US has declined over the past decades when cohort effects are accounted for.

⁷ Scholars have documented various socioeconomic differences between Protestants and Catholics or between Christians and Muslims (e.g., Andersen et al. (2017), Becker & Woessmann (2009), Weber (1905), Rubin (2017)).

religion. This theory, therefore, cannot explain why religion did *not* die out as modern institutions emerged and thus cannot explain current differences in religiosity. This is not a critique of the theory per se; the theory explains the emergence of religions based on moralizing so-called Big Gods – not contemporary differences in religiosity.⁸

Another influential evolutionary theory was set forth by cognitive anthropologist Pascal Boyer. Boyer (2008) takes religious ideas to be a subset of the ideas we are able to hold and argues, based on cognitive science, that ideas are more likely to attract our attention if they are interesting. This happens when they violate our intuitive expectations to a limited degree that still allows us to make inference. Culturally successful ideas, then, are those with a prominent counterintuitive feature that attracts our attention and at the same time have a rich inferential potential. Most religious rituals and beliefs are arguably somewhat counterintuitive and at the same time are handy explanations for the social environments in which they emerge. This theory is not meant to explain *differences* in either emergence of religion or current differences in religiosity, as it does not focus on differences across societies or individuals. Rather, it focuses on something ingrained in all societies and individuals.

The remainder of this chapter will describe and explore in more detail the theory of religious coping. We will use this theory to deepen our understanding of the emergence of religion and of differences in religiosity across contemporary societies. We are not claiming that religious coping is the only explanation. We are only claiming that it is *one* important explanation.

⁸ Moralizing gods is one aspect of religion, preceded by thousands of years with animistic religions and spirituality. Whether Big Gods or complex societies came first is still being debated, cf. for instance Whitehouse et al. (2019) and Beheim et al. (2019).

3. Religious coping

The religious coping hypothesis states that individuals draw on religious beliefs and practices to understand and deal with unbearable and unpredictable situations.⁹ Religion may provide comfort, it may be a way to make sense of events that are otherwise difficult to explain, or it may provide a sense of control in these situations.¹⁰ Indeed, when asked, religious survey respondents stated that one of the main purposes of religion is to provide buffering against life stressors.¹¹ Examples of religious coping are seeking a closer relationship with God, praying, or finding a reason for the event by attributing it to an act of God. When adversity hits in the modern world, only some of the few very religious would believe that God was directly responsible for the event. That is, most would not engage in the type of religious coping where religion provides an *explanation* for the event, though such coping was quite common in the past, as we shall see. Instead, most people using religion for coping in the modern world would use it for comfort and support when adversity hits - much like meditation or other recreational activities.¹² However, disasters - including earthquakes - are sometimes attributed to divine retribution even in the modern world. For instance, a Gallup survey conducted in the aftermath of the great 1993 Mississippi River floods asked Americans whether the recent floods were an indication of God's judgement upon the sinful ways of the Americans. 18% answered in the affirmative (Steinberg (2006)). A more recent example of direct attribution of disaster to acts of God is evident in the title of a sermon by Pastor Robert Jefress at an Evangelical Christian megachurch in Dallas, which asks "Is the Coronavirus a Judgement from God?" Indeed, a Pew Research Center survey from March 2020 revealed that more than half of Americans had prayed to end the coronavirus (Pew, 2020). Bentzen (2020) extends the analysis to the world and documents that half of the global population had prayed in an attempt to end the coronavirus. As we will see in Section 5, this tendency to attribute disaster to acts of God has its roots in the past, even in ancient history.

Numerous empirical studies document that individuals hit by various adverse life events, such as cancer, heart problems, death in close family, alcoholism, divorce, or injury are more religious than others.¹³ In addition, prayer is often chosen by hospitalized patients as a coping strategy above seeking information, going to the doctor, or taking prescription drugs (Conway (1985)). This literature faces the major challenge that being hit by adverse life events is most likely correlated with unobserved characteristics (such as lifestyle), which in turn may matter for the individual's inclination to be religious.

Norenzayan & Hansen (2006) addressed the endogeneity concern in four different controlled experiments of a total of 288 participants from North America. In lack of exogenous variation in adverse life events, they exploited exogenous variation in thoughts of death. For instance, they primed half of the participants with thoughts of death by asking them questions such as "What will happen to you when you die?" After the experiments, the participants primed with thoughts of death were more likely to reveal beliefs in God and to rank themselves as being more religious. In the remaining

⁹ E.g., Pargament (2001), Cohen & Wills (1985), Park et al. (1990), Williams et al. (1991). The terminology "religious coping" is taken from the psychology literature, but other labels have been used in the literature. For instance, religious buffering, the religious comfort hypothesis, and psychological social insurance.

¹⁰ Geerts (1966), Pargament et al. (2000).

¹¹ Clark (1958) and Pargament (2001).

¹² Vail et al (2010) argues that, compared to secular beliefs, religious beliefs are particularly useful for mitigating death anxiety as they are all encompassing, rely on concepts that are not easily disconfirmed, and promise literal immortality.

¹³ See e.g., Ano & Vasconcelles (2005) and Pargament (2001) for reviews.

experiments, they found similar effects for other supernatural beliefs. While solving the endogeneity issue, conclusions based on 288 participants – mainly students - from North America cannot necessarily be extended to the world at large. The study cannot tell us whether elderly from California or students from Pakistan would respond in the same way. Yet, the theory is that religious coping is not something peculiar to Christianity. For instance, Pargament (2001) notes that (p3) "While different religions envision different solutions to problems, every religion offers a way to come to terms with tragedy, suffering, and the most significant issues in life."¹⁴ Performing lab experiments for a representative global population is rather tedious and costly.¹⁵ Instead, one can exploit the presence of a natural experiment to obtain random variation in the extent to which individuals experienced unpredictable adverse events.

4. Natural disasters and religiosity today

Natural disasters form such a natural experiment, as they are adverse shocks and most of them are quite unpredictable. As opposed to other natural disasters, such as seasonal storms, earthquakes are particularly unpredictable - and they are better measured than most other disasters. Indeed, the belief that natural disasters carried a deeper message from God was the rule rather than the exception before the Enlightenment (e.g., Hall (1990), Van De Wetering (1982)). Later, the famous 1755 Lisbon earthquake has been compared to the Holocaust as a catastrophe that transformed European culture and philosophy.¹⁶ Penick (1981) documented that US states hit by massive earthquakes in 1811 and 1812 saw church membership increase by 50% in the following year, compared to an increase of only 1% in remaining states. More recently, Sibley & Bulbulia (2012) found that conversion rates increased more in the Christchurch region after a large earthquake hit the region in 2011, compared to the remaining four regions of New Zealand. Other disasters may have left an imprint on religiosity. For instance, Ager et al. (2016) find that church membership rose in counties affected by the Mississippi river flood of 1927.

Bentzen (2019a) exploited earthquakes, tsunamis, and volcanic eruptions as shocks that hit the globe at large. The remainder of this section reviews this research. While the studies reviewed thus far focus on a single country or a subset of individuals within one country, Bentzen identifies the impact of natural disasters on religiosity across the world. This enables testing of whether the religious coping hypothesis holds across all major religions, countries, and socio-economic groups, on average. To do so, Bentzen uses measures of religiosity provided by the World Values Survey and European Values Study, which are surveys of a total of 500,000 individuals from 109 countries interviewed over the period 1981-2014.¹⁷ The surveys contain multiple questions related to religiosity. The persons responsible for the surveys document that six particular measures span global religiosity (Inglehart and Norris (2003)). Bentzen conducts the analysis for these six questions,

¹⁴ See also Feuerbach (1957), Freud (1927), and Marx (1867) for similar statements, generalizing across all religions.

¹⁵ Other scholars have performed similar experiments to the Norenzayan and Hansen experiment for non-Christian students (e.g. Vail et al. (2012)), confirming the results.

¹⁶ See review by Ray (2004). In addition to being one of the deadliest earthquakes ever, it struck on a church holiday and destroyed many churches in Lisbon, but spared the red light district. Accordingly, many thinkers associate the earthquake with the decline in religiosity across Europe afterwards. According to religious coping theory, shocks can instigate leaving God or embracing him. Empirics show that the latter is most common (e.g., Pargament (2001)).

¹⁷ The surveys are constructed so that they can be appended and all measures are comparable across the two surveys.

which are "How important is God in your life?", "Are you a religious person?", "How often do you attend religious services?", "Do you get comfort and strength from religion?", "Do you believe in God?", and "Do you believe in a life after death?" These questions were answered by up to a total of 396,211 individuals interviewed in up to 105 different countries.¹⁸

One caveat of conducting a global analysis is that different measures of religiosity most likely do not compare across different religions and countries. It may not be possible to compare the religiosity of a Muslim from Indonesia with the religiosity of an American Protestant. Instead, Bentzen compares religiosity of the American Protestant only to other American Protestants and the Muslim Indonesian to other Muslim Indonesians. To do so, Bentzen exploits that the surveys contain information on the subnational district of the respondents to allow conducting within-country and within-religion analysis. The advantages of doing within country analysis, instead of having to compare across countries is that differences in individuals' understanding of the questions across countries is not a problem and also that unobserved country-level factors can be accounted for, such as national institutions and culture.

Bentzen (2019a) combines the survey data with data on the risk of natural disasters and data for actual earthquakes that hit the globe during the past decades.¹⁹ In the first part of the analysis (the cross-section analysis), Bentzen finds that individuals living in districts more frequently hit by earthquakes, volcanic eruptions, or tsunamis are more religious than those living in areas hit by fewer disasters. The main analysis focuses on earthquakes, as data on earthquakes is more precise than other disasters and since earthquakes are comparatively much more unpredictable.²⁰ Figure 1 illustrates the relation between earthquake risk and religiosity.^{21,22} The stippled line shows the linear regression line between the two variables, including baseline controls. The relation is clear: Individuals living in districts with higher earthquake risk are more religious.

¹⁸ The different questions were not raised in all waves and in all countries. Of the six questions, the question raised to the fewest people was "Do you believe in a life after death?" answered by 268,859 respondents in 82 different countries. The question asked to the largest number of respondents was "How often do you attend religious services?" answered by 396,211 persons in 105 different countries.

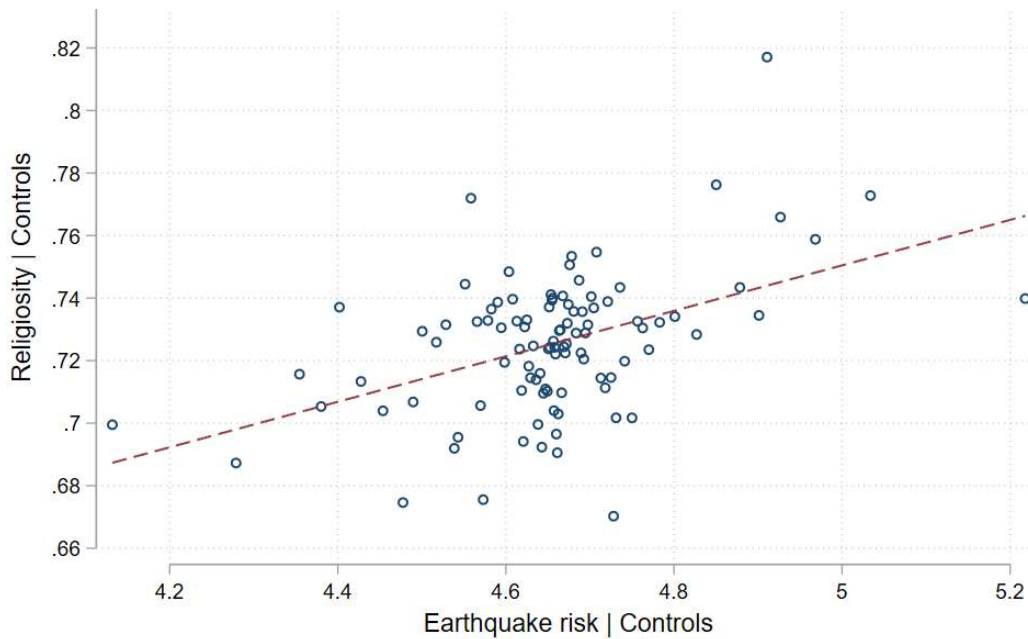
¹⁹ The data on earthquake risk measures the risk of being hit by an earthquake of a certain size within the next 50 years. The data on earthquake events measures the exact location of actual earthquakes of various strengths. Larger earthquakes increase religiosity more.

²⁰ The US Geological Survey (USGS) notes that earthquakes still cannot be predicted (<https://www2.usgs.gov/faq/categories/9830/3278>) and so does the study by Hough (2002). See also the following post about our ability to forecast storms and their paths, as opposed to our inability to forecast earthquakes: <https://www.tripwire.com/state-of-security/risk-based-security-for-executives/risk-management/hurricanes-earthquakes-prediction-vs-forecasting-in-information-security/>

²¹ In Figure 1, religiosity is measured by answers to the question "How important is God in your life?", which is the preferred measure of religiosity among the six measures, due to the much higher number of observations and the two main theoretical considerations that a) intrinsic religiosity should be more affected than extrinsic religiosity such as churchgoing and b) that the intensive margin (how strongly you believe) is more likely to be affected than the extensive margin (whether or not you believe). Earthquake risk is measured by 5000 km minus the distance to high-risk earthquake zones. Using distances to measure earthquake risk instead of the average across earthquake zones has the advantage that the mechanisms behind the relation between earthquake risk and religiosity can be disentangled, cf. Section 4.1.

²² Compared to the figures in Bentzen (2019), Figure 1 excludes districts that are located more than 1500 km from a high-risk earthquake zone. The rationale is that being located 100 km closer to a high-risk earthquake zone arguably does not matter much if you are already located 1500 km from high-risk earthquake zones. Other factors than earthquakes are more important for shaping religion in these regions.

Figure 1. Relation between earthquake risk and religiosity



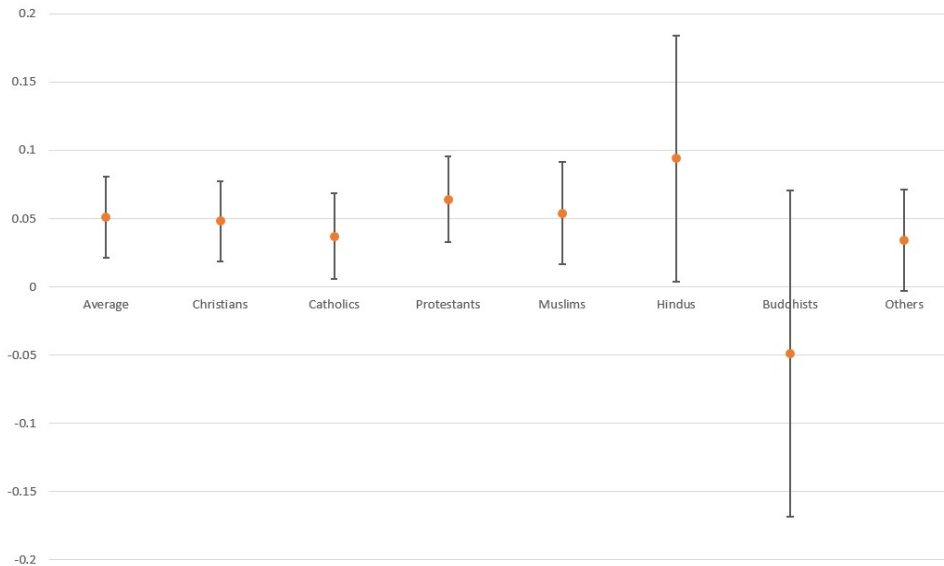
Notes. Binned scatterplot between religiosity measured by importance of God and earthquake risk measured by 5000 km minus the distance to high-risk earthquake zones. The figure is based on a regression across 186,944 individuals, controlling for age, age squared, gender, marital status, absolute latitude, distance to the coast, dummies for recent earthquakes, year fixed effects, and country fixed effects. The stippled line represents this regression. The slope is significantly different from zero at the 1% level. The sample is restricted to regions within a 1500 km radius of high-risk earthquake zones. Observations are binned into 100 equally sized bins.

Figure 2 illustrates that the effect is rather homogenous across the different major religions. The figure shows the impact of earthquake risk on religiosity for the world on average and for each major religious denomination separately. Religiosity increases for Christians (both Protestants and Catholics), Muslims, Hindus, and others, but is statistically indistinguishable from zero for Buddhists. The large standard errors for Hindus and Buddhists reflect that these are not well represented in the sample.²³ Thus, the analysis does not allow concluding whether the insignificance for Buddhists is due to imprecise estimates caused by few Buddhists in the sample or due to Buddhists not using religion for coping. In later research, Bentzen (2020) used Google search shares for prayer to document that people from all major religions have prayed to cope with the corona crisis.²⁴ However, Buddhists and Hindus seem to use their religions more for celebration of religious holidays than for coping with adversity. Bentzen (2019a) further documents that earthquakes increase religiosity to the same extent on all continents, and across all income and education groups. Thus, the impact of earthquakes on religiosity is not particular to any religious denomination, region, or socioeconomic group.

²³ The sample for which information on the religious denomination of the respondent drops to 88,000 individuals living in 580 districts across the world. Of these, 62 districts include at least one respondent identifying as Hindu and 89 districts are inhabited by at least one respondent identifying as Buddhist.

²⁴ Again, the estimates for the rise in prayer search shares for Hindus and Buddhists are quite imprecise. The rise is only significant at the 8 and 17% level, respectively.

Figure 2. Impact of disaster risk on religiosity across religious denominations



Notes: The figure shows the parameter estimate (indicated by the dot) on earthquake risk in a regression of religiosity, accounting for country fixed effects and a dummy equal to one if one or more earthquakes hit during the past year across 88,000 individuals in 580 districts across the world. The first parameter estimate is calculated for the full sample, the second is calculated using a sample restricted to Christians, the third is further restricted to Catholics, fourth is Protestants, fifth Muslims, sixth Hindus, seventh Buddhists, and the last estimate is estimated on a sample restricted to other religions. The vertical lines represent the 95% confidence intervals.

In addition to being statistically significant, the impact of earthquake risk on religiosity is also of a significant magnitude: A one standard deviation increase in earthquake risk increases religiosity by 3 percentage points. This coincides in magnitude to the fall in religiosity over the past 30 years. Put differently, the size of the effect amounts to 80% of the well-established gender difference in religiosity.²⁵ Similar results obtain for other unpredictable major disasters such as volcanic eruptions and tsunamis, and for different measures of earthquake risk (Bentzen (2019a)).

A first-order concern is that important factors have been left out of the analysis, biasing the results. The main analysis includes country-fixed effects, which means that country-level characteristics such as institutions and culture are accounted for. However, district-level factors may bias the results. Hypothetically, earthquakes may be more likely to occur along the coast, as some tectonic plate boundaries are close to the coast (e.g. Figure 4)²⁶. At the same time, religiosity may differ across individuals living close to the coast and those living inland for other reasons than coping. In that case, omitting distance to the coast in the regression would create a spurious relation between earthquakes and religiosity. To account for these omitted factors, Bentzen does two things: First, she

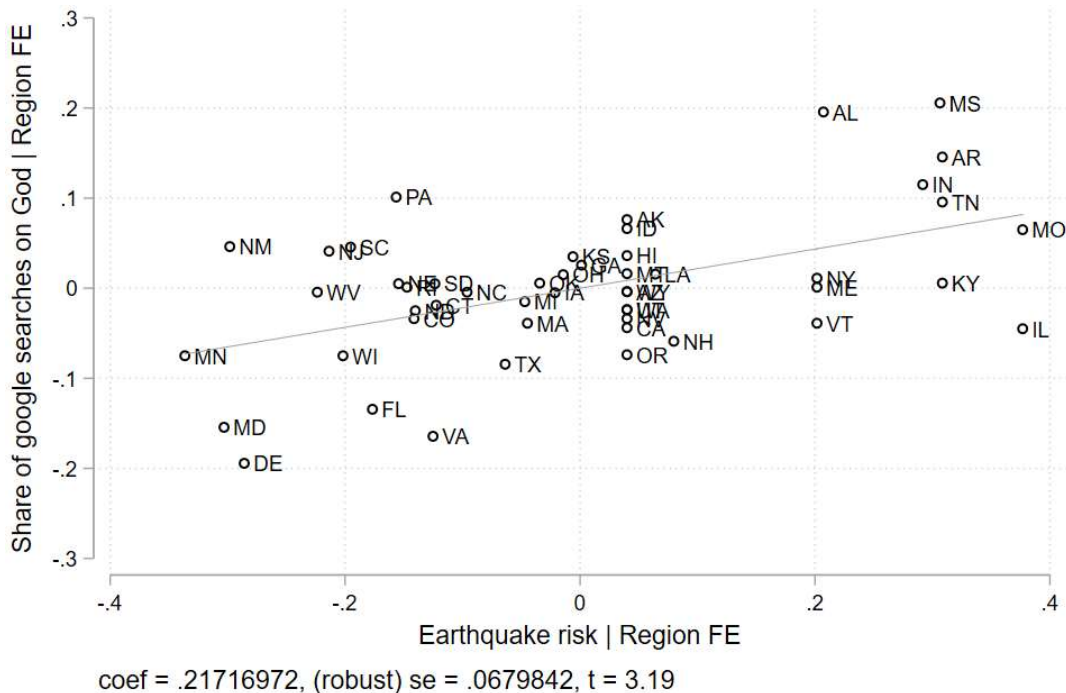
²⁵ It is a well-known finding that women are more religious than men (e.g., Miller & Hoffmann (1995)).

²⁶ To simplify, collisional/transpressional plate-tectonic boundaries are commonly sufficiently close to coastlines to produce related earthquake damage there, if one plate margin consists of oceanic crust and the other consists of continental (including island-arc) crust. This is the case in a significant share of the earth's surface (e.g. fig. 4), particularly the western coasts of the Americas, some shores of the Mediterranean and Black Seas, those parts of eastern shores of Asia where island arcs face Pacific plates, etc.

adds relevant controls to the analysis and next she exploits the time-varying feature of the data, which enables inclusion of district-fixed effects. Regarding the former, the analysis includes a control for distance to the coast, country fixed effects, absolute latitude, recent actual earthquakes, population density, light intensity, the share of arable land, average temperature, average and variance of precipitation, district area, and a dummy equal to one if the district is often hit by earthquakes, as well as individual-level confounders, such as age, gender, marital status, income, education, employment status, and various measures of other cultural values.

Bentzen proceeds to show that the results are not particular to the survey-based measures of religiosity. Google searches for religious terms are also higher in areas with higher earthquake risk, cf. Figure 3. This analysis is conducted across US states, where internet penetration is equally high. The share of Google searches for God, Jesus, Pray, and Bible is higher in states with higher earthquake risk, even accounting for region fixed effects, income, distance to the ocean, and absolute latitude.

Figure 3. Earthquake risk and Google searches for religious terms



Notes. The figure documents the relation between earthquake risk (measured by 5000 km minus the distance to high-risk earthquake zones) and religiosity measured by Google searches for God as a share of all Google searches. The line represents the regression line across 50 US states, including region fixed effects for the four major US regions. The slope is significantly different from zero at the 1% level.

While the analysis thus far has documented that religiosity is higher in areas where earthquakes more often hit, the next part of the analysis identifies the effect on religiosity of an actual earthquake. Unfortunately, the same individuals are not followed over time. Instead, Bentzen exploits that a third of the respondents are interviewed in subnational districts that were interviewed more than once. This enables constructing a so-called synthetic panel, where the districts are the panel dimension. In a

difference-in-difference analysis, Bentzen finds that district-level religiosity increases when an earthquake hit in between the years of interview, in keeping with the religious coping hypothesis. In particular, the religious become more religious, whereas those without a religion do not start believing.²⁷ Furthermore, an earthquake in a district that is otherwise rarely hit increases religiosity more than an earthquake in a district that is often hit. This is consistent with the theory that religion is used mainly to cope with unpredictable events, while people tend to use problem-focused coping to cope with more foreseeable stressful events, such as an approaching job interview.²⁸ Religion belongs to emotion-focused coping that deals with the emotional distress caused by a situation, while problem-focused coping aims at altering the situation more actively.

Average religiosity increases by 7.6 percentage points when an earthquake hits. This is twice as much as the fall in global religiosity over the past 30 years. Put differently, the rise amounts to increasing religiosity from the level in the median district to the level in the district at the 80th percentile. As expected, this rise in religiosity diminishes after a while, but a residual remains, which is passed on through generations. This persistent impact is investigated in the fourth part of the analysis, which identifies whether higher religiosity is transmitted across generations. This transmission is theoretically plausible: In a model of cultural transmission, parents will choose to transmit a particular cultural trait to their children if this grants utility to either parents or children (e.g., Bisin & Verdier (2001)). Empirical evidence suggests that religiosity may be such a trait: Religion is likely to improve mental health, life satisfaction, abilities to cope with adverse life events, and deter deviant behavior.²⁹ Bentzen (2019a) investigates this empirically by combining data on earthquake risk with a dataset containing information on children of migrants currently living in Europe, but whose parents came from various countries across the globe.³⁰ The data reveal that children of immigrants whose parents came from countries with high earthquake risk are more religious than those from low earthquake risk areas, independent of actual earthquake risk and level of religiosity in their current country of residence. It seems that living in high-earthquake risk areas instigates a culture of religiosity that is passed on to future generations like many other cultural values.

4.1. The proposed mechanism

Identifying an effect of earthquakes on religiosity does not confirm the religious coping hypothesis in itself. Alternative explanations for why religiosity increases in the face of disasters could potentially be that people go to church for material aid, that people move in the face of disasters, or that disasters also affect development or other cultural values, in turn affecting religiosity. Bentzen (2019a) documents that the main reason for the impact of disasters on religiosity is religious coping.

To disentangle these alternative explanations from the religious coping hypothesis, Bentzen (2019a) sets up testable predictions for the religious coping hypothesis vs alternative explanations.

²⁷ The result is robust to adding country-by-year fixed effects, individual and district level controls, and consistent with the idea that nothing correlated with religiosity is causing the earthquakes, future earthquakes have no impact on current levels of religiosity.

²⁸ Lazarus & Folkman (1984), Park et al. (1990), Norris & Inglehart (2011), Sosis (2008).

²⁹ For instance Miller et al. (2014), Clark & Lelkes (2005), and Lehrer (2004). See also reviews by Smith et al. (2000) and Pargament (2001).

³⁰ This analysis is based on the European Social Survey. The methodology used is termed epidemiological approach by Fernandez (2011).

First, religious coping involves a response to the psychological distress, while most of the alternative explanations involve a response to the physical losses caused by disaster. To substantiate that the rise in religiosity reflects a response to the psychological damage caused by disaster, Bentzen excludes districts that are directly hit by earthquakes from the analysis.³¹ What is left in the analysis are districts that are not physically hit, but that neighbor the damaged districts. The results are unchanged: Religiosity rises more in districts located close to districts that are hit, compared to districts located further away. The rationale is that people in surrounding areas may have friends and family members in these areas and may therefore suffer psychologically without suffering material losses. This indicates that the explanation has to involve psychological losses rather than material losses.

Furthermore, if the effect is simply driven by people going to church for material needs, church going should rise when an earthquake hits. On the other hand, the literature on religious coping finds that people mainly use their intrinsic religiosity (ones' personal relation to God) to cope with adversity, and to a lesser extent their extrinsic religiosity (going to church).³² Likewise, depressed individuals tend to prefer solitude to socializing as a coping strategy. Similarly, Bentzen's results reveal that only intrinsic religiosity increases in response to a recent earthquake, while church going is not affected. In addition, Google searches for God, Jesus, Bible, and Pray are higher in states with high earthquake risk, while searches for Church are not.

If the results had reflected that religion is used for obtaining material needs from the church, one would expect other disasters to have similar effects on religiosity, as long as they pose the same material losses. The degree of predictability of the disaster should not matter much in such responses. On the other hand, the religious coping hypothesis predicts that individuals use religion more when faced with adverse *unpredictable* events vs predictable ones (e.g., Norris & Inglehart (2011), Sosis (2008), Park *et al.* (1990)). That is, foreseeable events, such as an approaching feared exam or even an approaching devastating storm, are more likely to ignite problem-focused coping, which involves altering the source of the stress.³³ Thus, the religious coping hypothesis predicts larger effects for unpredictable disasters, while the "physical insurance" hypothesis predicts similar effects as long as material losses are similar. Major geophysical and meteorological disasters can be grouped in terms of predictability. For instance, meteorologists have a much easier time predicting storms than seismologists have in predicting earthquakes. Also, earthquakes can be grouped into more or less surprising ones based on recurrence frequency, where the latter hit areas frequently hit in general. Consistent with the religious coping literature, Bentzen finds that surprising disasters increase religiosity more than less surprising ones for equal amount of damage. For instance, elevated risk of earthquakes, tsunamis, and volcanic eruptions increase religiosity, while storm risk does not.

³¹ When using distances to high-risk zones as the main measure of earthquake risk, the main variation comes from *outside* the regions that are most severely hit. This enables removing the districts that are hit, and thus enables discounting alternative explanations based on the physical damage caused by earthquakes.

³² E.g., Johnson & Spilka (1991), review by Pargament (2001). Koenig *et al.* (1988) found that the most frequently mentioned coping strategies among 100 older adults dealing with three stressful events were faith in God, prayer, and gaining strength from God. Social church-related activities were less commonly noted. Similarly, a medical study by Miller *et al.* (2014) found that individuals for whom religion is more important in their lives experienced reduced depression risk (measured by cortical thickness), while frequency of church attendance was not associated with thickness of the cortices.

³³ See also Mattlin *et al.* (1990) on how practical everyday problems are less likely to trigger religious coping compared to large bad events. Skinner (1948) found that something similar to this reaction to unpredictability extends into the animal world. He found that pigeons subjected to an unpredictable feeding schedule were more likely to develop inexplicable behavior, compared to the birds not subject to unpredictability. Since Skinner's pioneering work, various studies have documented how children and adults in analogous unpredictable experimental conditions quickly generate novel superstitious practices (e.g., Ono (1987)). While these types of superstitious behavior are not necessarily directly comparable to religiosity, the studies are somewhat informative to the religious coping literature.

Storms result in comparable material and personal losses, and thus should instigate the same effect on religiosity if the explanation was physical insurance. In contrast, earthquakes in areas frequently hit by earthquakes affect religiosity less than earthquakes in areas otherwise rarely hit. Thus, this part of the analysis also supports religious coping as the main explanation.

In addition, if religion is a matter of physical needs, one would expect that the effect is larger for poorer individuals, since they are more likely to be in need for material support. On the contrary, both poor and rich can be in need for stress relief, and income should not matter for how much earthquakes increase religiosity. The data support the latter relation.

Turning to another alternative explanation, one could conjecture that the results are caused by atheists moving out in the face of disaster. In that case, one would not expect that the short-term effect on religiosity abates with time. Explaining this tendency with population movements would mean that atheists move out in the immediate aftermath of the earthquake, but then choose to move into the district again after 6-12 years, only to move out again when the next earthquake hits, an unlikely scenario. On the other hand, the fall in religiosity after a while is reconcilable with the idea that religion provides stress relief, reducing the need for religion after a while.

If the effect is purely due to a direct impact on income, the effect should vanish or at least fall drastically when accounting for development. This proved not to be the case: The impact is unchanged when accounting for personal or regional income or education levels. Last, if religiosity is just part of the characteristics of a different type of people emerging in earthquake areas, the effect should fall when controlling for cultural characteristics, such as trust, independence, thriftiness, or preferences for hard work. This is also not the case.

To sum up, the data do not support the alternative explanations involving physical insurance, direct economic loss, migration/selection, or a special culture evolving in high-risk areas. Nevertheless, we cannot rule out that each set of results is partly due to some of these explanations. However, the only explanation that can explain all results across all four analyses (cross-section, google searches, difference-in-difference analysis, and cross-generational analysis) is religious coping.

5. Earthquakes and religion in history

If earthquakes have strengthened religious beliefs in the contemporary world, it would certainly seem plausible that it has done so in the past. In this section, we show that strong religious responses to earthquakes have been characteristic of our past, taking forms that commonly changed religions and thereby changed the cultures harboring them. Our presentation is in two parts: First, we show that the origination of new religions through the millennia tends to occur where earthquakes are most severe and frequent. Of course, other factors may correlate both with seismic activity and religion. Therefore, we proceed in the second part to describe links between individual earthquakes in historical eras and their religious responses.

While the main type of religious coping today probably consists of religion providing comfort and support, the evidence that we present from the past is based in large part on attributing disasters to God's anger. Attributions of an earthquake to a punishing God provides a way to understand the disaster, but it is also a potential way to perceive control of future earthquakes through more virtuous/religious behavior. Of course, that might also be more comforting and, in that sense, the functions of comfort, meaning-making, and control become intermingled. All of these types of

religious coping were most likely at play in our past, but our evidence emphasizes attributing earthquakes to messages from God. Again, we do not claim that earthquakes (and other disasters) are the sole explanation for the emergence of religion. But we do claim that they are one explanation.

5.1. The origination of complex religions

The locales of origination of new complex religions through history could be a clue to perceived inadequacy of preceding simpler religions by their cultures. Here we compare the origination sites of today's most populous religions to seismic activity of those sites via their plate-tectonic positions. Table 1 compares today's religions numbering adherents over a million (from Wikipedia 2018) with the tectonic environments of the originating sites for each, listed as distance to the nearest plate-tectonic boundary, cf. Figure 4.

Table 1. Plate tectonic positions of world religions' originating sites

Rank and name	Adherents (million)	Originating site	Distance to boundary (km)	Plate boundary
1. Christian	2400	Jordan Valley	0	Af-Ar
2. Muslim	1800	Mecca	100	Af-Ar
3. Hindu	1150	Hastinapura ^a	100	In-Ea
4. Buddhist	521	Kushinagar ^b	110	In-Ea
5. Tao/Confucian	394	Zhou ^c	300	
6. Sikh	30	Kartarpur	0	In-Ea
7. Judaism	14.4	Jordan Valley	0	Af-Ar
8. Bahai	7	Acre/Haifa	60	Af-Ar
9. Jain	4.2	Patna	160	In-Ea
10. Shinto	4.0	Kyoto	500	PO-Ea
11. Cao Dai	4.0	Tay Ninh	1300	In-Ea

Notes. Omitted from the Wikipedia list are irreligious, ethnic/indigenous, African indigenous, spiritism, and neopagan, i.e. religious categories that are composite and have no single origin. Similarly, Zoroastrianism is omitted from calculations due to lack of definite origination site. Plate boundaries Af indicate African plate boundary; Ar Arabian; In Indo-Australian; Ea Eurasian; PO Philippine and Okhotsk plates.

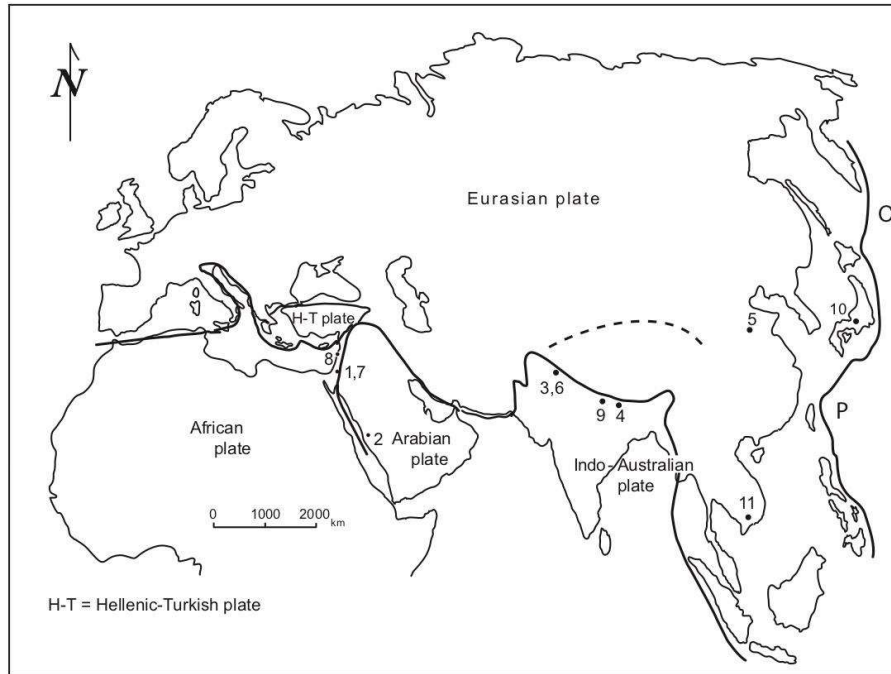
^a Hastinapura is taken for the coalescence of the religious traditions that became Vedic Hinduism.

^b Both Gaya is the traditional inspiration site but most sites pertinent to origination such as Kushinagar are about 110 km.

^c Confucianism and other traditional Chinese religions are thought to have been codified in Zhou times in their capital. The distance listed is that to the Altyn Tagh-Qinling fault system, a proto-plate boundary as discussed in Force (2015). Otherwise, the listed distance would be about 1500 km.

Taking an unweighted arithmetic average of site-distances from Table 1 gives 239 km, a remarkably small average distance on a globe with thousands of kilometers of distance available for founding religions. Indeed these originating sites form a cluster around tectonic boundaries that represent only 5.6 percent of the available land in the eastern hemisphere alone.³⁴ We can calculate the chance that this distribution is random. This probability would be 0.056^{11} , or 1.7×10^{-14} (one in several trillion). So regardless of causes, there is a strong spatial association of active plate tectonic boundaries with religious origination.

Figure 4. Locations of originating sites of major world religions relative to tectonic plate boundaries



Notes. The numbers refer to the religions in Table 1. The tectonic boundaries are marked by heavy lines. P and O are Philippine and Okhotsk plates respectively. Dashed line is the Altyn Tagh-Qinling fault system.

Perusing Table 1 also gives one the impression that religions with the most adherents originated closest to tectonic boundaries. An average weighted by number of adherents is called for. Dividing the product of adherents and distance by the number of religions gives 75.7 km for the average adherent-distance for originating sites, a much smaller distance confirming that religions with the most adherents tended to originate closest to plate-tectonic boundaries. It is clear from the table and Figure 4 that the northern margin of the Indian plate and the western margin of the Arabian plate were the locus of origination of disproportionately many religions, and those with many adherents.

The observation connecting religious origination sites with plate-tectonic environment is a simple one³⁵, which may have complex causes. For instance, the major religions also emerged in areas that became the origin of early complex societies. Perhaps complex societies first emerged in

³⁴ Even if the distance for Confucian/Tao had been listed as 1500 km, the average would still be only 251 km.

³⁵ Originating by Henry Spall of the US Geological Survey in the 1980's.

these areas and then later came the major religions.³⁶ In that case, the reason for the emergence of religion is not religious coping, but rather some link involving complex societies, which themselves tend to follow tectonic boundaries (Force and McFadgen 2010). This explanation, though, would have to explain why complex societies emerged close to tectonic boundaries. While we cannot rule out such alternative explanations in this dataset, we turn to another source of information that documents a direct link between earthquakes and religion in our past.

In particular, our goal is to evaluate whether the spatial association with earthquakes is with religion rather than some other cultural variable that makes the apparent relation with religion indirect. Previous research has shown a relation between seismicity and cultural character in the ancient world (Force and McFadgen 2010, Force 2015) and through history (e.g. deBoer and Sanders 2005, Hough and Bilham 2006, Nur 2008, Robinson 2016).³⁷ The question of whether physical factors – other than tectonic activity - explain the ancient cultural distribution has been addressed most systematically by Force (2015). Force included separate analyses of climate, soils, rivers, transportation potential, mineral resources, and topography. He found that cultural response was required to produce the observed distributions for all but one factor, potable water especially fault-related springs. The next step calls for a demonstration that religious factors dominate among cultural factors in response to earthquakes.

5.2. Case histories of religious responses to earthquakes through history

Seismic events have occurred all through human history, but human responses of most have gone unrecorded. This of course is a small fraction of recorded earthquakes for which only deaths and damage to palaces and religious structures appear in the records (e.g. Ambraseys 2009). Our analysis exploits response descriptions from historical descriptions of earthquake impact such as de Boer and Sanders (2005), Chester and Duncan (2009), Robinson (2016) and a survey of newspaper accounts, ancient texts, etc by Force (2020). In total, we have found 52 cases for which description of cultural and religious response to earthquakes has been sufficient to distinguish religious from non-religious responses (listed in the appendix and described in more detail in Force 2020).

Our 52 earthquakes were mostly quite damaging, but our sample necessarily was by description rather than earthquake magnitude. The analysis here is a compilation of case studies and provides evidence that religious responses are most common but show a variety in character that varies among time periods, especially in attribution of earthquakes to acts of God.

The listed earthquakes are mainly historic, ranging in age from antiquity to AD 2011. The list begins with religious responses in antiquity to fault movement known to be of the same era. For the others the date of earthquake is known. Most presented earthquakes were very destructive, but in a few cases modest earthquakes produced notable responses. The lists show that religious responses to earthquakes outnumber other cultural responses by 35 to 11. Six additional responses are composite; in these, religious reactions are immediate, but precede other responses. The ratio of religious to other cultural responses decreases somewhat into the modern era, perhaps because more cultural avenues became available.

Religious responses to earthquakes have included proclamation of divine appearances, warnings, and retribution (sometimes with priestly manipulation), of change to religious observance

³⁶ Indeed, this is what Whitehouse et al. (2019) documented. However, Beheim et al. (2019) document the reverse when correcting the data.

³⁷ These all enter the list in the Appendix.

(sometimes leading to different subsistence and military strategies), and of religion-based increase of nationalism. The types of non-religious responses include civic reorganization, revolution, and improved earthquake preparation, cf. the Appendix.

It should be noted parenthetically here that sudden volcanic events, a somewhat similar type of tectonic occurrence, produces somewhat similar cultural responses (e.g. Balmuth 2005, Grattan and Torrence 2007). The most nearly parallel compilation to ours lists a total of 41 religious responses to volcanic events and 11 non-religious responses, the latter only occurring post-1900 (Chester and Duncan 2007, 2009). Details of the volcanic responses differ; for example, veneration of the volcano can play a part, in contrast to an apparent lack of veneration for earthquakes themselves.

In the following, we provide some examples of religious, non-religious, and composite responses to earthquakes. First, ancient Hellenic and Judaic literature records cultural and religious responses to earthquakes. The Hellenic responses changed over time from religious as recorded in poetry and drama, to non-religious as recorded in historical and philosophical works, with the latter predominating as of about 500 BC. In ancient biblical literature, the treatment of earthquakes was entirely in a religious context. Later examples of religious responses vary; in the western world earthquakes were commonly a consequence of sin as preached by John Wesley in England, the Mathers in New England, and Mary Baker Eddy in San Francisco over a period of several hundred years (de Boer and Sanders 2005, Rozario 2007, Winchester 2006). An illustrative example of religious response is that from the New Madrid, Missouri earthquakes of 1811-1812 (de Boer and Sanders 2005), which saw nearby church membership increase much more than in farther states (Penick 1981). Religious responses in Japan to earthquakes in AD 1257, 1855, and 1923, involved the Lotus sect, religious imagery of earthquakes, and increased Shinto militarism respectively (de Boer and Sanders 2005, Robinson 2016).

Perhaps the most intricate religious response to earthquakes is that in the ancient Judaic world, exemplified by response to an earthquake of 760-750 BC known archaeologically (Dever 1992). This earthquake was “predicted” in nebulous terms by the prophet Amos (Amos 1:1), who also proclaimed that God would appear at such times. These appearances coupled earthquakes with God’s retribution for hundreds of years (Freedman and Welch 1994) and with earthquakes being used as a threat by seven subsequent prophets (Isaiah, Jeremiah, Ezekiel, Joel, Nahum, Haggai, and Zechariah). The Christian New Testament continues this treatment of earthquakes, resulting in a linkage of earthquakes as divine punishment that is occasionally invoked throughout the Judeo-Christian world (reviewed by Chester and Duncan 2009). Dread of earthquakes and their supposed divine retribution set a pattern of “god-fearing” religion in modern western culture, a pattern that now extends well beyond earthquakes.

Lisbon in 1755 gives us a glimpse of religious and other cultural responses unfolding sequentially. A severe earthquake offshore shook much of Western Europe, and was particularly damaging in Lisbon, which also suffered a related tsunami. Jesuit fathers attributed the earthquake to retribution for the sinful behavior of the citizens, and redoubled the Inquisition. The Marquis of Pombal, however, acquired enough power to rebuild the city - and banish the Jesuits from Portuguese possessions. This earthquake also had long-term philosophical repercussions, beginning with Voltaire, his *Candide* being an example (e.g. de Boer and Sanders 2005, Robinson 2016).

Even in the modern world, religious responses to earthquakes may be the more immediate. The Managua earthquake of 1972 prompted general priestly attribution to sinful behavior, but catalyzed the lengthy Sandinista revolt once this stage passed. Four other composite responses provide insight

into sequential composite responses that may actually be the norm. These encompass an immediate somewhat instinctive religious response, commonly orchestrated and/or manipulated by a priestly class, followed by longer-term cultural responses that may themselves be religious (such as reform) or quasi-religious (such as building a better temple). Other long-term responses may be civic, political, artistic, and/or scientific, but such cultural changes have been catalyzed and accelerated by earthquakes. In this way, earthquakes have forced the pace of cultural change via religious pathways.

An interesting example of non-religious responses from antiquity comes from Sparta in Greece, where the consequences of an earthquake in ca. 464 BC were described by classical authors. It permitted the revolt of serfs captured in Sparta's wars, leading eventually to the Peloponnesian wars (reviewed e.g. by de Boer and Sanders 2005). In the modern world an example comes from Mexico City in 1985, where the entrenched bureaucracy of the ruling party was unable to cope with recovery after an earthquake. A coalition of citizens formed a new alignment to deal with damage and rebuilding, eventually becoming a political party (Davis 2005).

These 52 examples suggest that direct and immediate religious responses to earthquakes are predominant. These may initiate religious reform or even new religions.

To sum up, ancient origination sites of major religions preferentially cluster around areas of greater seismic activity, providing a suggestion of a link to seismicity from earliest religious histories. Recorded histories from antiquity to the present era show that religious responses to earthquakes far outnumber the non-religious cultural responses; some responses are sequential, with religious response being more immediate vs. more long-term non-religious ones. The religious responses include religious reform, consistent with the distribution of religious origination. Prior to an understanding of natural causes of earthquakes, religious responses included fear of God's causing them - a response occasionally seen even today. However, the Enlightenment apparently was a discontinuity in the type of response to earthquakes.

6. Conclusion

Why did religion emerge in our distant past? Why has it not dwindled as societies modernized? And why are some societies more religious than others today? These questions have posed major puzzles within the social science. We point to religious coping as one explanation: People used religion as a way of explaining matters that were otherwise difficult to comprehend and as a way of obtaining stress relief. The role of religion as a coping tool may have led to the emergence of religion, but may also explain why religion has not vanished with modern science and why some societies are more religious than others: They may have a larger demand for religious coping.

We provide support for this explanation using three types of data. First, earthquakes, tsunamis, and volcanic eruptions have increased religiosity within all of the major religions, on all continents, and for individuals at all levels of income and education. The reason can be pinned down to being psychological rather than material. Second, the major religions of the world emerged in an unusually tight band near fault lines associated with plate-tectonic boundaries suggesting discomfiture with previous beliefs in the aftermath of seismic activity. Third, the historic record suggests that many of the cultural responses to past earthquakes have been religious. This is consistent with the idea that disasters – and earthquakes in particular – have instigated people to use their existing religion or even invent new religions throughout human history. Our lists of human responses to earthquakes are arguably not complete and a causal interpretation of this part necessitates further econometric scrutiny. This understanding of the causes of religion may eventually help us understand its consequences for various socio-economic outcomes.

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Appendix: Types of cultural responses to earthquakes

This appendix is intended to show that religious and other cultural responses are separable based on people's elemental responses to tectonic activity. Composite religious/other cultural responses, generally sequential, are compiled separately; references are listed together.

A. List of religious responses to historic earthquakes

Below we compile cases where religious responses are sufficiently well described to link them definitively to tectonic events. In a few cases archaeological evidence links religious responses to active fault planes.

We have listed only responses to earthquakes rather than including volcanic eruptions, as these can be quite different. Earthquakes generally seem totally other-worldly and unexpected, so that religious response begins at the event, whereas people living near a volcano are generally aware of that, and religious practice consequently focuses on pre- and syn-eruption protection (and in some cases volcano veneration). These are numerous and persuasive; volcanic ties with culture and religion have a literature of their own (e.g. Balmuth et al. 2005, Grattan and Torrence 2007). These ties have been catalogued by Chester and Duncan (2007, 2009), consisting of at least 41 examples, 25 after 1850 and 16 before. To their comprehensive volcanic compilation, we can add only a few (Oviedo 1529, Hamilton 1776, Elson 2007, Barnes in press).

The list below documents the religious responses to earthquakes, ranging from antiquity to the modern world. These are compiled from historical descriptions of earthquake impact such as de Boer and Sanders (2005), Chester and Duncan (2009), Robinson (2016) and our survey of newspaper accounts, ancient texts, etc. Most pre-modern (and some modern) earthquakes have insufficiently recorded and preserved cultural responses, whether secular or religious, to be categorized. Not included in this list are those pre-modern religious events--such as death of a prophet--accompanied by earthquakes, as these were easily manufactured after the fact to maximize impact. However, one such link is included in which a religion's appeal was changed. Also omitted are creation myths that involve earthquakes. Tsunamis are included if they are likely to be earthquake-generated. In a few remarkable items the link is directly to ancient fault activity rather than to earthquakes per se.

Pre-1300 BC: Mycenae, religious (Taylour 1970) focus on recently formed fault scarp (Force and Rutter, 2018)

Ca. 750 BC: an earthquake predicted by Amos (1:1) and known archaeologically (e.g. Dever 1992) began the entire earthquake theophany of zealous prophets (Freedman and Welch 1994).

8th to 4th cent. BC: Delphi, along active faults with episodic destruction; release of toxic gases as basis of predictions and veneration (Stewart and Piccardi 2017)

Ca. 485 BC: Delos (Greek island), earthquake sent as divine warning (Herodotus VI, 98)

5th cent. BC: Ephesus (Turkey), Hellenic temple sited on active fault scarp, apparently deliberately as votive niches are cut into scarp (Stewart and Piccardi 2017)

4th cent. BC: Cnidus (Turkey) as at Ephesus (Stewart and Piccardi 2017)

3rd cent. BC: Heiropolis (Turkey) priestly manipulation of fault-motion consequences (Piccardi 2007, Stewart and Piccardi 2017)

Ca. AD 32: “Holy Land”, death and resurrection of Jesus (Matthew 27:51-54, 28:2-4), earthquakes (not attested outside Bible) suggest divinity as first to be recognized outside Judaism.

AD 60; Denizli/Colossai (Turkey), archangel appears in earthquake (Piccardi 2007)

AD 77 then 365-400: Kenchraea (Greece), earthquake-submerged port becomes Christian basilica, then that is abandoned due to recurrent tectonic submergences (Scranton 1978)

Ca. AD 100: Philippi (Turkey), earthquake (not attested outside Bible) releases Paul and Silas from prison, converts jailer (Acts 16: 26-31), thought to be a miracle.

AD 115: Antioch, earthquake blamed on divine retribution (Sbeinati 2005)

AD 363: Jerusalem, divine causation of earthquake to punish Jews and Roman emperor (Nur 2008)

AD 365: Cyprus, “pagan” temples rebuilt after earthquake as Christian churches (Soren and James 1988)

AD 410: Corinth, earthquake destruction of “pagan” temples divert populace toward Christianity, now “official” (Rothaus 1996)

AD 1257: Kamakura (Japan), rise of lotus sect spurred by earthquake (deBoer and Sanders 2005)

AD 1382: Dover/Calais, earthquake attributed to divine retribution (Aberth 2001)

15th cent. AD: New Zealand, Maori belief systems shift with occupation patterns due to earthquakes and tsunami (McFadgen 2007)

AD 1580: London/Calais, provoked denial of natural cause of earthquake in favor of divine cause (de Boer and Sanders 2005)

AD 1638, 1727, and 1755: New England, the famous Mathers both father and son use each of these three earthquakes, preaching religious purification to avoid future earthquakes (Rozario 2007 reviews a large literature e.g. van de Wetering 1982,).

AD 1692: Port Royal (Jamaica), seismic destruction of town attributed by John Wesley to sinful behavior (de Boer and Sanders, 2005).

AD 1786: Lituya Bay AK, some Tlingit clans form tectonically related religions, largely in response to tsunami (Emmons 1911, Howell and Grant 2016)

AD 1812: New Madrid MO, earthquake increases local religiosity and is blamed by Tecumseh on Great Spirit (Penick 1981, Rozario 2007, Hough and Bilham 2006).

AD 1855: Edo (Japan), earthquake initiates religious imagery of earthquakes (Robinson

2016).

AD 1883: Krakatoa tsunami sparkes Islamic fundamentalist reform (Winchester 2003).

AD 1906: San Francisco earthquake, much Protestant preaching about divine retribution (Hartley 2000), Christian Science popularity sparked by earthquake (Winchester 2006).

AD 1908: Sicily earthquake, attributed to divine retribution (Bosworth 1981).

AD 1915, Avezzano (Italy), earthquake attributed to divine retribution (Anon. 1915).

AD 1923: Kanto (Japan), earthquake begins changes in Shinto religion which afterward included militarism and exacerbated intolerance (Robinson 2016).

AD 1940: Romania, earthquake attributed to divine retribution by Adolph Hitler (Anon. 1940).

AD 1976: Guatemala, earthquake popularly admitted to be due to divine retribution (Levenson 2002).

AD 2001: Gujarat, earthquake gives rise to increaased Hindu nationalism (Robinson 2016).

AD 2011: Christchurch (New Zealand), increase in religiosity after earthquake (Sibley and Bulbulia 2012)

B. List of civic and other non-religious responses to historic earthquakes

463 BC: Sparta, earthquake prompts serfs to revolt as so many Spartan soldiers killed (de Boer and Sanders 2005)

31 BC: Dead Sea, after earthquake Herod convinces Jews to rally against Arabs (Nur 2008).

AD 62/3: Pompeii, land restoration after moderate earthquake (Robinson 2016)

AD 1855: Wellington area, New Zealand, focus on rebuilding after earthquake (Grapes and Downes 1997)

AD 1877: Iquique (Chile), damage claims resulted in war between Chile and Bolivia (Farcau 2000)

AD 1960: Valdivia (Chile), world's largest known earthquake, improved organization of region (*Rytkönen 2000*). Inspired international seismic network

AD 1964: Alaska (Good Friday) earthquake leads mostly to civic responses (Fountain 2017).

AD 1970: Huascarán (Peru), earthquake and landslide led to (failed) experiment in social reform (de Boer and Sanders 2005)

AD 1976, Tangshan, little immediate cultural response to earthquake but end of Great Cultural Revolution (Robinson 2016)

AD 1985: Mexico City, self-serving government fails to aid victims, citizen group organizes recovery and becomes a political group (Davis 2005)

AD 2004: Aceh (Indonesia), earthquake prompts end of provincial rebellion (Robinson 2016).

C. List of composite religious/non-religious responses to earthquakes

AD 1157 and 1170: Syria, “holy land” sieges and battles between Crusaders and Moslems postponed by earthquakes, then politically influenced by damage (Raphael 2010)

ca. AD 1500: Italy, political manipulation of religious response to earthquakes (Belloc et al. 2016)

AD 1755: Lisbon, earthquake first blamed by clerics on impious populace, then reversed by Marquis de Pombal, meanwhile used by Voltaire to address question of God’s permitting evil in *Candide* and other works (many authors e.g. de Boer and Sanders 2005; Hough and Bilham 2006, Robinson 2016)

AD 1812: Caracas, earthquake in midst of uprising, Bolivar converts priestly manipulation to revolution, and recovery becomes a national symbol (Altez 2010, Robinson 2016)

AD 1886: Charleston SC, earthquake leads to pride in rebuilding (Hough 2002) after invocations of divine retribution (Steinberg 2000)

AD 1972: Managua, earthquake catalyzed Sandinista revolt (de Boer and Sanders 2005) following priestly attribution to sinfulness (Dobson and O’Shaughnessy 1990)

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