UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

WORKING PAPERS IN ECONOMICS

No 387

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September 2009

ISSN 1403-2473 (print)
ISSN 1403-2465 (online)

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Abstract

Natural disasters claim thousands of lives each year and can be a heavy burden for already vulnerable societies. Are natural disasters also a cause of violent conflict? While most studies based on systematic empirical research do find this to be the case, there are also known cases where natural disasters have contributed to a de-escalation of fighting. This paper shows, theoretically and empirically, that moderate earthquakes increase the risk of civil wars, but that stronger (and therefore more rare) earthquakes instead reduce the risk of civil wars. We use an exhaustive dataset on earthquakes from 1947 to 2001 collected by seismologists. The association between earthquakes and the incidence of civil war is decomposed into two separate effects: they affect the risk that new civil wars are started and they affect the chance that existing civil wars are terminated.

Keywords: civil war, earthquakes, natural disasters.
JEL classification: D74, Q54

1 Introduction

The great tsunami in South-East Asia in 2004 was caused by an earthquake with a magnitude of 9.1 on the Richter scale (henceforth M9.1) that had its epicenter in the seabed off the coast of Sumatra, Indonesia. At least 230,000 people in 12 countries died; 168,000 people died in Indonesia alone. Aceh in Indonesia, with a long history of secessionist conflict, was most severely affected. A combination of sheer destruction and war-fatigue advanced cooperation and negotiations, and helped end the fighting. In Sri Lanka, also with a long history of secessionist fighting, over 30,000 died as a result of the tsunami. After an initial period of less active conflict, the fighting gained renewed strength, and it

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is believed that the tsunami in fact exacerbated the conflict (Le Billon and Waizenegger 2007).

Hence, this natural disaster is linked to (at least) one case of de-escalated conflict and one case of escalated conflict, but why were the effects so different in Aceh and in Sri Lanka? At a glance, it appears that the conflict de-escalated where the natural disaster had its most severe effects and escalated where the effects were less severe. One of the questions addressed in this paper is whether this is part of a general pattern.

There are two diametrically opposing views in the literature on natural disasters and violent conflict (Le Billon and Waizenegger 2007). According to the first view, natural disasters can contribute to defuse tensions. They do so as they bind people to a common fate where all share the goal of successful reconstruction, and where previous disagreements seem relatively unimportant. This appears to have been the case in a number of situations, mostly at the international level, where antagonists really were brought together by disasters (UNDP 2004, Le Billon and Waizenegger 2007). In a review of case studies of natural disasters and conflict, WBGU (2008:108) concludes that some natural disasters provide an impetus for peace negotiations as they represent opportunities for the fighting parties to "overcome entrenched political-ideological differences." This view is indeed shared by both relief organizations and policy makers (Brancati 2007). The fact that relief organizations are likely to focus their efforts on more costly and devastating disasters suggests that this first view may reflect the outcomes commonly observed after very serious natural disasters.

The second view is that natural disasters make violent conflict more likely, and this view is supported by most systematic empirical studies. There are rational reasons to expect such outcomes: Natural disasters can hurt the economy, increase inequality, marginalize already vulnerable groups, exacerbate resource scarcities and latent grievances, lead to migration, and weaken the capacity and legitimacy of the state at times when the demands on the state grow and the tax base is diminished (Brancati 2007, Nel and Righarts 2008).[1]

Although the lion's share of the literature on natural disasters and conflict consists of case studies, a handful of studies use cross-sectional data. Olson and Drury (1997) use data on 12 countries that experienced a major natural disaster, and find a positive relationship between natural disasters and political unrest in general. Their interpreta-

[1] Natural disasters considered to have contributed to trigger new conflicts or to escalate existing violent conflicts include: the 1954 hurricane in Haiti, the 1972 earthquake in Nicaragua, the 1970 cyclone in present day Bangladesh, the 1976 earthquake in Guatemala, the flood and typhoon in 1974 and the flood in 1988 in Bangladesh, and the floods in 1980 and 1987 in India. Natural disasters considered to have contributed to defuse tensions or to a de-escalation of conflicts include the earthquake and tsunami in the Philippines in 1976, the 1986 earthquake in El Salvador, the 1999 earthquake in Turkey, the 2001 earthquake in India, the 2003 earthquake in Iran, and the 2005 earthquake in Pakistan. These events, and more, are discussed in WBGU (2008), Drury and Olson (1998), UNDP (2004), Albala-Bertrand (1993), Nel and Righarts (2008), Brancati (2007), and Kelman (2003).

tion is that disasters stress the political system and cause public dissatisfaction with the government. In a similar study, Drury and Olson (1998) find that the political systems of richer countries are less affected by natural disasters.

Brancati (2007) finds that earthquakes are positively associated with the incidence of civil war from 1975 to 2000. The effect is reported to be stronger for earthquakes that struck densely populated area, and if the strongest earthquake had a magnitude of M7.5-M8.5, rather than M5.5-M6.5. The proposed mechanism is that earthquakes create situations with resource scarcities, where relative deprivation makes potential rebels more motivated to fight, or where the more intense competition between groups can become violent. An inflow of aid can also increase the capacity of groups to carry out conflict.[2]

The first main question addressed in the present paper is whether more destructive natural disasters are associated with a lower risk of conflict, as some relief organizations appear to believe and the case of Aceh in 2004 seems to suggest, or with a higher risk of conflict, as Brancati (2007) claims.

Nel and Righarts (2008) find that natural disasters increase the probability of onset of civil war; the highest risk of conflict is after rapid-onset climatic or geologic disasters, and the effects are stronger in poor countries and in countries with sluggish growth or anocratic regimes. They describe natural disasters as "an extreme form of environmental change" and draw parallels to findings in the literature on environmental security, political ecology, and climate change. As such, their interpretation is that natural disasters can exacerbate grievances, strengthen the incentive to grab resources, and reduce the capacity of the state to respond effectively. They also emphasize that even if scarcities surely may motivate rebels, an active rebellion cannot occur unless it can be financed.

Natural disasters and climate change are surely similar in that they create scarcities and strain the capacity of the state. Yet the effects of most natural disasters are more immediate. Events such as earthquakes are also inherently unpredictable, and most of the damages are sustained directly or within a matter of days. Slow-moving mechanisms that tie climate change to conflict, such as large-scale migration, persistent under-development, and sclerotic states, cannot explain the effects of such rapid onset disasters.

The present paper proposes that a better understanding of the mechanisms involved can be gained if we use general economic models of civil wars, as in Collier and Hoeffler (2004), and formal models of conflict, as those in Grossman and Kim (1995) and Skaperdas (1996). Accordingly, it develops a theoretical model of the costs and revenues of rebellion in the wake of a natural disaster. The model suggests that relatively moderate disasters

[2] Brancati (2007) documents effects also on the number of "Conflict events" 1990-2002 and on the level of "Antiregime rebellion" 1985-2000. "Conflict events" are taken from news reports, and refer to kidnappings, battles, assassinations, coups, suicide bombings, riots, crowd control, etc. "Antiregime rebellion" refers to conflicts between an ethno-political minority group (collectively subject to discriminatory treatment and collectively mobilizing to defend their interests) and the state, or a group supported by the state.

should be positively associated with conflict, but that the opposite may be true for very destructive disasters.

The incidence of civil war is a stock variable, determined by the flow variables onset and termination. The incidence of civil war in the world rose after the 1950s and 1960s, as more wars were started than ended (Fearon and Laitin 2003). Then the trend was reversed in the 1990s, more due to a higher number of terminations than to a lower number of onsets (Hegre 2004). The number of natural disasters listed in the EM-DAT database (see Section 2) has also shown an upward trend since the mid 1970s (Bhavnani 2006). Consequently, for a few decades there were simultaneous increases in the frequency of (reported) natural disasters and the incidence of civil war. Such similarities are, however, not evidence of a causal relationship.

The empirical part of the paper employs the same raw data on earthquakes as Brancati (2007), but develops a new set of indicators of the size of earthquakes. The main reasons for using this data is that earthquakes are completely exogenous to conflict and that the number and severity of these events can be objectively measured.

While Nel and Righarts (2008) focus on the onset of civil war, Brancati (2007) investigates the incidence of civil war. The approach to only look at the onset or only at the incidence of conflict does not take the argument that natural disasters can de-escalate *existing* conflicts seriously. Prior studies that find a positive effect of natural disasters on conflict have tended, at least implicitly, to interpret this as evidence against the view that natural disasters can defuse tensions. The fact is, however, that no previous study has been designed to warrant such conclusions, since their object of study has never been the actual termination of existing conflicts.

The second main question addressed in this paper is therefore whether natural disasters can contribute to the de-escalation of conflicts. As this question is asked, it is natural to ask whether earthquakes are associated with the incidence of civil war because they affect the onset of conflict, the termination of conflict, or both. In order to answer these questions in detail, the empirical analysis considers three different dependent variables: the incidence, the onset, and the termination of conflict.

This paper contributes to the literature in the following ways. It presents the first formal model of natural disasters and violent conflict. The model predicts a nonlinear effect of disaster-related destruction on conflict risk. Further, it is the first paper to empirically demonstrate that moderate earthquakes increase the risk of violent conflict, but that stronger (and therefore more rare) earthquakes actually can reduce the risk of conflict. The empirical results are thus well in line with the theoretical predictions. To the best of our knowledge, these findings are also the first to link a fully exogenous measure of the *severity* of potential natural disasters – the seismic energy released by earthquakes – to the risk of violent conflict.

Moreover, it is the first systematic analysis of natural disasters and civil war termination. It is demonstrated that the association between earthquakes and the incidence of civil war can be explained by three effects: (i) moderate earthquakes increase the risk that new civil wars are started, (ii) strong earthquakes make it less likely that new civil wars are started, and (iii) strong earthquakes make the termination of existing civil wars more likely.

Section 2 discusses the direct effects of natural disasters, and Section 3 presents additional relevant findings from the civil war literature. A formal model of natural disasters and violent conflict is developed in Section 4. Section 5 describes the empirical strategy and the data, and Section 6 presents the results. Finally, Section 7 provides a few concluding remarks.

2 Natural disasters

Natural disasters can be geophysical (volcanic eruptions and earthquakes), hydrometeorological (floods, extreme temperatures, droughts, and windstorms), or secondary events (landslides and tsunamis). Also dramatic events such as wildfires, famines, insect infestations, and epidemics are sometimes listed as natural disasters (Strömberg 2007, Nel and Righarts 2008).

In slow onset disasters, such as droughts, the civil society's capacity for collective action has time to make a difference for the outcome. Rapid onset disasters, such as earthquakes, have shorter impact duration and more immediately evident effects. The need for direct actions after such disasters means that the authorities' level of preparedness becomes more apparent (Albala-Bertrand 1993).

Earthquakes are determined by tectonic forces, yet the location and timing of individual earthquakes still cannot be predicted.[3] The movements of tectonic plates create tensions and strain energy is accumulated in the ground. When the stored energy is sufficient to overcome the friction between the plates, Earth ruptures and the accumulated energy is transformed into heat, radiated seismic energy, and deformation of the rock. About 90 percent of all earthquakes occur along tectonic plate boundaries, although all plates also have internal stress fields.[4]

Earthquakes can put intensive strain on residential buildings, plants, dams, reservoirs, roads, gas and electric power lines, and irrigation systems, yet Kenny (2009) points out that they are costly also in terms of business interruption, lost private property, and reconstruction work. Moreover, the destruction of infrastructure means that the level of capital that can be effectively employed in production can fall by more than what the

[3] Bolt (2005) is an excellent introduction to earthquakes. See also USGS (2008) and Brancati (2007).

[4] The direct physical effects of an earthquake include shaking, rupture, and displacement of the ground, but also landslides, avalanches, ground liquefaction, tsunami, floods, and fires. The effects at a certain location depend on a number of physical factors: the seismic energy released, the distance to the epicenter, the focal depth, and local surface and subsurface geological conditions.

actual level of capital does. This is the case as even plants and businesses that have not sustained any direct damages can find themselves in situations where necessary raw materials or energy supplies are missing, or where it is impossible to transport the final products to the market.

Consider the following two illustrations of how earthquakes can affect the level of capital per capita. About 1,100 people died in the 2001 earthquake(s) in El Salvador. This amounts to about 0.02 percent of the total population of 7 million. At the same time there were considerable damages to buildings and vital lifeline structures. A rough estimate by Kenny (2009) is that up to 29 percent of the buildings in El Salvador may have been destroyed. The situation after the earthquake(s) was clearly characterized by a lower level of capital per capita.[5]

Horwich (2000) discusses the losses incurred in the, admittedly unusually costly, 1995 Kobe earthquake. About 6,500 out of a regional population of 4 million were killed, and the total damage to the capital stock has been estimated at US$114,000 million. He also reports that GDP per capita in Japan was US$39,640 in 1995 and takes the capital stock to be three times the annual GDP. These figures suggest that 24 percent of the regional capital stock was destroyed and that 0.2 percent of the regional population were killed. The surviving population certainly had a lower level of capital per capita in the immediate aftermath of the earthquake.[6] The insight that the effective level of capital per capita falls plays a key role in the formal model we develop in Section 4.

The economic effects of natural disasters are more dramatic in poor countries. Studies that use the EM-DAT database have found that even if rich countries do not experience fewer or weaker natural disasters (Kahn 2004), they report fewer deaths and lower economic losses (Kahn 2004, Strömberg 2007, Toya and Skidmore 2007). The reason is that they can afford better housing, warning systems, medical care, and evacuation plans (Strömberg 2007).

In a recent study, Noy (2009) finds that natural disasters hurt growth in the short term, but have almost no effect in the long run. Further, the negative effects of disaster damages apply only to developing countries, while the effects in the OECD sample are *positive*. In an earlier study, Albala-Bertrand (1993) found negative, but moderate, long-run economic effects in developing countries, yet no long-run effects in developed countries. Within countries, poor population groups face a disproportionately higher risk from natural disasters (UNDP 2004). Even in developed countries there can be widespread deprivation after natural disasters, as low income households tend to live in lower quality

[5]Kenny (2009) discusses how the average number of deaths per collapsed building varies considerably between countries and regions. The 2001 earthquakes in El Salvador and Peru resulted in about three to six deaths per 1000 collapsed or destroyed houses. In contrast, recent earthquakes in Turkey appear to have resulted in about one death per collapsed building.

[6]The total capital stock in the Kobe region: 3×4 million inhabitants $\times$ US$39,640 = US$476,000 million. Damages/ capital stock = US$114,000 million/US$476,000 million = 24 percent. Death toll / total population = 6,500/ 4 million = 0.16 percent of the population.

houses, less often have sufficient insurance, and receive only a small share of disaster relief (Albala-Bertrand 1993).

The effect of democracy is less clear-cut. While Kahn (2004) and Toya and Skidmore (2007) find that losses are lower in countries that are more democratic and have better institutions, Strömberg (2007) finds that the number of killed is higher in more democratic countries once government effectiveness is held constant. He suggests that this can be explained by more complete reporting by democracies.

Earthquakes generally cause both more damages and more concentrated losses than other natural disasters (UNDP 2004), yet they are less destructive to agriculture than, say, floods. The death toll from earthquakes is lower in rich countries, and more powerful earthquakes kill more people, but the death toll is neither higher nor lower in areas where earthquakes are more frequent (Kahn 2004, Anbarci et al. 2005). Further, there are no systematic differences between OECD and non-OECD countries, or between regions that are prone to conflict and regions that are not, when it comes to the frequency of earthquakes (Brancati 2007).

The use of the EM-DAT database in analyses of the effects of natural disasters can, however, be problematic. The database lists events that meet at least one of following criteria: 10 or more reported killed; 100 people reported affected; a declaration of a state of emergency; or there is a call for international assistance. Although this data is surely sufficiently accurate for many purposes, Noy (2009) points out the risk that governments exaggerate the damages and Strömberg (2007:201) even finds systematic differences in reporting "across time, level of income, and political regimes," and notes that this fact makes it difficult to assess the effects these factors have on the impact of disasters. Another potentially serious problem is that some of the deaths reported in disasters may in fact have occurred as a result of armed conflict, as found by UNDP (2004) for drought disasters.

3 Conflict

The two seminal papers in the general civil war literature, Fearon and Laitin (2003) and Collier and Hoeffler (2004), agree that financing does matter for rebel recruitment and the risk of violent conflict, but disagree on what mechanisms the economic variables proxy for in their analyses. According to Fearon and Laitin (2003), a low-income level proxies for a financially and bureaucratically weak state, in terms of administration, military, police, and infrastructure. According to Collier and Hoeffler (2004), factors that proxy for grievances are relatively unimportant compared to factors that proxy for economic motives and the cost for rebellion.[7]

In a similar vein, Collier et al. (2009) stress that active rebellion is found where it is militarily and financially *feasible* rather than where potential rebels are unusually

[7]For a recent review of the civil war literature, see Blattman and Miguel (2009).

motivated by gains that will be realized in the event of a victory. The reason that civil wars are not more common is that groups that are motivated for rebellion, be it by the capture of resources that the government is in control of or by the removal of a repressive and discriminatory rule, seldom have the means to finance it. Events that increase the revenues accrued by the rebels, such as an inflow of aid, or reduce the costs of rebellion, such as a fall in the opportunity costs for potential recruits, not only make rebellion potentially profitable for the rebel leadership but also feasible.

Economic factors also play a role for the termination or duration of civil wars. Civil wars last longer, i.e., are less likely to be terminated in each given year, if the income level prior to the onset was lower, if income inequality was higher, or if there has been an increase in the prices of the primary commodities that the country exports (Collier et al. 2004). Fearon (2004) finds that the duration is longer if the rebels have access to valuable contraband, such as gemstones or drugs.[8]

A central aspect of natural disasters is that they have dramatic effects on the supply and distribution of, and demand for, resources. This can in turn affect both the motivation for, and the feasibility of, rebellion. Natural disasters affect the supply of resources by destroying buildings, plants, and lifeline structures, as well as the ability to access resources. They affect the demand for resources such as shelter, water and food, medicines, and medical assistance.

Somewhat contradictory, both abundance and scarcity of resources have been linked to a higher risk of civil war. The link between resource *scarcity* and conflict is often referred to as the neo-Malthusian link. Using country case studies, Homer-Dixon (1994) finds that environmental scarcity causes persistent subnational violent conflict in the developing world. The proposed mechanism is that scarcity leads to social, political, and economic problems by increasing financial and political demands on governments. These problems can, in turn, destabilize countries, trigger new violent conflicts, and escalate existing conflicts (Homer-Dixon 1994, WBGU 2008). A scarcity of resources can also depress wages and thereby make rebellion more feasible via lower opportunity costs for the potential recruits (Brunnschweiler and Bulte 2008b).

A systematic study that finds a clear link between sudden scarcity and conflict is Miguel et al. (2004). With the use of rainfall as an instrument for economic growth in sub-Saharan Africa, they find that growth is strongly negatively related to civil conflict. That it is the sudden realization of poverty, rather than chronic poverty as such, that promotes rebel recruitment is argued by Barnett and Adger (2007). When people lose their source of income, and the young realize that education or employment will be hard

[8] The duration of civil war is also longer in countries with intermediate levels of ethnic fractionalization and shorter if there has been a military intervention supporting the rebels (Collier et al. 2004). The termination of conflict is more likely if there is a change in the foreign support for one of the combatants, or a change in the leadership of either side of the conflict (Fearon and Laitin 2007). The literature on civil war termination/duration is surveyed in Dixon (2009).

to get, more people become susceptible to rebel recruitment. Armed groups of young men, frustrated by a contraction of their livelihoods, is indeed a recurrent theme in civil wars (Barnett and Adger 2007). Still, some authors hold that the overall evidence for a link between resource scarcity and conflict remains weak, see Urdal (2005) and Nordås and Gleditsch (2007).

The links between the *abundance* of resources and violent conflict tend to be bundled under the heading of the resource curse (Humpreys 2005, Ross 2004). Collier and Hoeffler (2005) is one of the many studies that find a positive association between resource abundance and the onset of civil war.[9] An abundance of valuable natural resources, especially when easily extracted or easily lootable, could constitute an incentive for rebel groups to form and fight for control. It is well known that poor countries are more prone to conflict. Consequently, if resource abundance has negative externalities on more dynamic sectors of the economy it could be associated with a lower income level and, in the end, a higher risk for violent conflict. Regardless of the accuracy of this argument, such mechanisms of long-term nature are quite irrelevant when the object of study is the immediate effect of sudden and unpredictable events such as earthquakes.

An abundance of natural resources has been linked to various political motives for rebellion. A ruler with a steady inflow of non-tax revenues has less incentive to please the population or maintain a state apparatus that the population sees as efficient and legitimate. Resource abundance can also result in grievances caused by income inequalities, volatility in terms of trade, or forced migration. Yet again, such relatively slow-working mechanisms are of little relevance in the direct aftermath of rapid onset natural disasters.

The robustness of the positive association between resource abundance and the risk of conflict has been questioned. The fragility of the results in Collier and Hoeffler (2005) is demonstrated by Fearon (2005). More importantly, Brunnschweiler and Bulte (2008a, 2008b) find that an abundance of resources is associated with a *lower* risk of civil war when the endogeneity of the indicator of resource abundance has been dealt with. They also show that civil wars make countries depend on resource extraction, rather than the opposite. As pointed out by the authors, these results indicate that scarcity may be a more fundamental cause of conflict than abundance.

There are nevertheless still good reasons to expect that easily lootable resources can motivate rebels and make rebellion feasible. This could for instance be the case for alluvial diamonds, which are not included in Brunnschweiler and Bulte's (2008a, 2008b) analysis. It could also be the case for a sudden inflow of disaster relief, even if WBGU (2008) holds that the inflow of disaster relief after some disasters contributes to *de-escalate* existing

[9] Resource abundance has also been linked to the duration of civil war (Collier et al. 2004). A recent study by Lujala (2009) finds that none of the indicators for natural resources measured at the country level affects the number of combat-related deaths, but that there are more deaths in conflict zones with gemstone mining or oil and gas production. Drug cultivation in the zone has a negative effect on the death toll.

conflicts.

The administrative and military capacity of a state can be lower in the wake of a natural disaster that has destroyed infrastructure or made it harder for the state to fund and manage its regular activities in the affected area. In line with the argument in Fearon and Laitin (2003), such a weak state can make rebellion more feasible. WBGU (2008) finds that natural disasters can generate conflicts in power vacuums as groups try to take advantage of weakened or absent state functions. The problem with this argument is that also large-scale rebel organizations should face new organizational and logistic constraints. As such, the outcome should be problems such as theft, looting, and riots, rather than organized violent rebellion. Moreover, the state is likely to have a capacity that a potential rebel group will lack – to move in new military resources from other less affected areas. This argument is therefore equally compatible with an increase in the military advantage of the state and, accordingly, a decrease in the willingness to rebel.

There are of course good reasons to expect that some natural disasters are followed by sentiments that constitute political motives for rebellion: People may feel that the state is guilty of poor planning and lax enforcement of building codes, that the state is passive in the face of deprivation, that the state is conducting an insufficient and discriminatory relief effort, or that the state subjects them to unjust forced relocation (OECD 2004, Kahl 2006, WBGU 2008). The Red Cross (2007) finds that violence between groups can be triggered by emergencies such as natural disasters, since in such situations groups and individuals with a low social standing can become even more marginalized.[10]

Finally, natural disasters can create situations with considerable uncertainty. In what Collier et al. (2004) call the "rebellion-as-mistake" explanation of violent conflict, it is argued that misperceptions about the chance of victory can cause violent conflicts, as both sides overestimate their relative strength and their actual chance of a victorious outcome. The risk of conflict may increase if both parties believe that the other side was more weakened by the disaster, yet they should be just as likely to believe the opposite. A related argument is brought forward by WBGU (2008) in a discussion of how attempts made by the state to regain its authority and restore its functional capacity will suffer from incomplete information, and of how grievances can result from frequent use of harsh treatment and disproportionate use of force in such situations.

[10] The risk of violent reactions is amplified if migrants move to areas already constrained by resource scarcity. This was observed in India in the 1980s, Bangladesh in the 1980s and 1990s, and was a factor that contributed to the war between El Salvador and Honduras in 1969 (Reuveny 2007).

4 Theoretical framework

4.1 Basics

To provide a theoretical structure to the empirical patterns, consider the following economic model of violent conflict.[11] A fundamental aspect of natural disasters is that they destroy physical capital, and the model will carefully consider how this affects the cost and revenue sides of rebellion. Special attention is given to the notion that natural disasters of different sizes may affect the costs and revenues in different ways. The specification of the conflict technology is inspired by Grossman (1999). To keep the model reasonably simple, it is set in an environment with perfect information and perfect competition in the goods market, and abstracts from potentially interesting extensions such as multiple time periods and dynamic considerations.[12]

Our modeled game takes place in one period and is not repeated. There are two main agents that both act to maximize their expected net wealth. The government, denoted Q, is in power in the beginning of the period. The rebel group is denoted J. Besides Q and J, there is also a unit mass of identical workers, with a fixed labor supply, that can be hired as soldiers.

The rebel group may choose to gather a rebel army to start a civil war where the prize is the tax revenues collected by the agent acting as government at the end of the period. Let p be the probability that Q wins the war, and let it follow from a standard contest success function, i.e.,

$$p = \frac{S}{S + \theta I},$$

where S is the number of government soldiers hired by Q, and I is the number of rebel soldiers hired by J. θ indicates the relative effectiveness of the rebels. The government is assumed to be a more efficient fighter than the rebel group, $\theta < 1$. This is due to better access to intelligence and the international weapons markets, or because the defensive technology used by the government has a relative advantage over the offensive technology the potential rebel army must use. As in Grossman (1999), Q is the leader and sets S anticipating the actions of J. Observing S, J sets I. In the following discussion, the intensity of the conflict will be captured by the size of the rebel army I, as it is assembled with the sole purpose of fighting for power.

Workers can be employed in peaceful production. Total peaceful production comes from a standard AK production function where A indicates productivity and K is the

[11] Garfinkel and Skaperdas (2007) and Blattman and Miguel (2009) offer excellent overviews of the theoretical literature on conflict.

[12] A government can obviously never entirely neutralize the consequences of disasters, and people can be dissatisfied and have anti-state grievances even when the government actually does act. Hence, the inclusion of political motives demands that assumptions must be made about when a government is considered to have done enough, and about the reactions to a government that is considered to have done too little.

capital stock that can be used. Capital should be interpreted in a wide sense as including both private physical capital and infrastructure. To make the model tractable, it is assumed that production is linear in labor. All workers are potential (full-time) soldiers, and when hired as soldiers they are rewarded with the shadow wage enjoyed in production, making them indifferent between producing and fighting.[13]

Q and J start with resource endowments R_q and R_j, respectively. A central restriction of the model is that Q and J cannot use the promise of future incomes to pay for their armies, implying that R_q and R_j decides the upper bounds of S and I.

The resources available to the government can be thought of as a combination of retained tax revenues and government incomes from natural resource extraction in previous periods. The rebel group's resources stem from the smuggling of contraband, drugs, and valuable minerals, or from extortion, remittances, etc. If J becomes the new government, it can choose to keep these sources of revenue if it so wishes.

To capture the effect of a natural disaster, we let a fraction $\phi \in [0, 1]$ of the capital in the economy be destroyed in the beginning of the period. Destruction is understood in a wide sense; even capital that is not destroyed may be rendered useless if the supporting infrastructure is destroyed. For simplicity, it is assumed that the size of the population is not affected by the disaster.[14] This formulation is chosen to capture the effect on the level of capital per capita, which was discussed in Section 2. Due to the potential destruction ϕ, the available capital is $(1 - \phi) K$, where K can now be interpreted as the pre-disaster level of capital. The marginal product of labor becomes $A (1 - \phi) K$.

At the end of the period, the acting government levies a tax t on all labor incomes generated during the period, regardless of their source. A fraction $(1 - t)$ of pre-tax income is left as disposable income. A subsistence level of income $\underline{Y}$ is necessary for survival, and incomes below $\underline{Y}$ can therefore not be taxed.

4.2 The game

The solutions to the game are found through backward induction. Expected net wealth of the rebel group is $J (I \mid S) = R_j - w_f I + (1 - p) V$, where w_f is the compensation to fighters and V represents the value of governing at the end of the period. V is here taken to represent tax revenues only, but could in principle represent other non-pecuniary costs

[13] An alternative to the assumption that production is linear in labor and still keep the model tractable is to assume that a soldier's wage is constant and determined by an outside option, such as home production (Grossman 1999). We believe that the assumption that production is linear in labor is acceptable as it allows us keep the model tractable while also making it somewhat more realistic, by making the compensation to the fighters depend on the level of capital.

[14] We model a natural disaster where the capital per labor ratio falls, so this assumption does not affect the qualitative results of the model and is made for simplicity. The relaxation of this assumption as well as investigations of the potential effects of ϕ on R_q and R_j are left as interesting venues for future research.

or benefits as well. The *rebel resource constraint* is that $R_j \geq w_f I$, or that

$$I \leq I_{rrc} = \frac{R_j}{A(1-\phi)K}. \tag{RRC}$$

This condition, which is central to the model, is evidently less likely to be binding if w_f is lower. For J not to set $I = 0$, it is also required that the cost of hiring a rebel army is not greater than the expected gain from doing so, $w_f I < (1-p)\,tA(1-\phi)K$, or

$$I < (1-p)\,t. \tag{1}$$

This will be referred to as the *rebel incentive constraint.* Provided that the rebel resource constraint (RRC) is slack, I is found with straightforward optimization,

$$\frac{\partial J}{\partial I} = -A(1-\phi)K - \frac{\partial p}{\partial I} tA(1-\phi)K = 0.$$

This implies that

$$I^* = \begin{cases} \sqrt{\frac{S}{\theta}t} - \frac{S}{\theta} & \text{for} \quad S < \hat{S} \\ 0 & \text{for} \quad S \geq \hat{S}, \end{cases} \tag{2}$$

where $\hat{S}$ is the size of the government army that is required to completely deter J from gathering an army. The level of S that ensures that $I = 0$ is

$$\hat{S} = \theta t.$$

Expected net wealth for the present government is $Q(S \mid E(I)) = R_q - w_f S + pV$, where $E(I)$ is the expected size of the rebel army. The actions of the government could in principle also be constrained by its initial resources, but it is directly assumed that $R_q > AK - \underline{Y}$ as this will always rule out that $R_q < w_f S$. This allows the model to be focused on the arguably more realistic case that the rebel group is the agent constrained by its initial resources.

Noting that $I^* > 0$ gives that $p = 1/(1 + \theta I^*/S) = \sqrt{S}/\sqrt{\theta t}$ and that the optimal S when (RRC) is slack is found where

$$\frac{\partial Q}{\partial S} = -A(1-\phi)K + \frac{\partial p}{\partial S} tA(1-\phi)K = 0 \tag{3}$$

with the optimal size of the government army being

$$S^* = \frac{t}{4\theta},$$

except when $S^* \geq \hat{S}$, in which $S = \theta t$ is chosen, since $S > \hat{S}$ can never be optimal.

At the end of the period, it has been settled who will act as government and as such set the tax rate. Both Q and J will choose the tax rate that maximizes the agent's net wealth. This tax rate is set to maximize total tax revenues, $tA(1-\phi)K$, with the restriction that $t>0$ is ruled out when the workers' incomes net of taxes are below $\underline{Y}$. The condition that determines when positive taxes are possible is

$$A(1-\phi)K \geq \underline{Y}, \tag{4}$$

which holds when $\phi < \tilde{\phi}$, where $\tilde{\phi}$ satisfies $\tilde{\phi} = \frac{AK-\underline{Y}}{AK}$. (4) can thus be violated, and there will be no tax revenues, if productivity or capital is very low in relation to the subsistence income. From (4) follows that the tax rate that maximizes total tax revenues is $t = 1 - \frac{\underline{Y}}{A(1-\phi)K}$.

Consider the most intuitive and simple results first. In any given year, most countries do not experience civil wars. One reason is that potential rebels, while having a latent desire to take power, lack the resources to finance an army. If the rebels in this model completely lack resources, they are required to set $I=0$, and Q minimizes costs by setting $S=0$. This result may seem trivial, but is not obtained in many models of conflict that abstract from the fact that rebels need to have sufficient funding *before* the conflict starts, as they cannot credibly commit to pay their fighters after a potential victory.[15]

4.3 Outcome when the "rebel resource constraint" is slack

Next, consider the effect on the risk of conflict when a very destructive natural disaster, with a ϕ close to 1, has occurred. The massive destruction can depress the wages in the economy to, or below, the level where no taxes can be levied. Since the agents are motivated by future tax incomes, the result can be that neither party hires an army. Without armies there can be no war, and the current government stays in power.

Proposition 1 *When (4) does not hold, which is the case when $\phi > \tilde{\phi}$, the tax rate is set to zero and there is no war. The intensity of fighting is* 0 *and the present government stays in power.*

Proof. See Appendix A. ■

Consider now the case where the rebels' choice is not constrained by their initial resources, i.e., where they have sufficient resources to hire the optimal number of fighters.

Proposition 2 *There is war when $\theta > 1/2$ and both (4) and (RRC) are slack. The intensity of fighting is $\frac{A(1-\phi)K-\underline{Y}}{2\theta A(1-\phi)K}\left(1-\frac{1}{2\theta}\right)$ and the probability of a government victory is*

[15] A model that explicitly discusses an entry threshold for rebellion and highlights the problem of obtaining sufficient "start-up finance" can be found in Collier (2000). The threshold is derived from a survival condition and a minimum size of the government army rather than from the rebel's initial wealth.

$\frac{1}{2\theta}$. *The intensity of fighting is decreasing in ϕ and increasing in K. The probability of a government victory is independent of ϕ and K. The marginal effect of ϕ on intensity is increasing in K.*

Proof. See Appendix A. ■

In terms of ϕ, (RRC) is slack when $\phi > \hat{\phi}$, where $\hat{\phi} = 1 - \frac{1}{AK}\left(\frac{2\theta R_j}{\left(1-\frac{1}{2\theta}\right)} + \underline{Y}\right)$. Given that a high K reflects a high income in the country, this threshold is lower in poor countries, due to a lower shadow wage in production. The threshold is also lower if the rebels have more initial resources. This means that a disaster is more likely to have this outcome in poor countries, or in countries where the rebels have been able to accumulate more resources prior to the conflict.

When the rebel group's choice is not constrained by its initial resources, more devastating disasters are associated with less intense fighting, and this effect of destruction on conflict is even more negative in poor countries. Going from an intermediate to a higher ϕ when the rebel resource constraint is slack can result in a shift from the outcome with fighting described in Proposition 2 to the outcome with no fighting described in Proposition 1.

4.4 Outcome when the "rebel resource constraint" binds

The corner solution implied by a binding rebel resource constraint when $R_j > 0$ has not been considered yet. First, note that the rebel army is unambiguously chosen to be smaller when the government army is larger if both (4) and (RRC) are slack.[16] When J is not constrained by (RRC), a lower S therefore spurs J to set a higher I.

Second, note that the rebel resource constraint is binding at $\phi = 0$ only if

$$R_j \leq \frac{1}{2\theta}\left(1 - \frac{1}{2\theta}\right)(AK - \underline{Y}), \tag{5}$$

i.e, when A or K are high, and $\underline{Y}$ is low, relative to R_j. Unless (5) holds, there is no positive ϕ such that the rebels' choice of I is constrained by their initial resources.

When (RRC) is strictly binding, which will only be the case when $\theta > 1/2$, and (4) and (5) are slack, then the the rebel group cannot hire an army of size I^*, but is restricted to an I such that $I \leq I_{rrc}$, where I_{rrc} is the highest I possible given that (RRC) binds. Let S_{rrc} denote the size of the government army that makes I_{rrc} the optimal choice by J. The destruction compatible with such an outcome is $\phi \leq \hat{\phi}$.

Proposition 3 *When $\theta > 1/2$ and (4) is slack, there is war also when (RRC) is binding. The intensity of fighting is $\frac{R_j}{A(1-\phi)K}$ and the probability of a government victory is $1 -$*

[16]That $\partial I^*/\partial S < 0$ is evident if one differentiates (2) where $S^* < \hat{S}$.

$\sqrt{\frac{\theta R_j}{A(1-\phi)K-\underline{Y}}}$. *While the intensity is increasing in ϕ and decreasing in K, the probability of a government victory is decreasing in ϕ and increasing in K. The marginal effect of ϕ on intensity is decreasing in K.*

Proof. See Appendix A. ■

When the rebel group is constrained by its initial resources, the intensity of conflict is clearly lower. However, the intensity of conflict is increasing in ϕ, and ϕ has an even greater effect on the intensity of conflict in poor areas.

Due to lower wages, the intensity of conflict is higher in poor countries when the rebels are constrained by their initial resources. When the rebels are not constrained, the intensity of conflict is instead higher in rich countries as they are fighting for a more valuable prize. However, the rebels are more likely to be constrained in rich countries also in the absence of a disaster, and a more destructive disaster is required before the rebels are unconstrained in rich countries.

4.5 A graphic illustration

The simplicity of the logic that underlies these results is illustrated in Figure 1. The figure considers the intensity of conflict at different levels of disaster destruction ϕ. To make the exposition meaningful, it is assumed that the rebel resource constraint binds at $\phi = 0$, and that there are outcomes in which positive taxes can be set and where the rebels are not constrained by their initial resources. It is also assumed that $\theta > 1/2$, as this is always needed for $I > 0$.

Starting with arguably the most common case in the real world, that $\phi = 0$, the intensity of conflict is $I = \frac{R_j}{AK}$. When there is some destruction, but not so much that the rebels are not constrained, the intensity is $\frac{R_j}{A(1-\phi)K}$. The slope of the intensity-curve is positive and convex. This reflects that the rebel group can afford more fighters as the compensation to fighters falls when more capital is rendered useless. The slope is more steep in poor countries.

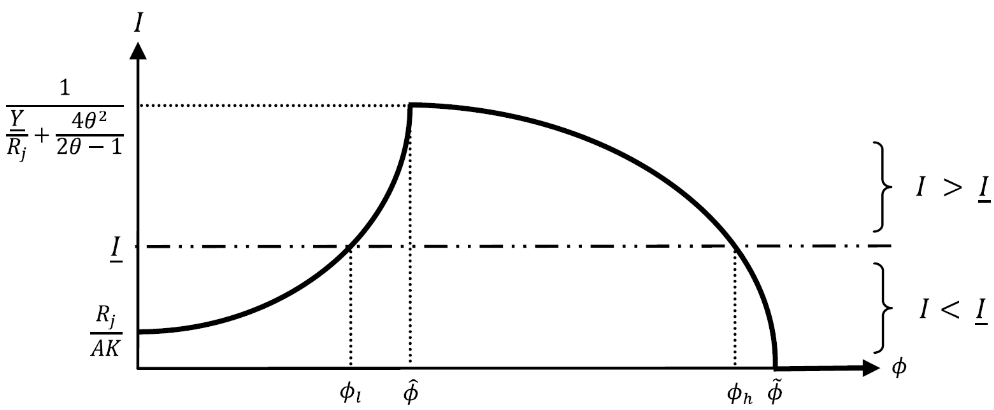

Figure 1. Conflict intensity after a natural disaster

Going from a lower to a higher ϕ, the rebel resource constraint no longer binds when ϕ is higher than $\hat{\phi}$. This level is higher in rich countries, hence it is less likely that a potential rebel group in a rich country becomes unconstrained due to a disaster. At $\hat{\phi}$, the intensity is $\frac{1}{\frac{Y}{R_j}+\frac{4\theta^2}{2\theta-1}}$. At $\hat{\phi} < \phi < \tilde{\phi}$, the intensity is $\frac{A(1-\phi)K-Y}{2\theta A(1-\phi)K}\left(1-\frac{1}{2\theta}\right)$. This is a negative and concave function of ϕ. The slope is more steep, meaning that the intensity falls more rapidly with ϕ, in poor countries.

At $\phi = \tilde{\phi}$, the tax rate must be set to zero, hence there is no conflict. Due to a lower K, a zero tax rate is more likely in poor countries, and thus also this mechanism behind a zero intensity of conflict.

Presence of fighting is not a sufficient condition for a situation to be coded as a civil war. Instead, thresholds such as 25 or 1,000 battle deaths are often set as the minimum for a conflict to be considered a civil war. In Figure 1, this threshold is captured by the constant $\underline{I}$. Intensities $I < \underline{I}$ are not coded as civil wars. At what level of intensity the $\underline{I}$-line should be drawn is obviously a completely arbitrary choice. As the line is drawn in the figure, it illustrates that even when $I > 0$, the conflict may not be violent enough to make it into a full-blown civil war.

The first situation where this is the case is when the rebels lack the resources to start a sufficiently large rebellion. A disaster with $\phi > \phi_l$ can here lead to a full-blown civil war as the costs for rebel recruitment will be lower. The second situation is when the potential gains from grabbing power are too low to motivate the costs associated with building a (sufficiently large) rebel army. This situation is more likely after a very destructive disaster, or when $\phi > \phi_h$.

Consider now the mediating role of the level of pre-disaster capital. Due to a lower wage, the rebel resource constraint is less likely to bind in poor countries. This implies that not as much destruction is needed before the constraint becomes slack in poor countries. When the constraint is slack, destruction has a more negative effect in poor countries. When the constraint binds, the effect that destruction has on intensity is more positive in poor countries. Also, a zero tax rate is a more likely outcome in poor countries, hence the negative effect on intensity is more likely the be found in poor countries.[17]

In sum, the model offers a rational explanation of how the destruction associated with a natural disaster can affect the risk of violent conflict. It shows that the risk of conflict is higher after a moderate natural disaster, but that the effect can turn negative after a very destructive disaster. The positive effect of moderate ϕ on the conflict risk is stronger in poor countries, and so is the negative effect of high ϕ.

[17] It can be shown that both ϕ_l and ϕ_h are higher in rich countries. This suggests that more destructive disasters are needed to increase intensity above $\underline{I}$ to begin with, i.e., that we are less likely to find unconstrained rebels in poor countries, and that more destructive disasters are needed before intensity falls below $\underline{I}$ again.

5 Empirical strategy and data

5.1 Empirical strategy

With these theoretical predictions at hand, recall the questions formulated in the introduction. The first question was whether more destructive natural disasters (here earthquakes) are associated with a higher or lower risk of civil war. The first step in the empirical analysis is therefore to investigate the effects of earthquakes of different sizes on the incidence of civil war. The second question was whether strong earthquakes make the termination of civil war more likely, and whether earthquakes in general are associated with the incidence of civil war because they increase the likelihood that civil wars are started or because they reduce the likelihood that civil wars are terminated. This question is addressed by estimating the effects of earthquakes both on the likelihood of civil war onset and on the likelihood of civil war termination. This section describes the dependent variables, estimation techniques, and the set of indicators of the number and size of earthquakes that will be used to answer these questions.

5.2 Dependent variables

The incidence of civil war, *Incidence*, is a binary indicator of whether an intrastate conflict that resulted in a minimum of 25 battle-related deaths in one year occurred or not in a given country-year observation. The binary indicator for the onset of civil war, *Onset*, indicates the start of a violent intrastate conflict that resulted in a minimum of 25 battle-related deaths in one year.[18] *Incidence* and *Onset* are both taken from the dataset on violent conflict compiled by PRIO/Uppsala (2008).[19] If no conflicts occurred, *Incidence* takes the value 0, and if no conflicts were started, *Onset* takes the value 0.

The binary indicator for termination of conflict, *Termination*, comes from the UCDP's (2008) "UCDP Conflict Termination dataset."[20] The variable is defined for country-years with a conflict in the previous year. If an intrastate conflict that was active in the previous year is inactive in the present year, then *Termination* is coded as 1. If it is still active, it is coded as 0.

The standard approach in the literature is to use binary dependent models on pooled data. The time dimension of the conflict data in principle allows the analyst to use panel

[18] The terms violent conflict and civil war are used interchangeably in this paper. While it is acknowledged that some consider conflicts with more than 25 but less than 1,000 yearly battle-related deaths as minor conflicts rather than civil wars, we argue that 25 deaths should be quite sufficient for a situation to be called a civil war.

[19] The variable has the following definition in the PRIO/Uppsala (2008) dataset: "Onset of intrastate conflict, 25+ annual battle deaths. 1 if new conflict or 8+ years since last observation of same conflict ID." The qualitative conclusions from the analysis are the same if alternative indicators, with a 2-year or 5-year threshold, are used rather than the one with this 8-year threshold. The 2007-4 version is used.

[20] The version used is "Version 2.1 – September 4 2008." The data is described in Kreutz (2010).

data techniques such as Fixed Effects (FE) Logit to control for unobserved heterogeneity. FE Logit demands that the sample consists only of countries for which the dependent variable has some variation in the sample. This means that countries that never experienced the occurrence/onset/termination of a conflict are dropped. This will bias the sample, wherefore FE Logit will only be used to test the robustness of the main findings.

5.3 Indicators for earthquakes

In their analysis of political unrest, Olson and Drury (1997) use the number of disaster fatalities to indicate disaster severity. Nel and Righarts (2008) draw natural disaster data from the EM-DAT dataset, and use the reported number of all types of natural disasters, sometimes weighted by population size. Brancati (2007) uses the number of earthquakes of M5.5 or more, mainly restricted to those striking areas with a population density of more than 50 people/km^2. Her data is drawn from the Centennial Earthquake Catalog (2008), which is used also in the present paper.

The Centennial Earthquake Catalog (2008) lists timing, magnitude, and location for a total of 13,000 earthquakes from January 1900 to April 2002.[21] From the 1930s to 1963 it includes earthquakes with M6.5 or more, and from 1964 to 2002 it includes events with a magnitude of M5.5 or more. Several different classes of seismic waves are radiated by earthquakes, but when used to calculate magnitude their results are approximately the same (USGS 2008). The creators of the Catalog have chosen the most appropriate magnitude measure for each earthquake, to best capture the actual strength of the event (Engdahl and Villaseñor 2002).

We have two approaches designed to capture the nonlinear effect of disaster destruction ϕ. The first is to include one indicator of the number of earthquakes and/or one indicator that captures the destructive potential of very strong earthquakes. The number of earthquakes is captured by *Qnum*, defined as the number of registered earthquakes per country-year observation with a magnitude of 5.5 or more. Hence, country-years 1964-2001 will be the units of observation in most of the specifications where *Qnum* is included.[22]

The most well-known measure of an earthquake's size is its magnitude on the so-called Richter magnitude scale. It can be used to order earthquakes of different sizes, but it is not a measure of their destructive potential. To better capture the potential damages to man-made structures, *TNT* is an approximation of the total seismic energy released by

[21] We match the locations of the epicenters to the land mass of different countries in ArcGIS, a geographic information systems (GIS) software.

[22] The paper followed the coding by Gleditsch and Ward (1999), to treat Russia as a continuation of the Soviet Union, Germany as a continuation of West Germany and so on. This means that earthquakes that occur in countries that today are independent countries are coded as occurring inside the country they were part of at that time. These categorizations of countries also constitute the basis for both the fixed effects estimations and the clustered standard errors.

earthquakes per country-year, in TNT equivalents. All figures for *TNT* are divided by 10^9 to simplify the presentation.

In order to construct *TNT* we make use of the *Gutenberg-Richter magnitude-energy relation*, which is the empirical relationship between earthquake magnitude and seismic energy. It is written as $\log_{10} E = 11.8 + 1.5M$, where M is the earthquake's magnitude, and E is energy in ergs.[23] It has been estimated that an M4.0 earthquake releases seismic energy corresponding to the energy released by the underground explosion of a thermonuclear bomb with a power equivalent to 1 kiloton of the conventional explosive material TNT (trinitrotoluene).

Since the *Gutenberg-Richter magnitude-energy relation* shows that one unit higher magnitude corresponds to 32 times more seismic energy, the energy radiated by an M6.0 earthquake corresponds to 1 million kilograms of TNT, and an M8.0 earthquake radiates the energy of 1,000 million kilograms of TNT. Even if figures like these are commonly referred to, it must be kept in mind that they are approximations that cannot take local surface and subsurface conditions into account. To avoid the influence of extreme outliers when *TNT* is included, the magnitudes are capped at M8.0, and the main results have been checked without this cap and with an M7.0 cap. Table B1 lists radiated energy in TNT equivalents, approximate annual occurrence and typical effects of earthquakes of different magnitudes.

In sum, our first approach to capture the effect of ϕ is to include *Qnum* and/or *TNT* as independent variables. *TNT* is intentionally constructed to capture the destructive potential of strong, and therefore rare, earthquakes. A positive effect of *Qnum* when *TNT* is held constant means that there is a positive effect of having more *but not very strong* earthquakes. A negative effect of *TNT* when *Qnum* is held constant means that given the number of earthquakes, the risk of war is lower if at least one of the earthquakes is strong.[24]

Our second approach to capture the effect of ϕ is to include different indicators of the number or occurrences of earthquakes of different magnitudes. A direct distinction between the effects of moderate and strong earthquakes can be made when we use alternatives to *Qnum* that represent seismic events above and below certain magnitudes, such as M6.5 or M7.0. In the few specifications where we restrict the focus to earthquakes with a magnitude of M6.5 or more, we can stretch the sample period to 1947-2001.

Countries differ greatly in their probability of experiencing an earthquake. A higher frequency of earthquakes may have indirect effects on the likelihood of civil war via the income level or the degree of political stability. We want to be sure that *Qnum*, *TNT*, and

[23] The correct formulation is $\log_{10} E = 11.8 + 1.5M_S$, i.e., a link between the Surface-Wave Magnitude (M_S) and seismic energy (E), but this rule is regularly applied to all magnitude scales.

[24] *Qnum* and *TNT* are positively correlated, partly because stronger earthquakes have more aftershocks. If there is a true positive effect of *Qnum* and a true negative effect of *TNT* and they are included separately they will be biased toward zero.

the other indicators capture only the effects of earthquakes in the present year. Hence, all specifications include *Qhist*, defined as the number of years since the country experienced an earthquake, not including earthquakes in the present year, divided by the maximum number of years for any country that year. Since the frequencies of earthquakes are approximately constant over time, the actual frequencies of earthquakes may be the best measure of the perceived risk of an earthquake. The average yearly number of earthquakes 1964-2001 is captured by the variable *Qmean*, and the average TNT from 1964 to 2001 is captured by $TNTmean$.

In Appendix B, we show that our indicators for strong earthquakes are associated with more serious direct consequences in terms of the number of dead, injured, and homeless, as reported in the EM-DAT database. We also show that the number of victims in natural disasters reported in the EM-DAT database is higher in countries that had a conflict in the previous year. In an analysis where the dependent variable is an indicator of conflict, it is thus clearly not ideal to use independent variables taken from sources such as the EM-DAT.

The model suggested that the effects of ϕ may be more pronounced in areas with a low K. To test this, the sample will be split into observations where GDP per capita (*Income*) in the previous year was above or below US$2,500. This is a level one could find in a typical middle income country. Slightly more than one out of five earthquakes from 1964 to 2001 struck a country with a low income level.

The G-Econ (2008) dataset is used to separate earthquakes with epicenters in poor regions from other earthquakes. The dataset lists data on income and population on a resolution of 1 degree latitude by 1 degree longitude, i.e., approximately 100 km by 100 km at the equator. The threshold for poor region is set at an average GDP per capita in 1990 of less than US$1,500. The level is chosen so that slightly more than one out of five earthquakes 1990-2001 struck such a poor region. Differences in income levels may reflect population densities. To limit the risk that this is what is picked up, we consider only earthquakes in regions with a population density of at least 10 persons per km^2.

We also separate earthquakes based on local infant mortality and population density. The infant mortality rate is sometimes used as an indicator of the provision of public goods; see, e.g., La Porta et al. (1999). The infant mortality rate is also a reflection of the local and national income level, and Nel and Righarts (2008) even use the national infant mortality rate as an indicator of inequality. A reasonable assumption is that a low infant mortality rate signals both relatively high incomes and that the state has a relatively strong presence.

We used digitized maps on infant mortality rates in 2000 (Global Poverty Mapping Project 2009) to separate earthquakes based on the infant mortality at the epicenter. Again, we considered only earthquakes in areas with a population density of at least 10 persons per km^2. Half of the earthquakes 1990-2001 had their epicenters in areas with an infant mortality higher than 40 per 1,000 live births, the threshold we chose for high infant mortality.

A high population density indicates that more people may have been directly affected, but also that the state is likely to have a stronger presence. There is no universal relation between population density and income level. According to Gallup et al. (1999), areas with a high population density are poor in some regions of the world but not in others.

Digitized maps on population density in 1990 from EDIT (2009) are used to distinguish between earthquakes with epicenters in areas with more or less than 50 people/km^2 in 1990. As above, we consider only earthquakes in areas with more than 10 persons per km^2. With this treatment, two out of five earthquakes 1990-2001 struck areas with a high population rather than a low population density. The number of people directly affected by a strong earthquake in an area with a high population density is potentially very large. Earthquakes with magnitudes of M6.0-M6.9 can be destructive in areas up to 100 kilometers across, and M8 earthquakes can cause "serious damage" in areas several hundred kilometers across, see Table B1. A hypothetical circular area with a radius of 100 km and a constant population density of 50 people/km^2 would contain 1.5 million people.

5.4 Controls

A strong predictor of civil war is whether there was one in the previous year or not. The approach in Brancati (2007), to include a lag of *Incidence*, is followed in specifications that have *Incidence* as the dependent variable.

All specifications with *Onset* as the dependent variable will instead include *Brevity of Peace*, as in Nel and Righarts (2008) and Urdal (2006). The argument is that the onset of conflict is more likely in countries where fewer years have passed since the last conflict. Following Urdal (2006) and Nel and Righarts (2008), the effect of the last conflict is assumed to decline geometrically with time. *Brevity of Peace* is therefore defined as $\exp\{(-years\ in\ peace)/4\}$, which means that the risk for *Onset* should be halved for each additional three years of peace.

In the same manner, we hypothesize that the likelihood of termination of conflict is higher if a shorter time has passed since the country last had peace. *Brevity of Conflict*, an indicator of the number of consecutive years of conflict, is included in all specifications where *Termination* is the dependent variable. We define *Brevity of Conflict* as $\exp\{(-years\ since\ peace)/4\}$.

The unpredictable nature of earthquakes means that they could be treated as natural experiments and that there is no strict statistical need to add more control variables. Nevertheless, the following ten variables, which are generally considered to be important, are controlled for in a few specifications.

From Heston et al. (2009) we use the log of real GDP per capita in PPP terms, the real GDP per capita growth rate, and the log of the size of the population. The following six variables are from Fearon and Laitin (2003), wherefore the sample ends in 1999 when they are included: the Polity2 score from the Polity project; a binary indicator of having an anocratic regime (a Polity2 score from -5 to 5); a binary indicator of changes in Polity2 score of more than two units; a binary indicator of having more than one-third of the export earnings from fuels; ethnolinguistic fractionalization; and the log of mountainousness. Finally, the log of land area (WDI 2008) is included, to control for the possibility that larger countries may have more earthquakes but be more conflict prone for other reasons. These variables are included as lags and are henceforth referred to as the *Standard Controls*.

We also include an indicator for international aid to investigate whether international aid can mitigate the effects of earthquakes. *DisRel* indicates the inflow of "emergency and distress relief aid" and is available from 1995 and onward from OECD (2009). Countries for which no aid inflow is listed are assumed to have received no aid in that year. For discussions on the components of this variable, see Strömberg (2007) and Fearon (2006). More disaster relief goes to poorer countries that are hit by disasters with a higher number of people affected or killed (Strömberg 2007). The inclusion of *DisRel* in the empirical analysis creates endogeneity issues since aid may be given to countries for the reason that they are already in, or are close to, a state of war (Fearon 2006).

Descriptive statistics and pair-wise correlations for the main variables can be found in Tables C1 and C2 in Appendix C.

6 Results

6.1 Incidence

The first columns in Table 1 show that a country that experiences one or more earthquakes (*Qnum*) is more likely to experience a violent conflict. This is in line with the findings in Brancati (2007). It is equally evident that the destructive potential of strong earthquakes (*TNT*) has the opposite effect, which is in contrast to Brancati's argument that stronger earthquakes have an even stronger positive effect on conflict.[25] *Qhist* is mostly negative and sometimes significant, indicating that the risk of conflict may be higher in countries where the last earthquake occurred more recently. *Lagged Conflict* has a strong positive effect in all columns.

Earthquakes are quite rare events. In a given year 14 percent of all countries experience an earthquake of M5.5 or more, and only 2.8 percent experience one of M7.0 or more. It

[25] Coefficients and standard errors are reported in all tables as this is standard in the literature. Except in the FE Logit estimations, the standard errors are robust and clustered by country.

is natural to ask whether the estimates reflect a few excessively influential observations. We tested whether this was the case and found that it was not.[26] Specification (1.4) is estimated with Fixed Effects Logit with year dummies added. While *TNT* remains significant, *Qnum* does not. This indicates that the negative effect of strong earthquakes may actually be the more robust of the two effects.

A set of alternative indicators for earthquakes are also presented in Table 1, to further test the validity of the interpretation that earthquakes of moderate strength have a positive effect on the likelihood of conflict, but that strong earthquakes do not. *Qnum(*$M < 6.5$*)*, *Qnum(*$6.5 \leq M < 7.0$*)*, and *Qnum(*$M \geq 7.0$*)* separate earthquakes into those with a magnitude lower than M6.5, those with a magnitude of M6.5 or more but lower than M7.0, and those with a magnitude of M7.0 or more, respectively.[27] This simple formulation means that the estimates for these variables are less sensitive to the effect of a few very strong earthquakes than the estimate for *TNT* is.

The results in Columns 5-8 show with clarity that while the effect of more moderate earthquakes is a heightened risk of conflict, the effect of strong earthquakes is the opposite. The highest risk of conflict is found for earthquakes with intermediate magnitudes, which is exactly what the theoretical model predicted.[28]

When there are no earthquakes, the probability that a country in the sample used for (1.6) experiences a violent conflict is 6.9 percent. Consider the following stylized scenarios. In the first scenario there are four M6.0 earthquakes. The probability that a violent conflict occurs in this scenario, given the estimates in (1.6), is 11.4 percent. In the second scenario there are also four earthquakes, but one of them is an M7.5 earthquake. The three others are still M6.0 earthquakes. The implied probability of conflict here is 4.1 percent, which is lower than if there was no earthquake. This is not an unrealistic combination of earthquakes. There are 38 observations with one or more M7.5 earthquake. Eighteen of these have zero to three earthquakes with a magnitude lower than M7.5 and 20 have more than three earthquakes with a magnitude lower than M7.5.[29]

These findings contrast Brancati (2007), who uses a variable that represents the highest magnitude of an earthquake in the given year. This variable is set to 0 if there are no earthquakes, and to 1, 2, or 3 if the strongest earthquake is M5.5-M.6.5, between M6.5-M7.5, or M7.5-M8.5, respectively. It obtains a positive estimate, and the interpretation of this in Brancati (2007) is that the incidence of civil war is more likely if the

[26] We dropped potential outliers from (1.3) based on (i) an (absolute) standardized residual greater than 2, (ii) an (absolute) deviance residual greater than 2, or (iii) a leverage greater than 2 times the average leverage. Both *Qnum* and *TNT* remain significant in all three cases.

[27] Only earthquakes with a magnitude of 5.5 or more are included, see Section 5.3.

[28] When *Qnum(*$M < 6.5$*)* and *Qnum(*$6.5 \leq M < 7.0$*)* are included separately they are both significant at the one percent level. When earthquakes with a magnitude lower than M7.0 are separated from earthquakes of M7.0 or more, the effect of *Qnum(*$M < 7.0$*)* is positive and significant both when *Qnum(*$M \geq 7.0$*)* is included and not (results omitted).

[29] Interestingly, in our data for earthquakes 1964-2001, there is not a single *Onset* in any year when there is a really strong (M7.5-M8.5) earthquake.

strongest earthquake had a magnitude of M7.5-M8.5 rather than M5.5-M6.5. We argue that this interpretation is incorrect, and that this variable captures the positive effect of the more common weak earthquakes, and that the ordinal scale formulation obscures the true negative effect of strong earthquakes.[30]

Table 1. Earthquakes and the incidence of violent conflict

Dep. Var	Incidence of Conflict							
	(1.1)	(1.2)	(1.3)	(1.4)	(1.5)	(1.6)	(1.7)	(1.8)
	Logit	Logit	Logit	FE Logit	Logit	Logit	FE Logit	Logit
Period	64-01	64-01	64-01	64-01	64-01	64-01	64-01	47-01
Qnum	0.11***		0.15***	0.09				
	(0.04)		(0.05)	(0.06)				
TNT		-2.11**	-3.30**	-3.07*				
		(1.06)	(1.59)	(1.58)				
Qnum($M < 6.5$)						0.14**	0.05	
						(0.07)	(0.07)	
Qnum($6.5 \leq M < 7.0$)						0.42**	0.37*	0.44***
						(0.21)	(0.22)	(0.13)
Qnum($M \geq 7.0$)					-0.69*	-0.96***	-0.75**	-0.69**
					(0.38)	(0.36)	(0.35)	(0.27)
Lagged Conflict	5.18***	5.20***	5.19***	3.27***	5.21***	5.21***	3.28***	5.08***
	(0.20)	(0.20)	(0.20)	(0.13)	(0.20)	(0.20)	(0.14)	(0.19)
Qhist	-0.33	-0.52**	-0.33	0.30	-0.55**	-0.34	0.30	-0.56***
	(0.23)	(0.23)	(0.23)	(0.38)	(0.23)	(0.23)	(0.38)	(0.21)
Year Dummies	-	-	-	Yes	-	-	Yes	-
Log LL	-1049	-1050	-1045	-673.3	-1049	-1041	-671.8	-1301
Pseudo-R^2	0.596	0.595	0.597	0.378	0.596	0.599	0.380	0.575
N	5691	5691	5691	3106	5691	5691	3106	7200

Note: (1.1)-(1.3), (1.5)-(1.6), and (1.8) have robust standard errors clustered by country in parentheses. (1.4) and (1.7) have ordinary standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Constants are omitted from the table.

The effects of earthquakes of intermediate and high magnitude remain statistically significant in the fixed effects specification (1.7), but the effects of the least strong earthquakes do not. Again it seems as though the effect of strong earthquakes is more robust, and that strong earthquakes *do* have a significantly negative effect on the risk of conflict.

[30]This variable is called "Mscale2" in Brancati's dataset, and there are 12 times more observations where it is 1 than ones where it is 3. As 86 percent of the observations have zero earthquakes, it is also close to acting as a dummy for at all experiencing an earthquake, rather than indicating the effect of earthquakes of different magnitude. When we set "Mscale2" to 0 if the strongest earthquake was M7.5-M8.5 and reestimated Brancati's specifications using the same dataset, the coefficient for this variable rose to 0.51 (from 0.33), and when we also set it to 0 if the strongest earthquake was between M6.5-M7.5, the coefficient rose to 0.93. Clearly, the inclusion of strong earthquakes in "Mscale2" depresses the coefficient, and this fact is at odds with Brancati's interpretation. We also created 3 dummies for the three magnitude intervals used to code "Mscale2". When these were used, jointly or separately, in Brancati's setup, the result was always that earthquakes of M5.5-M6.5 had a stronger effect, and that earthquakes of M7.5-M8.5 had a negative, though not significant effect.

The full sample period from 1947 to 2001 is used in the last column of Table 1 but then only indicators of earthquakes of M6.5 or more can be included. Moderate earthquakes make conflict more likely and strong earthquakes make conflict less likely, and the results are the same if the indicators are included separately and if Fixed Effects Logit is used.

The ten Standard Controls are included in specification (2.1) in Table 2. The estimates for *Qnum* and *TNT* are weaker than in (1.3) but nevertheless quite similar. Evidently, the effects of earthquakes are not driven by the omission of other known correlates of violent conflict.

A result of the theoretical model was that the effects of disaster destruction should be stronger in poor areas. The results presented in Column 2, for poor countries, and Column 3, for rich countries, are consistent with the model. The number of earthquakes has a stronger positive association with conflict risk in countries with low income when the destructive potential of strong earthquakes is controlled for. Holding the actual number of earthquakes constant, a poor country that experiences a very strong earthquake is less likely to experience a civil war than a country with a higher income level.

In Columns 4-7, earthquakes are separated based on basic local social conditions. Population density (the log of the number of people over land) and income are held constant to make sure that it is not these factors that the indicators for earthquakes pick up. Due to concerns about endogeneity, the samples in Columns 4-6 are limited to the period 1990 and onward.

The tendency is clear and consistent with the model – the overall conflict-promoting effect of earthquakes is more pronounced in poor areas. The indicators of strong earthquakes are not significant when added to Columns 4-6, perhaps because there are fewer observations, and fewer earthquakes, in the samples. The effects in areas with low or high infant mortality and low or high population density are all significantly positive. The estimates suggest that the effects are stronger in areas where the state is likely to have a stronger presence (high population density/low infant mortality), but the differences in each specification are not statistically significant.

In Column 7, the sample is stretched back to 1975 to allow a larger sample and more variation in the earthquake data. The difference between *Qnum(High Income)* and *Qnum(Low Income)* is statistically significant, but the difference between *TNT(High Income)* and *TNT(Low Income)* is not. Endogeneity could also be a real problem as the income data is still taken from 1990. With these caveats, we believe that the results in (2.7) should be seen as indications that both the positive effect of earthquakes in general, and the negative effects of very strong earthquakes, may in fact be stronger for earthquakes with epicenters in poor areas.[31]

[31] The indicators in (2.4) to (2.7) are defined only for earthquakes with epicenters in areas with a population density of at least 10 persons per km^2. An earthquake strong enough to cause damages 100 km from the epicenter will in such areas directly affect more than 300,000 people.

Table 2. Incidence: income, infant mortality, and population density

Dep. Var	Incidence of Conflict							
	(2.1)	(2.2)	(2.3)	(2.4)	(2.5)	(2.6)	(2.7)	(2.8)
Sample	All	Poor	Rich	All	All	All	All	All
Period	64-99	64-01	64-01	90-01	90-01	90-01	75-01	95-01
Qnum	0.12***	0.25**	0.16***					0.85***
	(0.04)	(0.12)	(0.05)					(0.18)
TNT	-2.82*	-11.92*	-2.85**					-37.10**
	(1.67)	(6.80)	(1.29)					(18.86)
d[Qnum(High Income)]				0.43				
				(0.28)				
d[Qnum(Low Income)]				1.59***				
				(0.49)				
d[Qnum(High InfMort)]					0.52*			
					(0.31)			
d[Qnum(Low InfMort)]					0.65**			
					(0.31)			
d[Qnum(High PopDen)]						1.00**		
						(0.40)		
d[Qnum(Low PopDen)]						0.51**		
						(0.25)		
Qnum(High Income)							0.36***	
							(0.10)	
TNT(High Income)							-4.00***	
							(1.26)	
Qnum(Low Income)							0.92***	
							(0.28)	
TNT(Low Income)							-14.68**	
							(7.27)	
DisRel								0.11***
								(0.03)
Qnum × DisRel								-0.05***
								(0.01)
TNT × DisRel								1.87*
								(0.96)
Lagged Conflict	4.73***	4.44***	5.59***	4.26***	4.26***	4.25***	4.95***	4.49***
	(0.25)	(0.24)	(0.33)	(0.31)	(0.30)	(0.30)	(0.24)	(0.38)
Qhist	0.15	-0.13	-0.33	-0.23	-0.41	-0.26	-0.18	-0.36
	(0.27)	(0.35)	(0.35)	(0.38)	(0.38)	(0.37)	(0.29)	(0.43)
St. Controls	Yes	-	-	-	-	-	-	-
Income, PopDen	-	-	-	Yes	Yes	Yes	Yes	-
Log LL	-824.8	-497.6	-450.9	-404.5	-414.6	-411.3	-714.5	-220.6
Pseudo-R^2	0.590	0.509	0.635	0.540	0.535	0.538	0.606	0.591
N	4281	1936	3133	1860	1899	1899	3821	1190

Note: Estimated with Logit. Robust standard errors clustered by country in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Constants are omitted from the table. d[.] indicates a dummy variable.

An inflow of aid can in itself constitute a new resource that can be captured by rebels. The results in (2.8) show that a higher inflow of disaster relief, *DisRel*, is associated with a higher risk of civil war. It is significantly positive also when the interaction terms are dropped. The positive association sits well with the idea that rebellions occur when and where they are materially feasible, but contradicts the idea that rebellions are driven by political motives.

Both interaction terms in Column 8 are significant. An inflow of aid thus appears to reduce both the overall positive effect of earthquakes and the negative effect of potentially very destructive earthquakes.[32] Since an inflow of aid could dampen the negative effects on the regular economy and on the rebels' opportunity cost, the first result is in line with the theoretical model. The second result is also in line with the model. To the extent that more disaster relief means that the future of the economy is less bleak, the interaction term may capture that the rebels are less discouraged from active rebellion.

Disaster relief should limit suffering, especially in the wake of a very strong earthquake. If rebellions were motivated by human suffering or anti-state grievances, we would expect a negative association between disaster relief and conflict, and the effect should be the strongest in the wake of the most serious disasters. The estimates in (2.8) are at odds with these expectations.

Taken at face value, the estimates nevertheless suggest that aid can be a positive force in the aftermath of earthquakes unless they are very strong. More research is clearly needed to uncover the mechanisms behind these effects on the aggregate level and before the true role of disaster relief in post-disaster situations can be settled.

In sum, the overall effect of earthquakes and the effect of moderate earthquakes is that violent conflict becomes more likely. Strong earthquakes work in the opposite direction and make peace more likely. The effects are stronger in poor areas, but not in areas where the state is more likely to be weak. These results agree well with the interpretation that an earthquake can make rebellion more feasible by lowering the opportunity costs of potential rebels, yet that the potential rebels can lose the economic motivation to rebel after a strong earthquake.

Consider an alternative explanation for the findings – that the state is weakened in post-disaster situations and that some groups exploit this fact. This explanation does not fit well with the finding that the effects may be stronger in areas where the state is likely to have a stronger presence. Perhaps even more problematic for this explanation are the negative effects of strong earthquakes. To accept this explanation one must first accept the quite counter-intuitive idea that the state is more weakened by moderate earthquakes than by strong earthquakes.

Another alternative explanation for the positive effect of moderate earthquakes is that they make people *politically* motivated to rebel. Perhaps the inefficiency, incompetence, or discriminatory policies of a government become apparent in the event of a disaster. What this explanation does not explain is why people, who should be a aware of such

[32] There are problems associated with including aid flows. Fearon (2006) notes that disaster relief often goes to countries with an existing civil war. The positive coefficient for *DisRel* may therefore reflect that countries with an ongoing conflict receive more disaster relief.

shortcomings and obviously already have the financial means to rebel, would choose not to rebel unless there is a natural disaster. Neither does it explain why strong earthquakes have a negative effect. Surely, the political motivation should not be weaker after a disaster that results in more suffering and more grievances.

At a first glance, the negative effects of strong disasters could instead testify that disasters unite individuals and groups and therefore de-escalate conflicts. The problem with this interpretation is that most of the destruction is realized directly, or within a matter of days, and that the threat to ones' safety therefore lies in the past rather than in the future. This means that cooperation may not be individually rational. Furthermore, this argument cannot explain why moderate earthquakes have a positive effect on the risk of conflict, or why the effects appear to be stronger in poor countries. There is no rational reason to expect disasters to unite people in poor regions more than they do in rich regions.

A final alternative explanation for the negative effect is that very strong earthquakes may make rebellion materially infeasible by in some manner destroying the potential rebel's capacity to form rebel groups. Suppose for instance that the rebels rely on revenues coming from the local population. When the population's normal income-generating capacity is destroyed, the revenue stream dries up and the rebels cannot finance their fighting and the risk for conflict will consequently be lower. The data at hand does not allow a full discrimination between this story and the argument advocated in the model, but we fail to see how this story can explain the fact that moderate earthquakes increase the risk of conflict. If the link to conflict is that a disaster implies less revenues for the rebels, then should not also weaker earthquakes be followed by a lower risk of conflict?

The results presented so far do not answer the question of whether moderate (strong) earthquakes make the *onset* of new conflicts more (less) likely or make the *termination* of ongoing conflicts less (more) likely. As such, they are silent on the issue of whether natural disasters can defuse tensions, a belief held by several relief organizations and policy makers. To make an investigation of this issue possible, the following two sections separate the analysis into the effects on the onset and the effects on the termination of conflict.

6.2 Onset

A country runs a significantly higher risk of witnessing a new civil war if there was an earthquake registered in the country that same year; see the first column in Table 3. *Qhist* is mostly negative, which indicates that a more recent earthquake is associated with a higher conflict risk, but the estimates are not robust. Nel and Righarts (2008) find that the *Brevity of Peace* has no significant effect when the dependent variable is onset of conflict with less than 1,000 deaths, and this is what we observe in most of our specifications as well.[33]

The destructive potential of strong earthquakes has a negative effect both when included separately, as in Column 2, and when included together with the number of earthquakes, as in Column 3. In results not shown, the square of *Qnum* was added to specification (3.3), and was not significant. The effect on the coefficient for *TNT* was marginal (from -23.1 to -23.8): hence what *TNT* is picking up is not some form of diminishing marginal effect of having many earthquakes.[34]

The probability of onset in the sample used for (3.3) is 2.1 percent if there are no earthquakes. Consider the same stylized scenarios as above. The estimated coefficients in (3.3) imply that the probability of onset in the first scenario, with four M6.0 earthquakes, is 4.5 percent. The implied probability of onset in the second scenario, with one M7.5 and three M6.0 earthquakes, is a mere 0.1 percent. Again, this is lower than if there was no earthquake.

Nel and Righarts (2008) find that the risk of onset was twice as high in countries that experienced an earthquake or a volcanic eruption. In results not shown we used a dummy to indicate whether there was an earthquake. The implied risk of onset was 3.0 percent if there was an earthquake, and 2.1 percent if there was not, but the p-value of the estimate was 0.11.

The estimates for *Qnum* and *TNT* are significant both when the ten Standard Controls are added and when unobserved country characteristics and year dummies are controlled for. Compare this with (1.4) where *Qnum* had no significant effect on the *Incidence* of conflict in a fixed effects estimation. Evidently, while *TNT* has a quite robust negative effect on both the occurrence and onset of conflict, the effect of *Qnum* seems to be more connected to the onset than to the incidence of conflict. As shown in the next section, this interesting result can partly be explained by the fact that strong earthquakes have a more robust effect on the termination of conflict than moderate earthquakes do. However, it should be noted that the effect of *Qnum* even on *Onset* is not entirely robust to the exclusion of potential outliers, while *TNT* is.[35]

[33] A negative coefficient for *Brevity of Peace*, which we find in some of our regressions, means that onset is actually more likely in countries with a longer tradition of peace. This result is somewhat of a puzzle, and would be interesting to investigate further.

[34] Specifications (3.3) and (1.3) were estimated with both Rare Event Logit (ReLogit) and OLS, and *Qnum* and *TNT* remain significant. Nel and Righarts (2008) use ReLogit, which they argue provides better estimates when the dependent variable represents "rare events." Fearon and Laitin (2003) and Collier and Hoeffler (2004) report no important differences when using ReLogit. The qualitative results are also the same when the higher threshold of 1,000 battle deaths is used to code the onset variable. An alternative *TNT* measure was created, where all earthquakes with magnitude above M7.0 were treated as having M7.0. In results not shown, the estimate for this alternative *TNT* measure, when used in (3.3) and (1.3), also showed a negative and significant effect of *TNT*. Also in results not shown, *Qnum* was replaced by the log of (1+*Qnum*) and *TNT* by the log of (1+*TNT*), both in (1.3) and in (3.3). Both variables retained their signs and were highly significant.

[35] *TNT* remains significant when we drop potential outliers from (3.3) as described in Footnote 26. *Qnum* is significant when observations are dropped based on high leverage, but not when dropped based on standardized or deviance residuals.

In Column 6, all earthquakes with a magnitude of less than M7.0 are separated from earthquakes of M7.0 or more. The results confirm that moderate and strong earthquakes have markedly different effects. Also, if *TNT* is added to (3.6) it is significant and *Qnum*($M \geq 7.0$) is not, which indicates that it does make sense to take both the number and the destructive potential of earthquakes into account.

Table 3. Earthquakes and the onset of violent conflict

Dep. Var	Conflict Onset					
	(3.1)	(3.2)	(3.3)	(3.4)	(3.5)	(3.6)
	Logit	Logit	Logit	Logit	FE Logit	Logit
Period	64-01	64-01	64-01	64-99	64-01	64-01
Qnum	0.09**		0.21***	0.24***	0.27***	
	(0.03)		(0.05)	(0.07)	(0.10)	
TNT		-6.92**	-23.07**	-28.37**	-18.96*	
		(3.50)	(9.94)	(14.04)	(11.10)	
Qnum($M < 7.0$)						0.15***
						(0.04)
Qnum($M \geq 7.0$)						-1.33*
						(0.76)
Brevity of Peace	0.11	0.15	0.08	-0.88**	-2.78***	0.08
	(0.29)	(0.29)	(0.30)	(0.35)	(0.41)	(0.30)
Qhist	-0.77***	-0.97***	-0.74***	0.05	-0.53	-0.77***
	(0.28)	(0.28)	(0.28)	(0.35)	(0.58)	(0.28)
Std. Controls	-	-	-	Yes	-	-
Year Dummies	-	-	-	-	Yes	-
Log LL	-629.2	-629.6	-624.3	-462.8	-352.0	-626.1
Pseudo-R^2	0.015	0.014	0.022	0.082	0.186	0.019
N	5691	5691	5691	4281	3196	5691

Note: (3.1)-(3.4) and (3.6) have robust standard errors clustered by country in parentheses. (3.5) has ordinary standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Constants are omitted from the table.

If there is no earthquake, the predicted probability in (3.6) that a new violent conflict starts is 2.2 percent. In the stylized scenarios with four earthquakes of moderate strength, the estimates imply a probability of onset of 3.8 percent. In the second stylized scenario, the implied probability of onset is 0.9 percent. Compared with the changes in the probability of incidence of civil war uncovered in the previous section, the effects on the probability of a new war appear to be weaker. This indicates that, in order to explain the overall effect on the incidence of conflict, earthquakes must indeed affect also the likelihood of conflict termination.

The results presented in the first columns in Table 4 confirm that the effects of *Qnum* and *TNT* are more pronounced in poor countries also when *Onset* is the dependent variable. In contrast to what was the case for *Incidence*, the effects on the likelihood of *Onset* do not depend on basic social conditions (income, infant mortality, population density) in the area that surrounds the epicenter. In fact, none of the indicators used in (2.4) to (2.7) are statistically significant when included here (results omitted). There are only 52 new violent conflict reported from 1990 to 2001. The variation in the data when these onsets are split into different categories may simply be insufficient to produce significant estimates.

In Columns 3-6 we find that the effects of *Qnum* and *TNT* are (i) not driven by some countries having more or stronger earthquakes on average, and significant also when we restrict the sample (ii) to countries that experienced an earthquake 1964-2001, (iii) to country-year observations with a positive number of earthquakes, and (iv) to countries that experienced both an earthquake and a civil war 1964-2001.

Table 4. Onset: income, sample restriction, and more

Dep. Var	Conflict Onset						
	(4.1)	(4.2)	(4.3)	(4.4)	(4.5)	(4.6)	(4.7)
Sample	Poor	Rich	All	Qmean>0	Qnum>0	Qmean>0 & WarCountry	All
Period	64-01	64-01	64-01	64-01	64-01	64-01	65-00
Qnum	0.41***	0.19***	0.27***	0.20***	0.21***	0.16***	0.32***
	(0.08)	(0.05)	(0.08)	(0.05)	(0.06)	(0.05)	(0.07)
TNT	-92.70***	-11.98*	-23.41**	-23.09**	-23.29**	-23.38**	-28.36**
	(21.09)	(6.72)	(10.07)	(10.17)	(9.99)	(9.76)	(12.72)
Qmean			-0.09				
			(0.11)				
TNTmean			-0.29				
			(2.90)				
future(Qnum)							0.04
							(0.06)
lag(Qnum)							-0.20*
							(0.12)
future(TNT)							1.17
							(1.27)
lag(TNT)							-0.18
							(2.08)
Brevity of Peace	-0.13	-0.61	0.08	0.29	-0.08	-0.53	-0.03
	(0.47)	(0.51)	(0.31)	(0.38)	(0.51)	(0.37)	(0.34)
Qhist	-0.49	-0.83**	-0.80***	-0.61	-0.37	-0.80*	-0.72**
	(0.61)	(0.38)	(0.30)	(0.47)	(1.52)	(0.42)	(0.32)
Log LL	-283.2	-262.6	-623.9	-346.0	-132.1	-312.9	-572.6
Pseudo-R^2	0.027	0.023	0.023	0.025	0.042	0.027	0.028
N	1936	3133	5691	2520	808	1681	5342

Note: Estimated with Logit. Robust standard errors clustered by country in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Constants are omitted from the table. (4.4) includes only countries that experienced at least one earthquake 1964-2001. (4.5) includes observations with at least one earthquake. (4.6) includes countries that had at least one earthquake and at least one conflict 1964–2001.

The last column in Table 4 shows that neither future number of earthquakes nor the future or lagged potential destructiveness can be linked to the likelihood of the onset of new conflicts, but that lagged number of earthquakes has a negative effect. When earthquakes contribute to escalate conflicts from non-violent to violent ones, an onset is recorded. These conflicts are not counted as onsets in the following year, which could explain the negative effect of lagged number of earthquakes.

A natural, yet important, conclusion from this subsection is that a central reason for the association between suffering from earthquakes and experiencing a violent civil conflict is simply that earthquakes affect the probability that violent conflicts are started. Whether earthquakes are also linked to conflict termination is investigated in the next subsection.

6.3 Termination

The theoretical model is not designed to provide clear predictions as to why conflicts eventually end. As a first approximation, we hypothesize that the effects of disaster destruction ϕ on the likelihood of termination are roughly the reverse of its effects on the likelihood of onset or incidence: moderate earthquakes should make the termination of conflict less likely and strong earthquakes should make the termination of conflict more likely.

The results presented in Table 5 show that earthquakes influence the probability that civil wars are ended. The sample used here consists of countries that had an active conflict in the previous year. It is therefore considerably smaller than the samples used when we focused on *Incidence* or *Onset*. That *Brevity of Conflict* is significant and positive in most of our specifications indicates that the termination of conflict is indeed more likely if the last year of peace is closer in time.

Specification (5.1) shows that *Qnum* and *TNT* have the predicted signs, but their effects on the likelihood of *Termination* are not significant. The results are the same if they are included separately.

The second column separates moderate earthquakes from strong ones, and now we see that strong earthquakes are positively associated with the likelihood of termination. The simplicity of these dummies may explain the different results in (5.2) as compared to (5.1). The effect of the dummy for moderate earthquakes has the predicted sign but is not significant. In fact, none of the indicators for moderate earthquakes ever enters significantly in the full sample unless conditions around the epicenter are considered. Hence, the dynamics that determine the termination of conflict only partly mirror those that determine the onset of conflict.[36]

In Column 3 we include only strong earthquakes and use the full 1947-2001 period to obtain a larger sample. This change hardly affects the estimate for strong earthquakes. Strong earthquakes are, as we have previously stressed, quite rare. Therefore, it is a com-

[36] The qualitative results in (5.2) are the same when ReLogit is used and if year dummies are added, but they are not robust to Fixed Effects. Moderate earthquakes have a significantly negative effect and strong earthquakes a significantly positive effect when the Standard Controls are added to (5.2). This appears to be a result of the smaller sample (202 observations less due to missing data).

fort that the results in (5.3) are not driven by a few excessively influential observations.[37]

The predicted probability of termination in (5.3) if there is no strong earthquake is 20.0 percent. The likelihood of *Termination* jumps to 35.3 percent if the country experiences an earthquake with a magnitude of 7 or more. Apparently, the magnitude of the effect is substantial and the result supports the view that natural disasters can contribute to de-escalate conflicts.

When we split the sample into poor and rich observations, we find that experiencing a strong earthquake makes the termination of conflict more likely and experiencing a moderate earthquakes makes the termination of conflict less likely only in the sample where the income level is low. The results in Column 6 confirm that the overall effects of earthquakes are more pronounced in poor regions. The effect of an earthquake that strikes a poor region is that it makes the termination of conflicts less likely, while an earthquake that strikes a rich area has no such effect. The indicators for strong earthquakes in rich or poor regions are, however, far from significant (results omitted).

Why is the effect of strong earthquakes in poor *regions* not at all significant when the effect of strong earthquakes in poor *countries* is positive and highly significant? It could be a matter of a small sample and lack of variation in the data. When there already are fairly few strong earthquakes, it matters that some are dropped because of missing data on income or population density on the regional level. As the sample is restricted to 1990-2001 and to countries that had an active conflict in the previous year, there may simply be insufficient variation in the data to identify the effects of strong earthquakes.[38]

It could also be that the income level in the area that immediately surrounds the epicenter is a very noisy measure of the directly affected people's income level. Instead, data on the national level may better capture the average income level in the whole affected area. A third explanation for the lack of significance is that the local income level is of minor importance when it comes to the economic motives for rebellion, but that the national income level is not. This would be the case if the rebels are fighting to take control of the whole country rather than only part of it. The data at hand does not allow us to discriminate between these alternative explanations.

The results in (5.7) show that strong earthquakes make conflict termination more likely only when a region with a population density of between 10 and 50 persons per km^2 is struck rather than an area with more than of 50 persons per km^2. Fewer people should be directly affected in less densely populated areas, hence the results show that what matters most here is not the number of people potentially affected, but rather that people in less densely populated areas are more likely to become isolated and that the state probably has a weaker presence in these areas.

[37] The indicator for strong earthquakes remains highly significant when we drop outliers as described in Footnote 26.

[38] The inflow of disaster relief has been included and interacted with the indicators for earthquakes. The results are not significant in any direction, quite possibly because the sample becomes very small.

The samples used in this subsection, and especially the samples used in Columns 4-7 are quite small; hence we should not overinterpret the results. Nevertheless, there are indications that a country with an ongoing civil war is more likely to become peaceful if it experiences a strong earthquake, and especially if it is a poor country or if the area surrounding the epicenter has a relatively low population density. On the other hand, the overall effects of (all) earthquakes with epicenters in poor areas may be that termination becomes less likely, i.e., they may instead prolong conflicts.

Table 5. Earthquakes and the termination of conflict

Dep. Var	Termination of Conflict						
	(5.1)	(5.2)	(5.3)	(5.4)	(5.5)	(5.6)	(5.7)
Sample	All	All	All	Poor	Rich	All	All
Period	64-01	64-01	47-01	64-01	64-01	90-01	90-01
Qnum	-0.01						
	(0.05)						
TNT	1.91						
	(1.47)						
d[Qnum($M < 7.0$)]		-0.33		-0.98**	-0.10		
		(0.25)		(0.49)	(0.29)		
d[Qnum($M \geq 7.0$)]		0.83***	0.78***	1.06***	0.69		
		(0.30)	(0.25)	(0.40)	(0.47)		
d[Qnum (High Income)]						0.08	
						(0.41)	
d[Qnum (Low Income)]						-0.97**	
						(0.44)	
d[Qnum ($M \geq 7.0$, High PopDen)]							-1.53
							(1.07)
d[Qnum ($M \geq 7.0$, Low PopDen)]							1.83***
							(0.71)
Brevity of Conflict	1.98***	1.94***	2.08***	1.76***	2.82***	2.33***	2.34***
	(0.36)	(0.35)	(0.36)	(0.51)	(0.43)	(0.50)	(0.49)
Qhist	-0.18	-0.29	-0.03	-0.27	-0.24	-0.53	-0.32
	(0.25)	(0.25)	(0.23)	(0.42)	(0.33)	(0.48)	(0.40)
Income, PopDen	-	-	-	-	-	Yes	Yes
Log LL	-460.6	-459.1	-534.3	-213.6	-175.2	-188.4	-188.8
Pseudo-R^2	0.057	0.060	0.067	0.056	0.118	0.098	0.099
N	954	954	1077	417	413	348	350

Note: Estimated with Logit. Robust standard errors clustered by country in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Constants are omitted from the table. d[.] indicates a dummy variable.

In sum, earthquakes affect both the onset and termination of conflicts and as a result the incidence of conflict. Furthermore, the magnitude of an earthquake is of fundamental importance, as are the social conditions in the area surrounding the epicenter. Moderate earthquakes increase the likelihood that conflicts start and may reduce the likelihood that conflicts end. Strong earthquakes are associated with a lower likelihood that conflicts are started and with a higher likelihood that conflicts are ended, and these effects tend to be stronger in poor countries, or when the epicenter is found in a region with a relatively low population density.

7 Concluding remarks

While the empirical literature has tended to find that natural disasters increase the risk of conflict, the intuition among some relief organizations is that natural disasters can contribute to reduce tensions and in the end reduce the risk of violent conflict. This paper shows that there is some truth to both of these stories and that the outcome in each case is determined by the severity of the disaster and the basic social conditions in the directly affected area.

We develop a theoretical model of natural disasters and violent conflict. The model shows how natural disasters can, via the destruction of physical capital, affect both the costs and revenues of rebellion. The moderate destruction caused by moderate natural disasters can make rebellion feasible by lowering the opportunity cost of potential recruits. More intense destruction means that the material payoff in the event of a victorious rebellion is lower. Taken together, the model predicts that violent conflict should be more likely after moderate disasters and less likely after very strong disasters, and that both these effects should be more pronounced in poor areas.

The empirical analysis employs an exhaustive dataset on earthquakes. We can establish that the general effect of moderate earthquakes is that they make new civil wars more likely, and maybe the termination of ongoing civil wars less likely. The effects of stronger earthquakes are the opposite, i.e., they make new civil wars less likely and termination of ongoing civil wars more likely. The findings are the first to link a fully exogenous measure of the severity of a potential natural disaster, namely an approximation of the seismic energy released by earthquakes, to the risk of civil war.

Most earthquakes are of moderate strength wherefore the overall effect is that violent conflicts are started and that ongoing conflicts are less likely to be terminated. The combined effect explains earlier findings of a generally positive effect on the incidence of violent conflict. The effects, both the conflict-promoting effect of moderate earthquakes and the conflict-defusing effect of stronger earthquakes, are more pronounced in poor areas and areas with a weak state presence. Accordingly, the results are consistent with the theoretical model.

We can now conclude that both the tradition claiming that natural disasters can cause violent conflict and the tradition claiming that natural disasters can end violent conflict hold pieces of the truth. As such, the present analysis constitutes the first systematic study to establish that natural disasters can give the impetus needed to end existing conflicts and prevent new violent conflicts from emerging.

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Appendix A

Proof of Proposition 1

If (4) does not hold, the choices of I and S are trivial as it implies that $V = 0$. The cost of hiring rebel fighters cannot be motivated when future incomes are zero, implying that $I = 0$. Expecting $I = 0$, Q sets $S = 0$.

Proof of Proposition 2

The rebel resource constraint (RRC) is slack when $I_{rrc} > I^*$, or when $\phi > \hat{\phi}$. The range of ϕ that is compatible with the conditions for Proposition 2 is therefore $\hat{\phi} < \phi < \tilde{\phi}$. There is fighting, $I > 0$, if $S^* < \hat{S}$, and this is the case when $\theta > \frac{1}{2}$, i.e., when the rebels are sufficiently efficient fighters.

When (4) and (RRC) are slack, the tax rate is $t = \frac{A(1-\phi)K-Y}{A(1-\phi)K}$, the size of the rebel army is $I^* = \frac{A(1-\phi)K-Y}{2\theta A(1-\phi)K}\left(1 - \frac{1}{2\theta}\right)$, and the size of the government army is $S^* = \frac{A(1-\phi)K-Y}{4\theta A(1-\phi)K}$. Also, (RRC) will not become binding at higher ϕ if it stops to bind at $\hat{\phi}$. The reason is that $\frac{dI^*}{d\phi} < 0$ while $\frac{dI_{rrc}}{d\phi} > 0$, as discussed below. This means that I_{rrc} will not fall as ϕ increases, but I^* will. This means that if $I_{rrc} > I^*$, it will stay that way when ϕ increases, and (RRC) will remain slack. The dynamics of I^* and p are evident from straightforward differentiation.

Proof of Proposition 3

The level of destruction compatible with the outcome in Proposition 3 is $\phi \leq \hat{\phi}$. When $\theta < 1/2$, the optimal I is $I^* = 0$. For (RRC) to bind, which requires that (5) holds, $I^* > 0$ is needed, i.e., $S^* < \hat{S}$, or $\theta > 1/2$. J will set $I = I_{rrc}$ under these conditions. On the one hand, when (RRC) binds, $I > I_{rrc}$ is not possible, wherefore any $S < S_{rrc}$ will still induce J to set $I = I_{rrc}$. On the other hand, any $S > S_{rrc}$ means that J sets $I < I_{rrc}$, but as this implies that (RRC) is slack, J simply sets $I = I^*$.

Importantly, as long as the S that Q sets implies a binding (RRC), Q can treat I as fixed at I_{rrc}. This is the case since when Q observes that the rebel resource constraint will be slack, it determines the optimal size S foreseeing two effects that the size of its army has on the probability that it wins the war. There is a *direct* effect in that a higher S

implies a higher p, but there is also an *indirect* effect as a higher S has a deterring effect on the I^* that J sets. Provided that the S that Q sets is in the range where it implies an optimal $I^* > I_{rrc}$, it turns out that Q only has to consider the *direct* effect of S on p. This means that whenever the government foresees that the rebel resource constraint will be strictly binding, it will set $S < S^*$, and the rebels will respond by setting I as high as possible.

Hence, if $\theta > 1/2$ and J wants to set $I^* > 0$ but (RRC) binds, J sets I_{rrc}. Foreseeing this, rather than setting S^* as if (RRC) were slack, the government chooses S to maximize its expected net wealth as in (3). Given that $I = I_{rrc}$, the probability of a government victory is $p = S/\left(S + \theta I_{rrc}\right)$ with $\partial p/\partial S = \left(\theta I_{rrc}\right)/\left(S + \theta I_{rrc}\right)^2$. Restricting S to be non-negative, the optimal size of the government army is $S_{rrc} = \sqrt{\theta I_{rrc} t} - \theta I_{rrc}$.

In sum, J cannot set $I > I_{rrc}$ and will not set $I < I_{rrc}$. Given $S_{rrc} = \sqrt{\theta I_{rrc} t} - \theta I_{rrc}$, any $I < I_{rrc}$ gives J a lower expected utility. This is clear as it is unambiguously the case that $J(I = I_{rrc} - b \mid S_{rrc}) < J(I = I_{rrc} \mid S_{rrc})$ for all positive b, given that $\theta < 1$. Rationally, J responds by setting I_{rrc}.

This I_{rrc} also satisfies the rebel incentive constraint (1), i.e. that $I_{rrc} \leq (1-p)\,t$. With $I = I_{rrc}$ and $S = S_{rrc}$, (1) can be rewritten as $I_{rrc} < \theta t$, which demands that $R_j < \theta\left(A(1-\phi)K - \underline{Y}\right)$, or that $\phi < \bar{\phi} = 1 - \frac{1}{AK}\left(\frac{R_j}{\theta} + \underline{Y}\right)$. When (RRC) binds, and therefore also (5), this will always be the case. Note also that $\hat{\phi} < \bar{\phi}$, i.e., that the level of destruction where (RRC) stops to bind is lower than the level where (1) binds. This implies that (RRC) is slack at all $\phi > \bar{\phi}$, and that at such ϕ, the relevant outcome is described in Propositions 1 or 2.

When $\theta > 1/2$ and (RRC) binds, the size of the rebel army becomes $I_{rrc} = \frac{R_j}{A(1-\phi)K}$ and the size of the government army becomes $S_{rrc} = \sqrt{\frac{\theta R_j (A(1-\phi)K - \underline{Y})}{(A(1-\phi)K)^2}} - \frac{\theta R_j}{A(1-\phi)K}$. The dynamics of I_{rrc} and p are evident from straightforward differentiation.

Appendix B

Basic facts about earthquakes

Table B1. Basic facts about earthquakes

Panel A	Magnitude	Annual average	
	3-3.9	130000	
	4-4.9	13000	
	5-5.9	1319	
	6-6.9	134	
	7-7.9	17	
	>8	1	
Panel B	Magnitude	Approximate TNT for Seismic Energy Yield	Example
	3.0	32 (metric) tons	
	4.0	1 kiloton	Small Atomic Bomb
	5.0	32 kilotons	Nagasaki Atomic Bomb
	6.0	1 megaton	
	7.0	32 megatons	Largest Hydrogen Bomb; Kobe, 1995
	8.0	1 gigaton	San Francisco, 1906
	9.0	32 gigatons	Chile, 1960
Panel C	Magnitude	Typical damage	
	<3.5	Generally not felt, but recorded.	
	3.5-5.4	Often felt, but rarely causes damage.	
	<6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.	
	6.1-6.9	Can be destructive in areas up to about 100 kilometers across where people live.	
	7.0-7.9	Can cause serious damage over larger areas.	
	>8	Can cause serious damage in areas several hundred kilometers across.	

Note: The source is USGS (2008).

Earthquakes and the number of disaster victims

The results presented in Table B2 indicate that we are correct in assuming that stronger earthquakes have more serious direct consequences. The data on earthquakes is taken from the Centennial Earthquakes Catalog (2008). The seriousness of disasters is captured by the variable *Disaster Victims*, which we define as the log of the number of dead, injured, or homeless due to natural disasters, as reported in the EM-DAT database. The data was retrieved from Nel and Righarts (2008). All specifications include a constant, *Qhist*, year dummies, and population size. The sample consists of observations with a disaster recorded in the EM-DAT database.[39]

[39] Observations for which no natural disaster is reported in the EM-DAT have zero *Disaster Victims*. We obtain the same qualitative results as in Table B2 when we include these observations in the sample

The first four columns are estimated with linear Fixed Effects. *Qnum*($M < 7.0$) indicates the number of moderate earthquakes, i.e., those with a magnitude of less than M7.0. Strong earthquakes, i.e., those with a magnitude of M7.0 or more are included as *Qnum*($M \geq 7.0$). In the table, it is evident that both moderate and strong earthquakes are associated with a larger number of disaster victims, and that the effects of strong earthquakes are more serious. That *TNT* is positive and significant when *Qnum* is held constant shows that it is not just the number of earthquakes that matters but also their size, i.e., more people die, are injured, or become homeless in earthquakes with a higher destructive potential, as approximated by *TNT*.

Table B2. Earthquakes and Disaster Victims

Dep. Var.	Disaster Victims			
	(B2.1)	(B2.2)	(B2.3)	(B2.4)
Sample	All	All	All	Qnum>0
Period	64-00	64-00	64-99	64-00
Qnum($M < 7.0$)	0.20***			
	(0.07)			
Qnum($M \geq 7.0$)	1.32***			
	(0.30)			
Qnum		0.24***	0.22***	0.13*
		(0.07)	(0.08)	(0.07)
TNT		2.62***	2.97***	3.48***
		(0.89)	(0.87)	(0.81)
Lagged Conflict			0.64**	
			(0.27)	
Qhist	1.55***	1.53***	1.06**	2.56
	(0.56)	(0.56)	(0.53)	(1.60)
Population	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes
Std. Controls	-	-	Yes	-
Adj. R^2	0.078	0.073	0.088	0.160
N	1762	1762	1554	548

Note: Robust standard errors clustered by country in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Constants are omitted from the table.

In Columns 3, we add the ten Standard Controls (see Section 5.4) plus a dummy for having had a conflict in the previous year. The dummy for having had a conflict in the previous year is significantly positive, i.e., a higher number of disaster victims are reported in countries that had a conflict in the previous year. This illustrates why the use of data from EM-DAT in an analysis of the effects of natural disasters on conflict can

and either use a Tobit model or a Heckman selection model, where we add a dummy for experiencing an earthquake to predict selection.

be problematic. In Column 4, only observations with a positive number of earthquakes in the Catalog are included. The sample now consists of countries where a natural disaster is reported in the EM-DAT database and an earthquake is listed in the Catalog. There are fewer observations, naturally, but we still obtain positive and significant estimates for *Qnum* and *TNT*.

The results presented in Table B2 thus show that our assumptions are correct and that stronger earthquakes have more serious direct effects.

Appendix C

Table C1. Descriptive statistics

	N	Mean	Median	Std. Dev.	Min	Max
Incidence	7376	0.150	0	0.357	0	1
Onset	7376	0.025	0	0.155	0	1
Termination	1077	0.224	0	0.417	0	1
d[Qnum]	5745	0.141	0	0.348	0	1
Qnum	5745	0.379	0	1.307	0	21
Qnum($M \geq 7.0$)	7376	0.034	0	0.213	0	5
TNT	5745	0.005	0	0.046	0	1.253
Income	5226	8.260	8.262	1.147	5.139	11.343
DisRel	1190	9.494	13.199	7.693	0	20.534

Note: The years are 1947-2001 for Incidence, Onset, Termination, and Qnum($M \geq 7.0$), 1964-2001 for d[Qnum], Qnum, TNT, and Income, and 1995-2001 for DisRel d[.] indicates a dummy variable.

Table C2. Pair-wise correlations

	1	2	3	4	5	6	7	8	9
1 Incidence	1								
	7376								
2 Onset	0.3778	1							
	7376	7376							
3 Termination	-0.778	-0.005	1						
	1077	1077	1077						
4 d[Qnum]	0.163	0.047	-0.026	1					
	5745	5745	954	5745					
5 Qnum	0.123	0.050	0.009	0.715	1				
	5745	5745	954	5745	5745				
6 Qnum ($M \geq 7.0$)	0.023	0.012	0.096	0.366	0.490	1			
	7376	7376	1077	5745	5745	7376			
7 TNT	0.015	-0.008	0.064	0.256	0.415	0.644	1		
	5745	5745	954	5745	5745	5745	5745		
8 Income	-0.202	-0.069	-0.012	0.051	0.020	0.014	0.022	1	
	5101	5101	830	5101	5101	5101	5101	5226	
9 DisRel	0.364	0.062	-0.123	0.179	0.120	0.041	0.034	-0.677	1
	1190	1190	206	1190	1190	1190	1190	1163	1190

Note: Pair-wise correlations and number of observations for each pair. The years are 1947-2001 for (1)-(3), and (6), 1964-2001 for (4)-(5) and (7)-(8), and 1995-2001 for (9). d[.] indicates a dummy variable.