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MSc Thesis

Macroeconomic effect of earthquakes on the economic growth

With respect to institutional differences

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Abstract

Earthquakes affect economic growth in both the short and long run and whether this effect is positive or negative depends on external factors, including institutional quality. The occurrence of an earthquake is exogenous, but the effect earthquakes have on GDP per capita depends on several factors, such as levels of income, openness and financial development. The effect of earthquakes is hard to determine as the costs they cause consist of direct costs, indirect costs and secondary effects. This thesis presents the results of a regression analysis using a fixed-effects model that examines the effect of earthquakes on economic growth in the short and the long run, using a dataset that covers 1996-2014. Economic growth is measured as the log differences of real GDP per capita. Examining the long run shows that earthquakes have a less negative effect in the fourth year, which shows that it takes four years until new technology that replaces old technology that is destroyed by earthquakes, outweighs the costs of its implementation. Earthquakes with different scores on the Richter scale affect economic growth differently, two variables for earthquakes are used; one representing moderate earthquakes and one representing severe ones. Splits are used in order to examine how this effect differs between low- and middle versus high income countries, closed versus open countries, and countries with a low versus a high level of financial development in the short run. An interaction term that consists of earthquakes with an indicator for institutional quality is added to examine how institutions influence these effects as well. Earthquakes have a less negative effect in high income countries and in countries with a higher level of financial development, showing how high income countries can afford better constructed buildings and structures, and how a higher level of financial development causes the increase in investment that occurs after an earthquake, to cover the losses after an earthquake. Closed countries experience less negative effects as well, while it was expected that they would experience a less negative effect, but this result shows how closed countries are able to deal with shocks independently. When a country has better institutions, the effect of earthquakes on economic growth is less negative in high income and in closed countries, but more negative effect in financially developed countries, which could be a result of bureaucratic rules delaying the recovery process.

1 Introduction

On December 26th 2004, a severe earthquake occurred in the Indian Ocean, which caused multiple tsunamis. Around 2 million people were affected and approximately 227 000 people lost their lives (Billon and Waizenegger, 2007). Severe earthquakes do not occur frequently and are hard to forecast (Skidmore and Toya, 2002). Scientist have not yet discovered what kind of signals happen before every large earthquake and only before large earthquakes and do therefore not know what indicates that a large earthquake is about to happen (Mckenna, 2011). As a result it is hardly possible for countries to implement additional last-minute preparation measures, such as the evacuation of people at risk. Compared to other types of natural disasters, earthquakes have an impact on a larger part of the economy, which results in a larger temporary decline in Gross Domestic Product (GDP) per capita (Felbermayr and Gröschl, 2014). GDP is a measure of a country's income that is based on the market value of everything that is produced within its borders. An example of how other types of natural disasters affect the economy is that a drought may affect a larger area than an earthquake, but will only affect the agricultural sector. As a result, more people are harmed by droughts, but the economic damage per affected person is less compared to earthquakes, as these mainly affect physical capital such as factory buildings (Loayza, et al., 2012). Earthquakes occur in a specific area, as they are caused by plate tectonics and occur on boundaries between plates. However, the damage they cause spreads outside this disaster area and affects the national economy. For example, damage to the capital stock and infrastructure that is located in the disaster-area such as delivery and transportation systems, will disconnect areas across the country (Noy, 2009). The resulting breaks in supply lines affect customers, suppliers and businesses in areas outside the disaster zone, thereby affecting the national economy. The damage is especially substantial when it involves oil or gas pipe lines as these supply numerous business and individuals (NRC, 1992). Furthermore, earthquakes reduce the capital stock and this has a negative effect on output as capital is a driver of economic growth (Ahlerup, 2013). Additionally, emergency relief operations and reparation costs related to destroyed infrastructure are costly. This, among other things, increases government spending (Klomp and Valckx, 2014). These examples show how earthquakes affect the national economy in multiple ways.

Three possible scenarios exist that show how earthquakes affect a country's development of GDP per capita; it can return to the original growth path or it can end on a higher or lower growth path. GDP per capita is a function of the capital-labour ratio and the technology level; and the impact of earthquakes on GDP per capita in the long run depends on how the capital-labour ratio and the level of technology are affected (Klomp and Valckx, 2014). The mechanisms behind these three scenarios are explained in more detail in chapter three. As earthquakes destroy capital, they alter the capital-labour ratio, which results in a drop in GDP per capita in the short run. However, the long run effect can be positive, when the destruction of capital increases the marginal returns to capital and the average returns of replacement capital, which stimulates capital accumulation, which stimulates economic growth (Loayza, et al., 2012). In addition, technology is a driver of economic growth. When destroyed capital is replaced with capital with better technology, the productivity of capital will increase in the long run, which stimulates economic growth (Rahman, et al. 2013; Klomp and Valckx, 2014). As a result, earthquakes can have a positive effect on economic growth in the long run.

Earthquakes are categorized as geophysical disasters and can be treated as quite exogenous, which means that their occurrence cannot deliberately be influenced by external factors. They only occur in

places where tectonic plates collide, such as in the United States and Japan (Kellenberg and Mobarak (2011). Seismometers are able to measure earthquakes by recording the seismic waves that are released during earthquakes, which gives the opportunity to categorize earthquakes according to strength. The occurrence of an earthquake does not depend on the level of development, as richer countries do not experience less severe earthquakes (Kahn, 2005; Strömberg, 2007). However, the damage that earthquakes cause depends on level of development and decreases when per capita income increases (Kellenberg and Mobarak, 2011). Ninety percent of the victims are from developing countries (Kahn, 2005). In addition to the level of development, institutional quality influences the impact of earthquakes as well. Institutional quality is difficult to measure, which is reason why studies use indicators, such as corruption or the level of democracy, to examine its effect (Kahn, 2005; Kellenberg and Mobarak, 2011). The number of earthquake-related deaths is higher in poor, highly urbanized countries than in rich, highly urbanized countries. High income countries are likely to enforce building codes more actively and to have disaster response plans (Kellenberg and Mobarak, 2008). This suggests that institutions in developed countries are of better quality; therefore, institutional quality is likely to have an effect on earthquake-related damage.

An additional concern is that population is growing fast in areas that are vulnerable to natural disasters (Kellenberg and Mobarak, 2011). An increasing number of people is forced to live near plate-boundaries as a result of population pressures and poverty in developing countries, where unsafe buildings increase the risks further (Kahn, 2005). Population pressures are also responsible for a growing number of megacities in vulnerable areas (Alexander, 1997). When megacities or areas with unsafe buildings are affected by an earthquake, the number of casualties will be high, due to a more densely populated area being affected. Therefore, it is important to study the effect of earthquakes and the factors that influence this effect, in order to find how their impact can be minimized and to prevent earthquakes, such as the 2004 earthquake in the Indian Ocean, to result in a high death toll.

1.1 Research question

The aim of this research is to examine how earthquakes affect economic growth and which factors influence this effect. The institutional quality of a country is an important factor, as explained above and in existing literature. The main research question is:

"How do earthquakes affect economic growth and how does institutional quality influence this relationship?"

This question is divided into the following two sub questions; *"How do earthquakes affect the short and long run economic growth conditional on institutional quality?" "How does this effect rely on income level, openness and the level of financial development?"*

A regression analysis is performed in order to find the effect of earthquakes on economic growth, measured as the log difference of real GDP per capita and to examine how institutional quality plays a role in this relationship. The used dataset consists of data taken from the National Oceanic and Atmospheric Administration (NOAA) and the World Bank and covers the period 1996-2014. The regression analysis is done using Stata 13. The methodology is further explained in chapter five.

1.2 Hypothesis

It is expected that earthquakes have a negative effect on real GDP per capita in the short run and that countries with better institutions experience a less negative effect. A country's quality of institutions consist of several factors that determine the impact of an earthquake, such as macroeconomic conditions, income inequality and level of democracy (Kellenberg and Mobarak, 2011). It is also expected that the long run effect is less negative compared to the short run effect, because a country needs several years to recover from an earthquake and the positive economic effect of this recovery process does not exceed the negative effect of the damage immediately. Countries with better institutions are better prepared and able to cope with extreme events, which means that they are likely to experience a less negative effect (McDermott, et al., 2014). The reasons for these expectations are explained in the following section.

1.2.1 Ex-ante measures

The impact of an earthquake can be influenced by ex-ante measures, which are defined as measures that can be implemented before an earthquake occurs in order to limit the damage. Countries with better institutions experience a less negative effect of earthquakes on economic growth, as they are able to better endure the shock of an earthquake and to direct the recovery process more efficiently, which will limit the negative effect on economic growth (Barone and Mocetti, 2014). These countries have less corruption in the building, which results in better constructed buildings that are able to withstand a moderate earthquake, resulting in less damage and a lower death toll (Escaleras, et al., 2007). The level of democracy indicates the quality of institutions as well and countries with a higher level of democracy often have governments that consist of large coalitions that rely on the provision of public goods to attract support of citizens, as Flores and Smith (2013) explain. Earthquake preparedness measures are public goods and examples are the training of firefighters and rescue workers and the availability of a stock of emergency supplies (Flores and Smith, 2013). Ahlerup (2013) also mentions that democracies invest more in disaster prevention measures, resulting in a lower number of casualties. Democratic leaders experience a higher risk of losing their position when a natural disaster results in a high death toll, which motivates them to implement measures that aim for limiting the death toll. Autocratic leaders hardly experience an effect of the number of casualties on their position as they only need to keep the loyalty of a small group, for which they can purchase private goods (Flores and Smith, 2013). Additionally, democratic countries have freer media, which increases political accountability by motivating the current governments, who know that their actions will influence the outcome of the elections and thus their position, to protect the citizens (Kahn, 2005). A country's level of income influences the ex-ante measures as well. Governments in high income countries can afford to provide for better infrastructure, to prevent building near plate boundaries by means of zoning laws and to invest in building codes, which leads to less damage when an earthquake occurs (Kahn, 2005; Kellenberg and Mobarak, 2008). As a result high income countries are likely to experience a less negative effect of earthquakes on real GDP per capita.

1.2.2 Ex-post measures

Ex-post measures also limit the negative effect of earthquakes on economic growth, which means that after the occurrence of an earthquake, a country's reaction to this event influences the effect of the earthquake. Institutional quality influences the effectiveness of these ex-post measures as well, as aid is less likely to disappear into corruption when countries have better institutions, which increases the motivation of donors to give aid (Ahlerup, 2013; Barone and Mocetti, 2014). Aid has an

important influence on the economic effect of earthquakes, as countries only experience a positive effect of natural disasters when they receive aid (Ahlerup, 2013). Additionally, aid that is used for economically unproductive activities harms economic growth and decreases the quality of institutions (Barone and Mocetti, 2014). The income level also affects the impact of earthquakes, as low- and middle income countries experience a greater effect of earthquakes on GDP per capita, which can be a result of weak institutions or limited access to international markets, as Felbermayr and Gröschl (2014) explain. Access to international markets stimulates the process of replacing and upgrading destroyed capital (Felbermayr and Gröschl, 2014). High income countries have better institutions that are able to cope with natural disaster-related damage, thereby limiting the negative effect on GDP (Kellenberg and Mobarak, 2008). Additionally, countries that are open to trade are likely to experience a less negative effect, as they are able to increase investment without a change in consumption, which enables them to recover from the decrease in economic growth more rapidly (Felbermayr and Gröschl, 2014). Trade is also a source of technology transfer that stimulates economic growth (Yanikkaya, 2003). As a result, countries that are open to trade are likely to replace and upgrade destroyed capital more easily, which enables a country to return to its original growth path, as Klomp and Valckx (2014) explain. Institutional quality influences the amount of trade as well, which is shown by democratic countries usually being more open (Ahlerup, 2013). They also have lower levels of protectionism, which stimulates trade (Thacker, 2007). Protectionism refers to measures meant to protect the national economy for international competition. When citizens experience economic benefits due to trade, it is likely that democratic governments increase openness and lower the levels of trade protectionism, as Thacker (2007) explains. Another factor that influences the impact of earthquakes is the level of financial development, which occurs when financial markets, instruments and intermediaries lower the costs of information, enforcement and transaction, thereby stimulating economic growth (Levine, 2005). Consequently, countries with developed financial systems are unconstrained economies with better access to credit, whereas in credit-constrained economies access to credit and to the services of banks is more problematic (McDermott, et al., 2014). As a result, the increase in investment that occurs after an earthquake is lower in constrained economies than in unconstrained economies, and not sufficient to compensate for the earthquake-related losses. This leads to a decline in economic growth in the long run (McDermott, et al., 2014).

The previous section explained why countries are expected to experience a less negative effect of earthquakes on real GDP per capita when they have a higher level of income, are more open to trade or have a more developed financial system. The next chapter explains the economic effect of earthquakes by means of a model for disaster risk management, followed by chapter three that explains the differences that can be found in the literature on the effect of earthquakes on economic growth and the various factors that influence this effect. Chapter four explains the effect of institutional quality on economic growth, in relation with earthquakes in more detail. Chapter five describes the methodology, followed by the results and the discussion of the results in chapter six. This thesis ends with a conclusion in chapter seven, the list of references and the appendices that contain the graphs and tables.

2 Natural disaster model

In order to understand the economic risks of earthquakes, their effect can be analysed using theoretical models. A theoretical model that is often used is the model for disaster risk management, which Hochrainer (2009) uses to assess disaster risk as a function of hazard, exposure and physical vulnerability (figure 1). Hazard refers to the characteristics of a natural disaster that affect a specific location, for example an earthquake's score on the Richter scale measured in this specific location. Exposure refers to the assessment of the relevant elements that are exposed to this earthquake, such as population and capital stock. Physical vulnerability refers to factors that influence the risk that people have of being affected and that the capital stock has of being destroyed, which means that this determines the actual damage that is caused by the earthquake. Examples of these factors are income level, openness to trade and institutional quality (Hochrainer, 2009). Hazard, exposure and physical vulnerability together determine the economic impact.

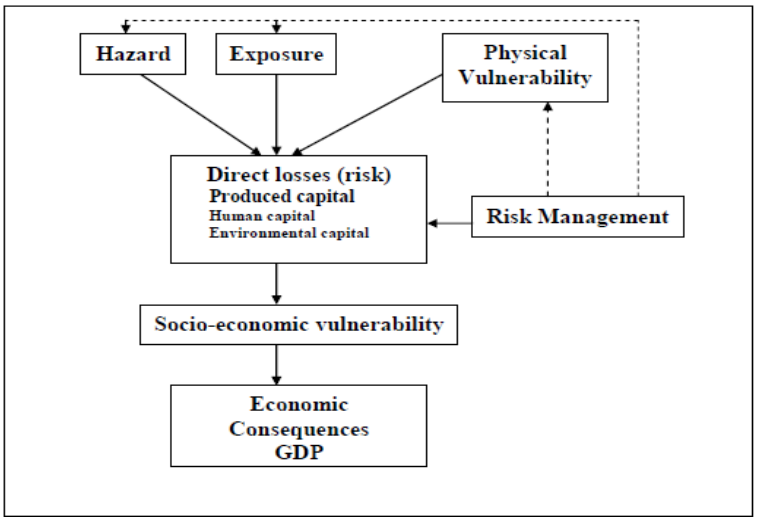


Figure 1, Model for riskmanagament (Hochrainer, 2009)

The occurrence of earthquakes is hard to predict and does not depend on other economic growth-related determinants, as earthquakes are caused by plate tectonics, making the hazard exogenous (Simonsen, 2012). However, exposure and vulnerability are not exogenous but endogenous, as they can be influenced by other factors. It is known where the boundaries of tectonic plates are located, therefore exposure can be influenced by investing in the quality of buildings and infrastructure in these regions and by zoning laws. Physical vulnerability is endogenous as well. Measures to influence exposure are costly, which means that mainly rich countries can afford these investments and also have emergency care of better quality, which enables them to limit their physical vulnerability (Kahn, 2005). Institutional quality also influences physical vulnerability as corruption lowers the quality of buildings, which increases vulnerability to earthquakes by increasing the damage and death-toll when an earthquake occurs. Altogether, exposure and physical vulnerability are endogenous as they can be influenced, but earthquakes as hazard are exogenous.

3 Effect on economic growth

The effect of earthquakes on economic growth depends on several country-specific factors, but also on time, as the passage of time is required to determine the true costs of earthquake-related losses

(Pelling, et al., 2004). Studies that choose to focus on different country-specific factors are likely to have different results, as these factors affect an earthquake's impact differently.

3.1 Costs of earthquakes

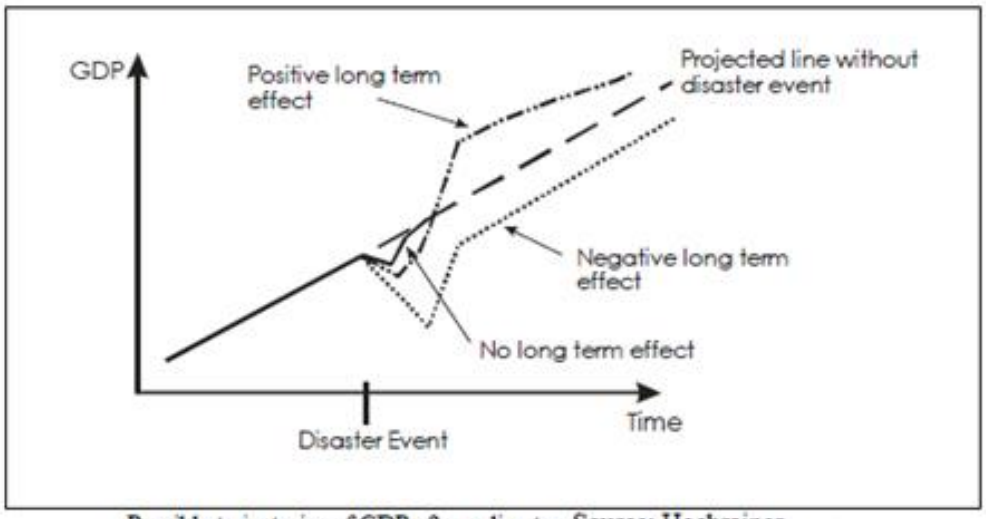
The true costs of an earthquake are hard to determine. Calculating the sum of the reparation costs and the costs of medical expenses related to earthquakes only measures the direct costs and does not cover all earthquake-related losses. The direct costs refer to the physical damage caused by earthquakes, including the damage to productive capital, economic infrastructure such as roads, and social infrastructure such as houses, while the total loss of an earthquake also includes indirect costs and secondary effects (Pelling, et al., 2004). The indirect costs consist of costs that are a result of the direct costs (Kliesen, 1994; Pelling, et al., 2004). The indirect costs are a result of the disruption to the flows of goods and services that leads to a drop in output, loss of earnings and disruption to the basic services (Pelling, et al., 2004). Diseases, injuries and deaths occur more often in affected areas, which increases medical costs and reduces productivity of citizens and these costs are also indirect costs (Pelling, et al., 2004). Secondary effects are a result of indirect losses and refer to the impact on the overall economy and can be felt in the year the disaster occurred and several years after (Pelling, et al., 2002). Examples are changes in levels of indebtedness and monetary reserves and in GDP. The effect on economic growth is therefore a secondary effect.

The indirect costs and the secondary effects are hard to determine, if they can be determined at all. To find out how the destruction of capital affects economic growth in the long run and how the recovery process develops takes several years (Pelling, et al., 2004). Furthermore, it is not possible to know what a person's precise future gains or earnings would have been under normal circumstances (Kliesen, 1994). To conclude, the impact of an earthquake can last several years and it is not possible to determine what the development of GDP would have been in absence of an event, therefore it is difficult to determine the total loss of earthquakes.

3.2 Long run effect scenarios

Three scenarios can be distinguished when examining how earthquakes affect the growth path of a country's GDP (Hochrainer, 2009). Figure 2 shows the short- and long run development of a country's GDP in these three scenarios in relation to the expected growth path under normal circumstances. The short run is defined as the first five years that follow an event and the long run refers to the period beyond five years (Hochrainer, 2009). Figure 2 shows that the GDP level drops in the short run after an event in all three scenarios, although the magnitude of these drops differs. This is a result of destruction of production capacities and disruption of the economy in the short run (Klomp and Valckx, 2014). The long run developments of the scenarios are more apart. The line consisting out of stripes in the graph shows the scenario where the GDP level experiences the smallest drop, after which it returns to the original growth path. The destruction of capital increases the return on capital, which attracts savings and FDI inflow (Klomp and Valckx, 2014). Furthermore, investment that is related to reconstruction restores the reduced capital-labour ratio. However, it is also possible that investment is hindered by financial constraints, which prevents a country from full recovering from the decline in the capital-labour ratio (Klomp and Valckx, 2014). As a result, a country ends on a lower growth path and this scenario is shown by the dotted line, which also shows the largest initial drop in GDP. The third scenario shows a moderate initial drop in GDP level, after which a country ends on a higher growth path. This positive effect in the long run could be caused by the replacement

of old, destroyed capital with more efficient and productive capital, which increases productivity that causes economic growth to increase (Rahman, et al. 2013; Klomp and Valckx, 2014).



Possible trajectories of GDP after a disaster. Source: Hochrainer

Figure 2, Effect of natural disasters on GDP (Hochrainer, 2009)

3.3 'Creative destruction' and the 'broken window' hypothesis

The third scenario in figure 2 illustrates the mechanism of 'creative destruction'. Rahman, et al. (2013) explain 'creative destruction' as a Schumpeterian concept, describing how earthquakes and other natural disasters can have a positive effect on economic growth through a 'rebuilding-effect'. This effect explains how natural disasters provide opportunity to replace destroyed capital with capital that has new and more productive technologies, which stimulates economic growth (Skidmore and Toya, 2002; Rahman, et al., 2013). However, Skidmore and Toya (2002) do not find evidence of this 'rebuilding-effect' for earthquakes in specific. This could be a result of another mechanism, which is called the 'broken window' hypothesis, which is based on a theory by Bastiat (Rahman, et al., 2013). The 'broken window' hypothesis shows how capital that is used for reconstruction-based investment cannot be used for other economy-stimulating activities, resulting in no positive economic effect. An example is the time that is required to train workers and to fully adapt the new technology into the production process, which causes a short run productivity loss (Kellenberg and Mobarak, 2011). According to the 'broken window' hypothesis, the benefits that the new technology will cause in the long run, will not exceed the costs of implementing the new technology. However, not implementing new technology may seem beneficiary in the short run, but not in the long run. Although implementing older technology will help to restore the production process more quickly and minimize the short-term productivity loss, it will not improve the productivity in the long run, which can cause a country to become stuck in a poverty trap (Kellenberg and Mobarak, 2011). This also shows how time plays a role in examining whether earthquakes have a positive effect or a negative effect on economic growth. This also supports the necessity of dividing the costs into direct costs, indirect costs and secondary effects, as proposed by Pelling, et al. (2004), as especially secondary costs cover the effect over a longer time period. The next section explains different factors that influence the effect of earthquakes on growth.

3.4 Factors influencing the economic effect of earthquakes

Several country-specific factors influence which of the three scenarios from figure 2 a country's GDP will follow after an earthquake. This section explains how the levels of income, income inequality, openness to trade and financial development affect the impact of earthquakes on real GDP per capita.

3.4.1 Level of development

One of the main factors that influence the impact of earthquakes is the level of development. Various studies show that the reported number of deaths and economic losses due to natural disasters is lower in rich countries, although they do not face less or less severe events (Ahlerup, 2013). A reason for this is that developing countries are less prepared for natural disasters (Loayza, et al., 2012). High income countries have more financial means that they can use for preparedness measures, such as investing in stronger buildings, which will limit the losses (Strömberg, 2007; Toya and Skidmore, 2007). Toya and Skidmore (2007) show how the number of natural disaster-related deaths and the damage/GDP decrease with a country's development. They use a dataset that covers 151 countries over the period 1960-2003 and consists of data that are taken from various data bases. They estimate two sets of regressions, one for the number of deaths and one for the damage/GDP. They find that developed countries experience a less negative effect of earthquakes on growth, which could be a result of people in developed countries having a higher private demand for safety and of high income countries having greater resources to safety (Toya and Skidmore, 2007). Kahn (2005) also focusses on disaster-related deaths and uses a dataset with data from Emergency Events Database (EM-DAT) that covers 73 nations over the period 1980-2002. In line with Toya and Skidmore (2007), Kahn (2005) shows that the death toll has an adverse relation with the level of development, as richer nations are able to invest more in precautionary measures. Examples are the enforcement of zoning and building codes and the improvement of infrastructure, thereby increasing the accessibility of the affected regions so that emergency aid can arrive more easily (Kahn, 2005). As countries without access to good medical care or emergency treatment experience a higher death toll caused by natural disasters, investing in preparedness measures reduces the disaster-related death toll. Kahn (2005) also explains that institutions influence the level of protection of the population from natural disaster-risks and this is shown by a lower number of disaster-related deaths in more democratic countries. A mechanism through which institutions affect the death-toll is corruption, which has a negative effect on the enforcement of building codes and the quality of infrastructure (Kahn, 2005). Additionally, democracies invest more in disaster prevention measures, resulting in a lower number of casualties (Ahlerup, 2013). This shows how the death toll is influenced by institutional quality as the level of democracy is an indicator for institutional quality.

Additionally to the death toll, the level of develoment also influences the effect of earthquakes on GDP per capita, which is shown by Felbermayr and Gröschl (2014). They use earthquake data from the 'Incorporated Institute for Seismology' that cover the period 1979-2010 to show that earthquakes have a greater negative effect on GDP per capita in low- and middle income countries than in high income countries. Earthquakes destroy capital, but they also allow for an increase in investment that refills the capital stock and they create an opportunity to update old equipment and structures (Felbermayr and Gröschl, 2014). This can cause a temporary boom in growth, but only when a country has good institutions, as democracies have better access to foreign funds and investment goods, which stimulates the recovery process and limits the negative effect on GDP per

capita (Felbermayr and Gröschl, 2014). Democracies also have better protected property rights, which encourages investment that has a positive effect on economic growth.

Raschky (2008) also finds a less negative effect of disasters in high income countries, by studying the relation between natural disaster losses and institutions, using EM-DAT data that cover the period 1984-2004. High income countries experience a lower death toll and less economic losses, although the strength of this relation decreases with an increasing level of development (Raschky, 2008). This means that death toll and economic losses differ less among high income countries than low income countries. Raschky (2008) makes no distinction between different types of natural disasters, but included earthquake data into the overall natural disaster variable. Despite not focussing on earthquakes, the study is relevant for this research, because it explains how institutions affect the impact of natural disasters. Raschky (2008) explains that the lower number of natural disaster-related deaths is a result of a stable government that has better preventive policies and is able to enforce them. These studies show that high income countries experience a lower death-toll and less negative effect on real GDP per capita as a result of an earthquake.

3.4.2 Income inequality

In addition to income level, income inequality influences the effect of earthquakes on economic growth as well. A high level of inequality has a negative effect on economic growth. It influences a country's political stability by increasing social conflict, which results in lower levels of investment and in higher levels of violence and crime (Anbarci, et al., 2005). This has a negative effect on GDP per capita, as citizens spend time participating in crimes and riots instead of working (Barro, 2000). Earthquakes cause additional unrest, as they threat the supply of basic needs, such as food or medicines, which can cause plunder. The death-toll caused by an event is also higher in countries with a higher level of income inequality, as population in these countries mainly consist of poor people, which can obstruct the building of social capital and trust in government institutions, decreasing the likelihood of achieving collective action (Kahn, 2005). Anbarci, et al. (2005) define collective action by society as the communal preparedness and mitigation activities such as zoning regulations and enforcement of high-level building codes. This shows that the government is not the only part of society that can limit the negative consequences caused by earthquakes. Anbarci, et al. (2005) examine 269 earthquakes that occurred over the period 1960-2002 and had an intensity of at least six on the scale of Richter and find that the likelihood of achieving collective action is a function of a lower inequality level and a higher income level. The income level needs to be sufficient to cover the costs of the resources that are needed for mitigation activities and disagreements concerning the distribution of these costs among the involved parties can cause conflict, which lowers the likelihood of collective action (Anbarci, et al., 2005). Therefore, society as a whole is able to limit the impact of an earthquake, but this is less likely to happen when a country has a higher level of inequality.

3.4.3 Openness to trade

An earthquake's effect on economic growth is also influenced by a country's trade level, which is often used as indicator for openness. More open countries experience less natural disaster-related losses (Toya and Skidmore, 2007). Similar to democratic countries, open countries have access to foreign funds and investments goods, which can refill the capital stock quicker (Felbermayr and Gröschl, 2014). They are also likely to experience a smaller shock in demand for their products (Noy, 2009). Additionally, they are likely to receive a higher international aid inflow that is meant for reconstruction (Noy, 2009; Ahlerup, 2013). Ahlerup (2013) shows the importance of receiving aid

using a sample that consists of EM-DAT data that includes data on 157 countries over the period 1965-2008, to examine the effect of natural disasters on income per capita. No negative effect is found of natural disasters in general or of geophysical disasters in particular on economic growth. On the contrary, they can stimulate income per capita in the short and long run, but this is only the case for democratic countries that receive humanitarian aid. Democratic countries usually are more open and more willing to receive aid and assistance, which has a positive effect on the impact of earthquakes (Ahlerup, 2013).

Barone and Mocetti (2014) support this finding by showing that aid does not always have a positive effect on economic growth. They examine two earthquakes that occurred in two Italian areas, which are Friuli, in 1976, and Irpinia, in 1989 and compare the development of GDP per capita in these two regions to their expected development paths over the period 1951-2004. Countries with better institutions experience a positive effect of aid that helps to limit the drop in GDP that is caused by earthquakes and allows for immediate reconstruction (Barone and Mocetti, 2014). However, countries with weak institutions are likely to use aid for economically unproductive activities, which has a negative effect on the technical efficiency and worsens institutional quality further. This is harmful in both the short and the long run and has a negative effect on a country's capability to deal with future disasters (Barone and Mocetti, 2014).

Other mechanisms that explain how trade stimulates economic growth are technology transfer, economies of scale and comparative advantages (Yanikkaya, 2003). Comparative advantages stimulate a country to use their resources more efficiently as a country can import goods and services that have a costly production process and thereby focus on products that are cheaper to produce. Exporting products wherein a country has a comparative advantage generates income. Trade also allows a country to produce larger quantities of certain products, thereby decreasing production costs as a result of economies of scale, as it is less expensive to produce a larger quantity of a product. Furthermore, trade provides a country with access to investment and intermediate goods, which stimulates the development process and economic growth (Yanikkaya, 2003). Trade also stimulates the 'building-back' effect by stimulating technology transfer, resulting in an increase in productivity and thereby boosting economic growth. These studies show how open countries experience a less negative effect of earthquakes on economic growth, if institutions are of better quality.

3.4.4 Level of financial development

The level of financial development is another factor that influences the effect of earthquakes on growth. A developed financial system increases the mobilization of savings, which enhances capital accumulation, resource allocation and technological innovation, thereby stimulating growth (Levine, 2005). An indicator for the level of financial development is the amount of credit to the private sector and financial systems that distribute more credit to the private sector are likely to be more active in terms of risk management, provision of financial services and selecting investment projects, instead of merely allocating credit from the government to state-owned enterprises (King and Levine, 1993). As a result, countries with a higher level of financial development have better access to credit, thereby affecting the impact that earthquakes have on economic growth. McDermott, et al. (2014) examine panel data on 180 countries that cover the period 1979-2007 to analyse how the annual growth rate of output per capita is affected by natural disasters and how financial development, measured as the amount of credit to the private sector, influences this effect. Similar to the research

by Raschky (2008), they make no distinction between different types of natural disasters, but because it explains how financial development affects the impact of natural disasters on economic growth, this paper is relevant for this study as well. McDermott, et al. (2014) explain that financially underdeveloped countries experience credit-constraints that hinder investment opportunities, causing the increase in investment that occurs after a natural disaster not to be sufficient to compensate for the losses to the capital stock. As a result, the short run output decreases and a country ends on a lower growth path. This is in line with the conclusion of Felbermayr and Gröschl (2014), of increased investment in developing countries that is caused by an earthquake not being sufficient to compensate for the losses. Credit constraints hinder economic growth as they are caused by information asymmetries that exist in underdeveloped systems, which especially affect the poor by preventing them from using investment opportunities (Levine, 2005). As a result, capital cannot flow to the optimal allocation, thereby negatively affecting economic growth. Financial development stimulates the efficient allocation of credit and limits the effect of earthquakes on GDP. In the aftermath of an earthquake, it is especially important that the poor also have access to credit, as it is an important tool to recover from the damage. Therefore, a higher level of financial development is an important factor that limits the negative effect of earthquakes on economic growth.

3.4.5 Summary

The effect of earthquakes on economic growth differs among countries and these differences are caused by several factors, including the level of development, income inequality, openness to trade and access to credit. As a result, the effect of earthquakes on growth is hard to predict, as it is determined by various factors. Another key factor is institutional quality. The factors that are discussed in this section are all influenced by institutional quality, which shows that it has an important influence on economic growth. The next section focusses on institutional quality in more detail.

4 Institutions

The institutional quality of a country is difficult to measure, as no worldwide accepted definition exists, which led to the existence of multiple diverse definitions (Kaufmann, et al., 2011). In spite of these different definitions, a common agreement exists on the presence of the relation between institutional quality and economic growth and the effect that the quality of institutions have on the impact of national disasters, such as earthquakes. The institutional quality of a country is formed by historical and geographical factors (Felbermayr and Gröschl, 2014). Furthermore, the institutional vulnerability of a region determines whether or not a natural process results in a natural hazard (Raschky, 2008). The effects of natural hazards on society are shaped by climatic, topographic and socio-economic factors, but a natural process is only a natural hazard when humans or a form of capital is threatened and/or destroyed (Raschky, 2008). Therefore, institutions are important, as they can limit the adverse effect of earthquakes, which is reflected in both the death toll of an earthquake and the overall economic losses. Countries with better institutions experience faster economic recovery, which is caused by the stimulating effect they have on investment (Felbermayr and Gröschl, 2014).

As no clear definition of institutional quality exists, indicators are needed for researching the influence of institutional quality. Examples of indicators are heterogeneity measures, historical

variables such as settler mortality risk and Polity 4 data that represents the general openness of political institutions of a nation (Kahn, 2005). The choice for the most appropriate indicator for a specific research depends on the used definition of institutional quality. This research uses the Worldwide Governance Indicators (WGIs) as an indicator for institutional quality. The definition of governance used by Kaufmann (2011) is: "*the traditions and institutions by which authority in a country is exercised*" (Kaufmann, et al., 2011, page 3). The WGIs cover over 200 countries and are objective, as they include data from multiple sources (Kaufmann, et al., 2011). The WGIs consist of the following six dimensions (World Bank, 2015b):

- Voice and accountability (VA)
- Political stability and absence of violence (PV)
- Government effectiveness (GE)
- Regulatory quality (RQ)
- Rule of law (RL)
- Control of corruption (CC)

These six dimensions represent three areas of governance. VA and PV represent the method of selecting, monitoring and replacing governments. GE and RQ show if governments are able to formulate and implement sound policies. RL and CC indicate if the institutions relating to the governing of economic and social interactions are respected by the state and the citizens (Kaufmann, et al., 2011). These six dimensions have a strong positive correlation across countries and are therefore interdependent, as Kaufman, et al. (2011) explain. For example, it is likely that countries with a better accountability mechanism experience less corruption. However, this causes no problems for this research as these six dimensions are combined in one variable that represents institutional quality and the method by which this was done is described in section 5. This section explains how the six dimensions are related to economic growth.

4.1 Voice and accountability

The indicator 'voice and accountability' represents the degree to what citizens are able to select their government, and to the freedom of expression, association and media (Kaufmann, et al., 2011).

This dimension is related to democracy, as democratic countries have freer press, more transparent institutions and are likely to have a stronger reaction to natural disasters, compared to autocratic governments (Noy and Nualsri, 2011). In the same way as developed and developing countries differ, democratic countries do not experience less severe natural disasters than nondemocratic countries, but they do experience less severe consequences, which could be because these countries are often poor (Strömberg, 2007). In addition, low or middle income countries suffer from more substantial economic losses due to earthquakes (Strömberg, 2007; Felbermayr and Gröschl, 2014) and experience a higher death toll (Kahn, 2005). This is explained in more detail in chapter 3.4.1. The impact of an earthquake depends on the response of the government and this response differs between democratic and nondemocratic countries. A governments' response is shaped by the citizens' access to information and the government's accountability to the public (Flores and Smith, 2013). Democratic governments are held accountable for the casualty level of natural disasters, therefore the level of protest increases with a higher death toll as citizens perceive this as the government performing poorly (Flores and Smith, 2013). Due to the free media, citizens are better informed about the actions of the government. This works as an incentive for them to be more

accountable and to protect the citizens as they want to be re-elected, as Kahn (2005) explains. As a result, they take proactive steps that will limit the damage when an event occurs (Kahn, 2005). This could also explain the finding by Strömberg (2007), of disaster relief being more responsive in countries where newspapers are being read by more people, which shows the positive effect of free press on the impact of natural disasters. Besley and Burgess (2002) find a similar result, by explaining how newspaper circulation is associated with a more active governmental response to disaster-related food shortages when citizens are able to participate in the political process. The media informs citizens about the behaviour of politicians, which affects their voting behaviour. In order to gain more support, politicians are more inclined to react to the needs of the vulnerable, as Besley and Burgess (2002) explain. They also find a relation of literacy with the responsiveness of the government, which shows how newspapers and other written media have an influence on the impact of natural disasters. The media is also able to influences the behaviour of other countries. When a disaster receives international media attention, neighbouring countries are discouraged to take advantage of the affected country that is weakened by the natural disaster (Nelson, 2010). However, this does not mean that a country will not be exploited by lower-level threats and actions against the affected country, therefore future research is needed to examine this further, as Nelson (2010) emphasizes.

Democratic countries are also associated with a higher level of transparency, which is likely to increase the confidence that citizens have in the government, which they need especially during elections and re-elections. It will also result in better informed citizens about the existing risks, which helps them to make decisions based on these risks (Raschky, 2008). These points show that in democracies, election and media stimulate the responsiveness of governments to earthquakes, as the way they deal with natural disasters influences the voting behaviour of citizens.

4.2 Political stability and absence of violence

This indicator represents the probability of governments being destabilized or overthrown by unconstitutional or violent mean, such as terrorism or violence that is politically motivated (Kaufmann, et al., 2011).

Acemoglu, et al. (2003) explain how macroeconomic problems, such as slow economic growth, are not caused by bad macroeconomic policies but are a result of weak institutions. When distortionary policies cause discontent among parties and there are hardly political constraints in place, a lot can be gained from being in power, which explains the frequent coups occurring worldwide. However, this also causes political instability, which can translate into economic instability, as the parties in power do not act in the country's best interest (Acemoglu, et al., 2003). As it is not clear how weak institutions result in economic instability, Acemoglu, et al. (2003) propose future research to gain more understanding concerning this relation. However, it is clear that political instability decreases incentive to invest and produce and this has a negative effect on economic growth (Barro, 1991; Ahlerup, 2013). Threats to property rights reduce investment, which reduces an economy's output, which in turn negatively affects economic growth (Barro, 2000). The level of political stability is one of the factors that explains cross-country differences in physical and human capital accumulation that stimulate economic growth (Skidmore and Toya, 2002).

Additionally, political instability is related to the level of inequality. Barro (2000) explains how the equalizing of income will discourage citizens to participate in crime and riots and encourage them to

work, which results in political stability and an increase in economic growth (Barro, 2000). As mentioned in chapter three, countries with a higher level of inequality experience more social conflict, which leads to more violence and crime (Anbarci, et al., 2005). This shows how inequality lowers the motivation to abide by the law. Inequality also lowers investment levels and decreases the capability of countries to deal with external shocks such as earthquakes (Anbarci, et al., 2005). Additionally, increased violence and crime also decrease economic performance by increasing medical costs, using of resources for managing the conflict and violence instead of using it for more productive activities and through the loss in productivity of the injured (Anbarci, et al., 2005). Conflict does not only negatively affect output, but output has an influence on the number of conflicts as well. Acemoglu, et al. (2003) explain the vicious circle of how weak institutions and low output cause a rise in the number of conflicts, which decreases output even further. This vicious circle results in larger fluctuations caused by external shocks compared to when this country would have better institutions.

Political stability reduces the number of deaths caused by natural disasters and reduces the overall economic losses (Raschky, 2008). The existence and enforcement of better preventive policies and the existence of a better investment climate that protect property rights, is more likely under stable governments (Raschky, 2008). A reason for the increase in number of conflicts after an event is that competition for scarce resources such as water and medicine increases (Brancati, 2007). Civil conflict can be explained in a simplified model consisting of grievance and political opportunities (Omelicheva, 2011). Grievance over for example income inequality or shortage of basic resources, stimulates people to actively improve their situation, for which they can use revolt as a means. However, people need to have access to certain resources and they need to feel that the costs of revolt are worth the benefits, and these two factors define political opportunities (Omelicheva, 2011). Earthquakes are especially a cause for political instability, as they cannot be predicted and thereby surprise both the citizens and the government (Omelicheva, 2011).

Most studies explain how natural disasters can amplify already existing conflicts, but Le Billion and Waizenegger (2007) show that this differs per situation. They show that after the 2004 Indian Ocean tsunami, the conflict that existed in Sri Lanka intensified, while the conflict that existed in Aceh ended within eight months after the event. Le Billion and Waizenegger (2007) examined differences between these regions based on the military, the socio-political and the socio-economic dimensions. For example, Aceh had their first democratic presidential election three months prior to the disaster, which resulted in a new leadership who was willing to end the conflict. Sri Lanka, on the other hand, was an older democracy and was in the middle of an ongoing peace process (Billon and Waizenegger, 2007). The strength of an earthquake affects the likelihood of conflict as well, as Ahlerup (2009) explains. Moderate earthquakes are likely to increase the risk of civil wars, while stronger, less frequent earthquakes are likely to decrease this risk and to end existing civil wars. This is especially the case in poor areas and in regions where the epicentre is located in less densely populated areas (Ahlerup, 2009). Besides the strength of an earthquake, basic social conditions, such as income and infant mortality, also determine the effect of earthquakes on existing conflicts and the likelihood of new conflicts, as Ahlerup concludes (2009).

Furthermore, the effect earthquakes on conflict depends on the type of conflict as well, as intrastate conflict and interstate conflict are affected differently by natural disasters, as Nelson (2010) explains. Intrastate conflict is likely to increase after an event, but interstate conflict is not. Nelson (2010) examines natural disaster data over the period 1950-2006 and finds no case of an interstate conflict

that occurred as a result of a natural disaster. Intrastate conflict after an event only occurred as a result of an event when a history of internal conflict already existed in the countries where the event took place. This means that natural disasters can have an aggravating effect when the state already is unstable due to earlier conflict, but natural disasters do not cause it (Nelson, 2010). Additionally, aid can help to mitigate the effect of natural disasters, but it can also be used to finance conflicts. A report from the UN explains that the most important reason for the hunger in South-Sudan is the decisions of the South-Sudanese government. The government spend their income mainly on weapons instead of food for the population, while national conflict is the main cause for this hunger (NOS, 2017). These examples show the importance of institutional quality in relation to the impact of earthquakes and conflict.

4.3 Government effectiveness

The indicator 'government effectiveness' refers to the quality of public services, the civil service and the level of their independence from political pressures. It also refers to the quality of formulation and implementation of policies and to the government's credibility of their commitment to these policies (Kaufmann, et al., 2011).

Government effectiveness influences the way governments react to natural disasters. The effect of natural disasters can be minimized by implementing measures, such as improving the construction of buildings and providing medical care and food distribution, which is often the responsibility of the government (Strömberg, 2007). As a result, countries that are ruled by a more efficient and accountable government are likely to experience a less severe effect of natural disasters. As these natural disaster-related measures are costly, high income countries experience less severe consequences from natural disasters (Strömberg, 2007). Governments in democratic countries are likely to be more effective, as they depend on the support of the citizens during elections (Flores and Smith, 2013). These elections motivate governments to respond quickly and efficiently after an event, as Besley and Burgess (2002) explain. They benefit from being accountable, as citizens are able to show their satisfaction or dissatisfaction during elections. These arguments are explained in more detail in chapter 4.4.1.

4.4 Regulatory quality

This indicator represents how able governments are to formulate and implement sound policies and regulations in order to stimulate private sector development (Kaufmann, et al., 2011).

In order to rule a country effectively, a government needs to be able to formulate and implement regulations efficiently. After the occurrence of a natural disaster, the response time of the government can help to limit the negative consequences and to quicken the recovery process, and governments can adapt their policy in order to influence this process. Noy (2009) and Noy and Nualsri (2011) show how these policy changes differ between governments in developed and developing countries. Governments in developed countries tend to follow a countercyclical policy after an event, which means that they increase spending and cut taxes (Noy and Nualsri, 2011). Investing in the reconstruction process limits the negative impact of an event. On the other hand, governments in developing countries tend to follow a procyclical fiscal policy, where they decrease their spending and increase revenues (Noy and Nualsri, 2011). Developed countries experience a less negative economic effect of natural disasters of similar magnitude (Toya and Skidmore, 2007; Noy, 2009; Felbermayr and Gröschl, 2014) as well as in number of deaths (Kahn, 2005; Toya and Skidmore,

2007). Therefore it would seem beneficial for developing countries to follow a countercyclical policy instead of a procyclical fiscal policy. However, it is likely that they lack financial means to increase spending and cut taxes.

In addition to the opportunity for citizens to express their satisfaction or dissatisfaction through voting during elections, they can also show this by means of protests and riots. In democratic countries, the occurrence of natural disasters does not influence the number of protests, but the death toll caused by natural disasters does (Flores and Smith (2013). Democratic governments usually consist of large coalitions and benefit from pursuing a public goods-oriented policy, as Flores and Smith (2013) explain. In order to keep the support of the citizens, the government cannot appear to be incompetent. However, small coalitions only need the support of a smaller group. Flores and Smith (2013) also show that the number of protests in countries that are governed by small coalitions in nondemocratic countries, does not depend on the number of disaster-related deaths, but on the ability of citizens to coordinate and to organize. For example, citizens that had to leave their homes because of an event and are united in shelthers are more easily targeted, compared to when they would be living scattered across the country (Flores and Smith, 2013). Therefore, governments can influence the effect of earthquakes by means of the type of policy they follow and this decision is influenced by a country's level of development and the level of democracy.

4.5 Rule of law

The indicator 'rule of law' refers to the confidence citizens have in the rules and to the extent they abide them. This especially includes the quality of contract enforcement, property rights, the police, the courts ant the possibility of crime and violence (Kaufmann, et al., 2011).

People are more likely to abide by the rules when the benefits of abiding by the rules are larger than the benefits of not abiding. As previously discussed in chapter three, people are less likely to abide when they feel that they do not have equal chances as others (Anbarci, et al., 2005). A higher level of inequality results in more social conflict, which increases a country's crime and violence rate and negatively affects the economic performance. As a result of this increase in the crime and violence rate, citizens feel less protected, which will decrease the incentive to abide by the rules even further (Anbarci, et al., 2005). The time and energy that citizens put into crime could have been used for more productive purposes that benefit economic growth (Barro, 2000). As a result, countries with a higher crime and violence rate are likely to have a lower per capita income and experience a higher impact of earthquakes, as high income countries experience a less negative effect of earthquakes on economic growth.

Enforcement of property rights stimulates certainty and lowers transaction costs, which has a positive effect on economic growth (Raschky, 2008). Additionally to this positive effect, it will benefit natural hazard management by influencing the efficient allocation of resources that are needed for natural hazard management (Raschky, 2008). A stable government is associated with a better investment climate that has better protection of property rights and is able to issue and enforce better preventive policies such as enforcement of building codes. Raschky (2008) concludes that better protection of property decreases both the death toll and the overall economic losses from natural disasters. Investor protection and creditors' rights are also a part of property right protection. Furthermore, Acemoglu, et al. (2003) explain that ineffective property right protection is an indicator for the existence of weak institutions and also influences investment behaviour of agents. The Solow

model for long-term economic growth shows that investment stimulates capital accumulation, which is a main driver of economic growth. After a part of the capital stock is destroyed by an earthquake, thereby altering the capital-labour ratio, investment helps to restore this ratio (Klomp and Valckx, 2014). Investment is discouraged when property rights are threatened, which reduces productivity and thereby economic growth (Barro, 2000).

The protection of property rights is related to financial development as well, as it has a positive effect on resource allocation among firms, which stimulates economic growth (Levine, 2005). Furthermore, countries that legally protect the rights of creditors and enforce these rights have better developed banks (Levine, 1998). A reason for this could be that this enforcement leads to a decrease in both uncertainty and delays in returning loans, increasing the confidence that banks have in the full repayment of loans, as Levine (1998) explains. Yamamura (2013) shows how legal protection of investors is likely to be related to investment and has an important effect on recovery after a shock, such as an earthquake. Investors in French-civil-law countries have the weakest legal protection and experience no effect of natural disasters on capital accumulation and technological progress. Non-French-civil-law countries experience a positive effect of natural disasters on capital accumulation and technological progress. This shows how property rights protection is related to investment and economic growth, which can help to limit the impact of an earthquake and to stimulate citizens to abide by the rules.

4.6 Control of corruption

The last indicator, 'control of corruption' represents the degree to which public power is used for private gain. This includes forms of petty and grand corruption and the "capturing" of the state by elites and private interests (Kaufmann, et al., 2011).

The existence of distortionary policies and the absence of political constraints will enable parties to take over the power and engage in corruption (Acemoglu, et al., 2003). As a result political instability will increase and this induces economic instability. Corruption decreases investment levels and makes countries less attractive for foreign direct investment, thereby limiting economic growth (Escaleras et al., 2007). Corruption is a serious problem in certain countries, but it is difficult to acquire accurate data on corruption as corruption is hard to measure and corrupt countries are not likely to be truthful about it. Corruption has a substantial effect on earthquake-related damage, as corruption often affects the quality of buildings (Escaleras, et al., 2007). A large part of the number of earthquake-related deaths is caused by collapsing buildings, and urban areas, which are more densely populated and have more multi-storey buildings, experience a higher death toll when these areas are affected by an earthquake, as Escaleras, et al. (2007) explain. The cause is not always the absence of regulations but the lack of enforcement of existing regulations. Escaleras, et al. (2007) show how corruption in the public sector has a positive relation with the number of earthquake-related fatalities. In some countries, contractors pay bribes to the government in order to reduce construction costs. As a result, buildings are more vulnerable to earthquakes, which increases damage and the number deaths when one occurs (Escaleras, et al., 2007). The existence of building codes is not enough and this is supported by the example of the 1999 earthquake in the Turkish region Marmara, which had a death toll of 17,118. Seismical building standards existed in Marmara at the time of the event, but were often ignored in order to accommodate the rapidly growing population by being able to build faster (Escaleras, et al., 2007). The lack of inspection during the construction process led to this high number of deaths. In order to exterminate corruption, extreme

inspection is needed during each of the various phases that exist in the construction process. This is a reason why corruption is hard to eliminate, leading to severe and lethal consequences during earthquakes (Escaleras, et al., 2007). Additionally, the impact of corruption is not known until earthquakes occur and buildings collapse, resulting in a high death toll (Kellenberg and Mobarak, 2011). This increases the difficulty of fighting corruption. Although the death toll is usually higher in urban areas, they do not always have a higher number of earthquake-related deaths, as Anbarci, et al. (2005) explain. This becomes apparent in the example of the 2002 earthquake in Iran, which killed 261 people. Iran's building codes were similar to those in the US, but those were only enforced in large cities, resulting in a higher death toll in smaller villages, compared to urban areas (Anbarci, et al., 2005). The examples of Marmara and Iran show how corruption enhances the negative effect of earthquakes, is hard to eliminate and how fighting corruption can limit their impact.

Barone and Mocetti (2014) explain how proper use of public resources is an important part of the recovery process. Economic growth can be stimulated by using these public resources for improving infrastructure, among other things, but this will not happen when these resources are used for favouritism or for rent-seeking behaviour (Barone and Mocetti, 2014). Corrupt countries are likely not to use an aid inflow for economically productive activities, which has a negative effect on economic growth and decreases the quality of institutions further, as Barone and Mocetti (2014) explain.

In summary, institutional quality has a substantial effect on the impact of earthquakes, which is shown by means of discussing six dimensions that represent the WGIs. The next chapter explains the methodology of this research.

5 Materials and methods

The aim of this research is to determine how earthquakes affect annual change in real GDP per capita in the short and the long run. Therefore a regression analysis is performed in Stata, using a panel data set that consists of data that are taken from the World Bank (2015; 2016b) and the National Oceanic and Atmospheric Administration (NOAA, 2016) and covers 196 countries. The data set covers the period 1996-2014 and this time frame is chosen because of availability of the Worldwide Governance Indicators (WGIs) data that are used as an indicator for institutional quality. The units of observation are countries. The data set includes missing observations and is therefore unbalanced. The dependent variable is the log difference of real GDP per capita and the independent variables are the lag (the observation of the year prior) of real GDP per capita, the number of earthquakes per square kilometre and the lag of the variable that consists of the WGIs. Additionally, a set of control variables is added and this set is specified later in this section. An interaction term that is composed out of the magnitude and the WGIs is included as well. A list that contains an over view of all the used variables can be found in appendix A. The next section provides the empirical analysis of this research and starts with a short description of the variables.

5.1 Variables

5.1.1 Economic growth

The variable of main interest is the dependent variable economic growth, which is represented by a country's annual log difference of real GDP per capita (constant 2005 US$). The data are taken from

the World Bank (2016b). As the data are in constant US$, the inflation is taken into account, which means that changes in GDP per capita are adjusted to changes in a country's price level. As countries have different price levels, takin inflation into account makes it possible to compare GPD per capita across countries.

5.1.2 Lag of income

The dataset contains also the lag of income, measured as real GDP per capita. Income in successive years is strongly related, as it is a function of capital-labour ratio and the technology level. Under normal circumstances, these production capacities do not change dramatically annually, which means that real GDP per capita does not change dramatically an annual basis either. Therefore a variable for the lag of real GDP per capita is added.

5.1.3 Magnitude variable

This research examines how earthquakes affect economic growth and the occurrence of earthquakes is represented by a magnitude variable that contains an earthquake's score on the Richter scale. This variable is the main independent variable. The risk management model of Hochrainer (2009), which is explained in chapter two, shows that earthquakes as hazard are exogenous, as their occurrence is not affected by other relevant variables. Therefore earthquakes are an appropriate independent variable as the other variables in this model are not influenced by the earthquake variable and as a result, this variable only represent the effect of earthquakes on economic growth. Additionally, the magnitude variable is the only independent variable that is not added in lag, as earthquakes start to affect economic growth immediately and the aim of this research is to examine this effect of earthquakes. The earthquake-data are taken from NOAA's Significant Earthquake Database (2016) and show a country's annual number of earthquakes and their score on the Richter scale. In order to be included in this database, an earthquake has to meet at least one of the following five criteria: Damage of approximately $1 million or more, 10 or more deaths, a magnitude of 7.5 or more on the Richter scale, Modified Mercalli Intensity X or greater, or the earthquake must have generated a tsunami (NOAA, 2016). As a result, this data base does not include every earthquake that have occurred, for example earthquakes in remote areas with a magnitude below 7.5 are excluded. These earthquakes will hardly have any effect on economic growth and including them will weaken the relation between earthquakes and economic growth and thereby affecting the results.

The unit of measurement for earthquakes is the Richter scale and this scale ranges from 0.0-10.0. The earthquakes are categorized into seven groups based on their score, using the following classification: 2.1-4.0, 4.1-5.0, 5.1-6.0, 6.1-7.0, 7.1, 8.0, 8.1, 9.0 and 9.1-10. Earthquakes with a score below 2.0 are not present in the dataset. Table 3 in appendix C shows the distribution of the number of observations over these categories. As the chance of the occurrence of an earthquake is higher in large countries as they have a larger surface, the magnitude variable is divided by the size of land, taken in square kilometre, taken from the World Bank (2016b). The magnitude data are added to the dataset in three ways. The first one is as a variable that contains the total number of earthquakes. The second way is as seven variables, according to the classification described previously. The final way is as two variables, where the moderate earthquakes are separated from the severe ones. One variable contains the categories 2.1-6.0 and the other variable contains the categories 6.1-10.0. The first method does not take different strengths into account. However, Felbermayr and Gröschl (2014) explain that disasters in the top percentile of the disaster index distribution cause a larger reduction in economic growth, which shows that the strength of an earthquake matters. Furthermore, more

severe disasters, such as earthquakes, attract more aid and this also affects the impact of earthquakes on economic growth (Strömberg, 2007). Earthquakes can only have a positive effect on economic growth in the long run, when a country receives aid (Ahlerup, 2013). The second way takes the strength of earthquakes into account by categorizing the number of earthquakes in seven groups, resulting in seven variables that differ in their number of observations (table 3). As a consequence, category 9.1-10.0 contains just one observation, which leads to outcomes that belong to this specific event and makes these outcomes not representative. The third method takes different strengths into account, while increasing the number of observations per variable by separating the moderate earthquakes from the severe ones. The median of 6.0 is chosen to separate moderate earthquakes from severe ones as this results in a more equal number of observations per group, which increases the validity. The group with moderate earthquakes has 327 events and the group with the severe earthquakes has 292 events (table 3).

5.1.4 Institutional quality

A factor that affects economic growth and the impact of an earthquake on economic growth is a country's institutional quality and this effect is explained more elaborately in chapter four. Countries with better institutions experience less disaster-related deaths (Kahn, 2005). These countries are also more capable of protecting their economy against the initial shock of an event and to prevent additional spillovers into the macro economy (Noy, 2009). Furthermore, they experience faster recovery, which limits the adverse effect on per capita income (Felbermayr and Gröschl, 2014). They also experience a positive effect of disaster-related aid on GDP (Barone and Mocetti, 2014). The WGIs are used as an indicator for institutional quality. This variable is composed of the following six dimensions: 'control of corruption', 'government effectiveness', 'political stability', 'regulatory quality', 'rule of law' and 'voice accountability'; these dimensions are discussed in more detail in chapter four. The data are taken from the World Bank (2015b) and cover the period 1996-2014. The WGIs are composed by means of several hundred variables that are related to government perceptions and are taken from 31 sources. Each country received a score for these six dimension that ranges between -2.5-2.5, where -2.5 is weak and 2.5 is strong (Kaufmann, et al., 2011). These six dimension are combined into one variable using factor analysis that resulted in one variable for institutional quality. This is more convenient as the aim of this research is to analyse the effect of institutional quality as a whole. Using factor analysis, each dimension is given a value based on how much of the overall variance they explain, which can result in one or more factors that explain most of the variance based on their correlation. In the case of the WGIs, it resulted in one factor. This method uses logarithms (logs) and therefore the results are interpreted as elasticities, which means that one percentage change in the institutional quality variable leads to a percentage change in the economic growth variable.

5.1.5 Control variables

The effect of earthquakes on real GDP per capita is influenced by several additional factors, which is explained in more detail in chapter three. A list of control variables is added to the model in order to control for effects of these factors and this list is based on a list used by Loayza, et al. (2012). It consists of the log of domestic credit to the private sector, annual population growth, the log change of the GDP deflator, the log of aid, investment, government consumption and trade. The data for these variables are taken from the World Bank (2016b).

The log of domestic credit to the private sector taken as percentage of GDP indicates the level of financial development of a country. Chapter three explained that financial development stimulates economic growth through reductions in the information, enforcement and transaction costs (Levine, 2005). Additionally, countries with a higher level of financial development have a more efficient financial system that does not merely allocate credit from the government to state-owned enterprises, but also allocates credit to the private sector (King and Levine, 1993). A better allocation of credit reduces information asymmetries. These asymmetries lead to credit constraints that especially affect the poor that do not have access to financial means and capital is not able to reach its optimal allocation, as Levine (2005) explains. Furthermore, underdeveloped financial systems hinder investment, as they hinder the availability of funds for research and development for firms (Levine, 2005). This shows why domestic credit to the private sector has added value to the model and is likely to have a positive effect on economic growth.

Despite economic growth being represented by GDP per capita, the number of people in a country has an effect on economic growth as well, especially because this number is always changing. Most economist find a negative effect of population growth on economic growth, which is a result of diminishing marginal productivity when using natural resources, such as land (Becker, et al., 1999). Furthermore, the highest population growth rate can be found in poor countries, while high income countries have a low population growth rate, as Galor and Weil (2000) explain. Although real GDP per capita is a function of capital-labour ratio and the technology level, economic growth is driven by changes in the labour force and not by a growing population that cause an increase in demand. Therefore, population growth is expected to have a negative relation with economic growth and is this variable added to the model, as the annual log difference of population total.

The log change of the GDP deflator as annual percentage represents inflation and is added as an indicator for the quality of macroeconomic management. Unstable policies are associated with crises, which negatively affect economic growth (Acemoglu, et al., 2003). A stable economy has a low and steady inflation rate, while a high inflation rate could indicate the existence of underlying institutional problems. Acemoglu, et al. (2003) explain that these problems cause more uncertainty, and have a negative effect on investment, technological change, relative prices and thereby on economic growth. Pursuing a high inflation rate will lead to lower levels of investment and technological change and to distortions of relative prices, which has a negative effect on economic growth (Acemoglu, et al., 2003). Therefore, this variable is likely to have a negative relation with economic growth.

The log of aid is added as the net official development assistance (ODA) received per capita as a share of GDP. It consists of financial flows that can be used for stimulating economic development. Chapter three explained that aid only has a positive effect on economic growth in countries with good institutions, as these countries are more likely to use aid for economically productive activities (Barone and Mocetti, 2014). In addition, Ahlerup (2013) finds that countries only experience a positive effect of natural disasters on economic growth when they receive aid. Therefore aid is likely to have a positive effect on economic growth.

The gross capital formation as percentage of GDP is used as indicator for investment and is likely to have a positive effect on economic growth. The Solow growth model explains the link between investment and long-term economic growth and shows how investment leads to capital

accumulation, which is a main driver of long-term economic growth. Investment is both time and capital consuming, but it increases efficiency, which stimulates economic growth. Therefore, this variable is added to the model as well.

Government consumption is represented by the general government final consumption expenditure which is the sum of government current expenditures for purchases of goods and services (in percentage of GDP). Government consumption has a negative effect on per capita growth, due to the its negative effect on savings, which is caused by distorting effects, such as taxations (Barro, 1991). Another reason could be that a larger ratio of government consumption to GDP results in a lower steady state level of output per effective worker, thereby decreasing economic growth (Barro and Lee, 1994). Government consumption also includes expenditures that do not directly aim at increasing productivity. Therefore government consumption is likely to have a negative effect on economic growth.

The final control variable is the amount of trade, measured as the sum of exports and imports of goods and services as percentage of GDP. Trade liberalisation is positively associated with increasing economic growth, as it is often implemented during economic crises and is often used to escape decreasing growth rates in developing countries (Krueger, 1998). Following an outer-oriented trade regime stimulates the industry, as producers find their best possibilities on the world market and policy makers are able to stimulate trade by improving infrastructure, among other things, as Krueger (1998) explains. Furthermore, chapter three explained that trade affects economic growth through multiple channels, including technology transfers, economies of scale and comparative advantages (Yanikkaya, 2003). Therefore it is likely that trade has a positive relation with economic growth.

These variables should be normally distributed as it could otherwise influence the standard errors, the confidence interval and thereby the outcome of the regressions. Therefore histograms are created to analyse the distribution of these variables and they can be found in appendix B. When a variable is normally distributed, its histogram will have a bell shape. Appendix B shows that the assumption of normality cannot be made for domestic credit to the private sector, inflation and aid. To solve this problem, these variables are transformed to log variables. However, the inflation variable includes negative values and it is not possible to take logs of negative values. Therefore the log is taken of (1 + inflation). Furthermore, high income countries do not receive aid and have no data for this variable. These observations are treated as missing, which decreases the number of observations and affects the results. In order to prevent this, the values of these observations are set to zero. The new histograms, which are also in appendix B, show that the assumption of normality can be made for these transformed variables.

5.1.6 Interaction term

The effect of earthquakes on real GDP per capita depends on institutional quality. Therefore, it is likely that the institutional quality variable interacts with the magnitude variable. If this is the case, the outcomes of the regressions will be affected and the magnitude variables will not merely show the effect of earthquakes on economic growth, but the effect of earthquakes on economic growth conditional on institutional quality. To test if this is the case in this model, interaction terms are created. They consist of the magnitude variables multiplied with the lag of the WGI variable, and they show if and how much of the effect of earthquakes depends on institutional quality.

5.2 Model

These variables are used to estimate the following regression model:

$$Ln(Y_{it}) - Ln(Y_{it-1}) = \alpha + \beta Ln(Y_{it-1}) + \gamma \Sigma mag\_ar_{it-j} + \delta Inst*qual_{it-j} + \theta control_{it-j} + \Sigma sMag*ar*Inst*qual_{it-j} + \eta_i + \varepsilon_{it}$$

- $Ln(Y_{it}) - Ln(Y_{it-1})$ represents economic growth, as the annual change of real GDP per capita of country i in year t
- $Ln(Y_{it-1})$ is the lagged log of real GDP per capita
- $\Sigma\gamma\ mag\_ar_{it-j}$ is the earthquake magnitude
- where j represents the number of lags
- $Inst\_qual_{it-j}$ is the lagged factor score of the WGIs
- $control_{it-j}$ represents the lagged control variables
- $Mag\_ar\_Inst\_qual_{it-j}$ is the interaction term
- η_i represents the country fixed effects model
- ε_{it} is the error term.

A Hausman-test is performed to determine if a Fixed Effects (FE) model or a Random Effects (RE) model should be used in order to perform the regression analysis, as the dataset consists of panel data. Diagnostic tests that test for the existence of heteroscedasticity, autocorrelation and correlation between the control variables are performed as well. The next chapter shows the results of the regression analysis, of which the tables can be found in appendix C.

6 Results and discussion

6.1 Testing for the correct model

The Hausman specification test, which shows if an FE or an RE model should be used, is performed for the regression model excluding the interaction terms and the output of this test can be found in table 4[1]. The chi-square of 131.80 and a p-value of 0.000 show that the FE model is more appropriate than the RE model. The FE model focusses on differences within a country over time, as it assumes country-specific intercepts and controls for the time-invariant differences between countries. The first column of table 5 shows the output of the regression using the FE model. All variables are significant, excepting the earthquake magnitude and inflation. Diagnostic tests are performed in order to test if the model is correctly specified. The second column of table 5 shows the results of the fixed effects regression using robust standard errors, which excludes heteroscedasticity. The estimates of the coefficient are unaffected, but the standard errors are slightly higher, excepting the standard errors of the magnitude variable and the government consumption variable. Additionally, a correlation matrix shows if strong correlation between the control variables is a problem in this model, which is not the case as all values are below 0.8 (table 6). The Woolridge test for autocorrelation is performed as well (table 7). The F-value of 51.33 and the corresponding p-value of 0.000 show that the null hypothesis of no first-order autocorrelation is rejected, which means that autocorrelation is present in this model. Using robust standard errors does not control for both

[1] The first regressions where done using pooled ordinary least squares (OLS). However, pooled OLS is not appropriate, as it does not recognizes the panel structure of this data set. As a result, it does not make a distinction between different countries over time, leading to incorrect error terms in this regression.

heteroscedasticity and autocorrelation, therefore an alternative is needed. A possible alternative that solves both issues is performing the regression with Driscoll-Kraay standard errors, as these are both heteroscedasticity and autocorrelation consistent and can be produced for pooled OLS estimations and FE regressions. Additionally, an unique characteristic of this model is that it is robust to cross-sectional dependence (Hoechle, 2007). This is important as the units of observation are countries and as the international exchanges of goods and services connect countries all over the world to the global economy, events in one country can affect the economy of other countries. Other advantages of this regression model are that it can be used for both balanced and unbalanced panels, can handle missing values and still functions when the time dimension (T) is smaller than the number of panels (N) Hoechle, 2007). This is the case in the used dataset covers 217 countries (N=217) over 19 years (T=19).

6.2 Short run effect on economic growth

The output of the fixed effect regressions with the Driscoll-Kraay standard errors is shown in table 8 and shows the short run effects of earthquakes on economic growth. The second column shows this regression, including the interaction term. Table 9 shows the results of three regressions, where each regression uses one of the three forms of the earthquake-variable as described in section 5.1.2. The first column shows the output of the model using the overall variable, the second column shows the model including seven magnitude categories and the third column shows the model using a variable for moderate earthquakes and one for severe earthquakes. The corresponding interaction terms are included tot these regressions as well. The regressions in tables 8 and 9 show that the effect of institutional quality is positive with a CI of 99% (table 8). An increase of one percent in institutional quality increases economic growth by 1.14 percentage point. This positive effect is in line with the hypothesis as countries with better institutions are better able to endure the shock of an earthquake and are better able to guide the recovery process, as Barone and Mocetti (2014) explain.

Table 9 shows the results of the fixed effect regressions with the Driscoll-Kraay standard errors using the three forms of the earthquake-variable. The first column shows the regression using the overall earthquake magnitude variable and this variable is significant within the 99% CI, showing that one additional earthquake causes economic growth to increase by 0.1 percentage point[2]. The effect of earthquakes on economic growth is not influenced by a country's institutional quality, as the interaction term does not significantly differ from zero. This is not in line with the hypothesis, but could be a result of the magnitude variable not making a distinction between earthquakes of different magnitudes. The second column of table 9 shows that two of the seven individual categories are significantly positive, which are the categories 5.1-6.0 and 6.1-7.1. Both categories are significant with a CI of 95%. For an additional earthquake with a score between 5.1-6.0 on the Richter scale, economic growth increases by 0.24 percentage point[3]. The interaction term is significant and shows that an additional earthquake with a score between 5.1-6.0 that occurs in a country with median institutional quality, increases economic growth further by 0.19 percentage point[4]. As a result, the total effect of earthquakes in this category is an increase of 0.43 percentage point in countries with median institutions. This shows how countries with better institutions experience a less negative effect of earthquakes on economic growth. An additional earthquake with a score

[2] (Coefficient(earthquakes)*100) / mean(land area): (0.190*100)/190.0456 = 0.100
[3] (Coefficient(earthquakes)*100) / mean(land area): (0.451*100)/190.0456 = 0.2373
[4] (Coefficient(earthquakes) + Coefficient(interaction)*median(institutional quality)) / mean(land area) * 100 = (0.451 + 0.217*-.4296) / 190.0456 * 100 = 0.1883

between 6.1-7.0 on the Richter scale increases economic growth by 0.12 percentage point[5]. The interaction term, which is also significant, shows that in a country with median institutional quality, an additional earthquake with a magnitude between 6.1-7.0 increases economic growth further by 0.09 percentage point[6]. The total effect in countries with median institutions is 0.21 percentage point. An additional earthquake with a score between 4.1-5.0 on the Richter scale does not have an effect economic growth, but when one occurs in a country with median institutional quality, it causes economic growth to increase by 0.08 percentage point[7]. This shows the positive effect of institutions on the economic impact of earthquakes with a score between 4.1-5.0 on the Richter scale. The third column shows that moderate earthquakes, which are defined as earthquakes with a score between 2.1-6.0 on the Richter scale, have a significant effect on economic growth with a CI of 90%. An additional moderate earthquake increases economic growth by 0.15 percentage point[8]. Institutions have no additional influence on this effect, as the interaction term is insignificant. Severe earthquakes that score between 6.1-10.0 on the Richter scale, do not have a significant effect on economic growth. However, when an additional severe earthquake occurs in a country with median institutional quality, economic growth decreases by 0.05 percentage point with a 90% CI[9].

These results are not in line with the expectations that earthquakes reduce economic growth in the short run due to destruction of production capacities of the economy (Klomp and Valckx, 2014). However, McDermott, et al. (2014) explain that the stimulating effect of reconstruction activities that start after an event, dominates the negative effects caused by the destruction of production capacities due to moderate events. This explains the less negative effect of moderate earthquakes in the short run. Furthermore, it is possible that this is a cause of the insignificant value of the overall magnitude variable, as this variable includes both moderate and severe earthquakes and these have contradicting effects on economic growth, as severe earthquakes usually cause a decline in economic growth in the short run (Ahlerup, 2013). It is possible that neither one dominates in the overall earthquake variable, resulting in an insignificant value. Moreover, institutional quality does not influence the economic effect of earthquakes as the interaction term is insignificant, which is not in line with other literature that shows a relation between earthquake-related damage and institutions (for example Escaleras, et al., 2007; Kellenberg and Mobarak, 2008; McDermott, et al., 2014). This could be caused by the time frame of the studies as these studies discuss the long-run effects, while table 9 shows the short-run effects. It could also be an effect of this regression using one overall earthquake variable that does not distinguish between different magnitudes, while severe earthquakes have a greater negative effect on GDP than moderate ones (Felbermayr and Gröschl, 2014). Therefore it is likely that taking different strengths of earthquakes into account will show significant regression outcomes.

The importance of taken different strengths into account can be seen in the second column of table 9 that shows the regression that uses seven variables to represent seven earthquake categories. Earthquakes that have a score between 5.1-6.0 and 6.1-7.0 on the scale of Richter have a significant positive economic effect, which shows the relevance of making a distinction between earthquakes of

[5] (Coefficient(earthquakes)*100) / mean (land area): (0.232*100) / 190.0456 = 0.1221
[6] (Coefficient(earthquakes) + Coefficient(interaction)*median(institutional quality)) / mean(land area) * 100 = (0.232 + 0.145*-.4296) / 190.0456 * 100 = 0.0893
[7] Coefficient(interaction) * median(institutional quality) = -0.188 * -.4296 = 0.0808
[8] (Coefficient(earthquakes)*100) / mean(land area): (0.287*100) / 190.0456 = 0.151
[9] Coefficient(interaction) * median(institutional quality) = 0.107 * -.4296 = -0.046

different magnitudes. It also confirms the hypothesis of moderate earthquakes having a less negative effect on economic growth in the sort run and it shows that countries with better institutions experience an less negative effect as well as their interaction terms are significant as well. Earthquakes with a score between 4.1-5.0 on the Richter scale only have a significant less negative effect in countries with median institutions and this supports Felbermayr and Gröschl (2014), who explain that earthquakes can only cause a temporary boom in economic growth when a country has good institutions. A reason why the variable for this category is not significant could be that earthquakes in this category are not severe enough to have a significant effect. Reason why the categories 2.1-4.0, 7.1-8.0,8.1-9.0 and 9.1-10.0 are insignificant could be because of the low number of observations in these categories, as these categories each contain less than 100 observations, while categories 4.1-5.0, 5.1-6.0 and 6.1-7.0 all contain over a 100 observations. Therefore, it increases the quality of the results to use a moderate and a severe earthquake variable, which increases the number of observations per variable, while taking different strengths into account, as is explained in chapter 5.1.3.

The third column of table 9 shows the regression using a variable for moderate and a variable for severe earthquakes and shows that moderate earthquakes increase economic growth by a small percentage and that this effect does not depend on institutional quality. This supports the finding by McDermott, et al. (2014) of the dominating and stimulating effect of reconstruction activities over the negative effects caused by the destruction of production capacities as a result of moderate events. This is also in line with literature that explains how moderate earthquakes cause a less negative effect on economic growth, although this literature examines the long run effects. It is possible that this also accounts for the short run, as the short run effect influences the long run effect. Severe earthquakes do not affect economic growth significantly, but when they occur, countries with median institutions experience a worse effect on economic growth. Severe earthquakes cause greater damage to production capacities than moderate earthquakes and they disrupt product processes immediately, which affects economic growth instantly, therefore this result is not as expected. A reason for this effect could be bureaucratic rules, which cause public spending to be less effective (Barone and Mocetti, 2014). When this diminishes the effect of public spending related to reconstruction activities, the will increase the negative economic of earthquakes. Bureaucracy is also a problem in democratic countries, where it delays the reconstruction process, which explains why countries with better institutions can experience a more negative effect of earthquakes on economic growth (Simonsen, 2012).

6.3 Long run effect on economic growth

Earthquakes have a long-term effect on economic growth and in order to examine this long-term effect, five lags of the overall magnitude variable are added to the regression, of which the outcome can be found in table 10. Only one of these five variables is significantly different from zero, which is the fourth lag. This shows that an additional earthquake increases economic growth by 0.05 percentage point, four years after the first earthquake[10]. This could be the case because earthquakes destroy capital, which increases the marginal return to capital, stimulating economic growth in the long run (Loayza, et al., 2012). Destroyed capital also provides opportunity to replace it with capital with better technology (Rahman, et al. 2013; Klomp and Valckx, 2014). It takes time before the positive effect on economic growth is noticeable and this regression suggests that it takes four years

[10] (Coefficient(earthquakes)*100) / mean (land area): (0.0926*100) / 190.04560 = 0.0487

before the benefits of the recovery process compensate for the losses. Kellenberg and Mobarak (2011) explain that the implementation of new technology requires extra time to train workers and to adapt the new technology into the production process. This slows the production process down in the short run, which results in an initial productivity loss, as time is costly. According to this regression, it takes four years before the benefits related to the implementation of new technology outweigh their costs. However, the used overall magnitude variable does not take into account that moderate earthquakes affect growth differently than severe earthquakes and no distinction is made between developed and developing countries, or between countries with different levels of openness or different levels of financial development. Additionally, this regression shows the effect of earthquakes on economic growth in the first five years that follow an earthquake, while Hochrainer (2009) considers the long run to be beyond five years. As a result, this regression containing five lags does not include enough lags of the earthquake variable to draw valid conclusions considering the long-term effect of earthquakes on economic growth. Future research is needed to examine how earthquakes affect the long run economic growth in more detail and to examine how institutional quality influences this effect. Due to time limitations, this was not possible for this research.

6.4 Short run effect on economic growth using the splits

The effect of earthquakes on economic growth depends on several country-specific factors, as is explained in chapter three. The following section discusses three of these factors and how they influence the effect that earthquakes have on economic growth in relation to institutional quality. For each factor, the observations are separated into two groups on which the regression is performed in order to examine how the results differ among the groups. The factors that are examined are income category, level of openness and level of financial development and are explained in detail in chapter three[11]. The first split uses the income classification from the World Bank (2016a) to separate high income countries from low- and middle income countries. This income classification divides countries over income groups based on their gross national income (GNI) per capita. GNI differs from GDP as it is based on a country's citizens' income, even if it is earned beyond borders, while GDP is based on everything that is produced within borders. The factor trade is defined as the sum of import and export as percentage of GDP. The second split uses trade to separate closed countries, defined as countries having an amount of trade that is below the median of 80.78, from open countries that have a median above 80.78. The third split uses the amount of domestic credit to the private sector as percentage of GDP as an indicator for financial development and defines countries with higher level of financial of development as countries that supply more credit to the private sector. This split compares financially undeveloped countries that have a median below 3.46 with financially developed countries. The median of a variable is defined as the value that belongs to the middle observation, when the data are sorted by this variable. This leads to a more even distribution of the observations when dividing them into two groups as this distribution is not influenced by extreme values. Tables 11, 12 and 13 show the number of observations per split. The low- and middle income group has 2468 observations and the high income group has 1252 observations. The group with closed countries has 1695 observations and the open group has 2025

[11] The split using the median of the Gini coefficient as separation gave the same results. High income countries showed similar results as countries with a low Gini coefficient. Therefore this split is left out. This shows that the groups of high income countries are similar to the group of countries with a Gini coefficient below median and thus high income countries have more income equality.

observations. The distribution among the final split is 1632 observations in the group including countries that are financially underdeveloped and 2088 in the group with financially developed countries. The mean effect of earthquakes on economic growth is calculated by dividing the coefficients of the magnitude variable by the mean land area. All the calculations are added as footnotes. Table 14 contains the output of these six regressions and table 15 shows the third column of table 8 separately, which is the model using two magnitude variables.

6.4.1 Short run effect based on income category

The first and second column in table 13 show the output of the regressions for middle-and low and for high income countries. The control variable for aid is omitted from the regression for the high income group, which is likely to be a result of high income countries not receiving aid. These countries were given the value of zero in order to prevent additional loss of observations, resulting in omission of this variable due to lack of variety.

The regressions shows that moderate earthquakes do not have a significant effect in low- and middle income countries and in high income countries. The interaction term is not significant for low- and middle income countries, but is significant for high income countries with a CI of 95%. This means that an additional moderate earthquake in a high income country with median institutional quality, increases economic growth by 0.53 percentage point[12]. This supports the findings of Toya and Skidmore (2007) and Felbermayr and Gröschl (2014), who show that high income countries experience a less negative effect of earthquakes on GDP per capita as they have high income countries have more resources to invest in safety measures. This also supports Kellenberg and Mobarak (2008), who explain that high income countries have better institutions that have a better response to natural disasters and are able to cope with natural disaster-related damage more efficiently (Kellenberg and Mobarak, 2008). They also have better quality of building codes and engineering structures, which leads to better buildings and structures that are better able to withstand an earthquake, resulting in less damage and lower death toll.

Severe earthquakes in low- and middle income countries do not have a significant effect on economic growth, which is not in line with the hypothesis of low- and middle income countries experiencing a more negative effect. This lack of significant results could be due to underreporting of the number of natural disasters. Disaster reporting is likely to be more complete in later years and in developed countries (Strömberg, 2007). When low- and middle income countries, which are usually developing countries, underreport the number of earthquakes, it is possible that the regression shows a less negative or insignificant relation between earthquakes and income per capita. Severe earthquakes have a significant effect in high income countries. An additional severe earthquake increases economic growth by 0.35 percentage point with a CI of 99%[13]. The effect of severe earthquakes in low- and middle income countries and in high income countries does not depend on institutional quality. It was expected that both moderate and severe earthquakes have a less negative effect in high income countries, but it was not expected that severe earthquakes have a less negative effect than moderate earthquakes. However, the earthquake classification is based on the Richter scale, while damage does not merely depends on the magnitude of an earthquake. The top five costliest natural disasters in history includes four earthquakes, of which two had a magnitude

[12] Coefficient(interaction) * median(institutional quality) = 0.212 * -.4296 = 0.5332
[13] (Coefficient(earthquakes)*100) / mean (land area, high income): (0.771*100) / 218.3287 = 0.3531

below seven on the Richter scale (Zhang, 2013). This illustrates how earthquakes that cause most damage are not necessarily earthquakes with the highest score on the Richter scale, as the damage depends on the quality of buildings and structures as well. As a result, countries with inadequately built buildings experience more damage from a similar earthquake than countries with adequately built building, as inadequate buildings are more likely to collapse. The result of high income countries experiencing a less negative economic effect is in line with the hypothesis and shows how the effect of earthquakes on real GDP per capita is endogenous. High income countries can afford to invest more in the quality of buildings and structures and have more financial means for the recovery phase, which limits the total damage caused by earthquakes. Furthermore, high income countries often are countries with better institutions that are willing to invest in these measures. They also have better means to start and guide the recovery process more efficiently. These factors limit the negative economic effect of earthquakes in high income countries and explain why high income countries experience a less negative effect of an earthquake with a certain score on the Richter scale than low- and middle income countries.

6.4.2 Short run effect based on level of openness

The third and fourth column of table 13 show how moderate and severe earthquakes affect closed and open countries differently. Moderate earthquakes do not have a significant effect on economic growth in both closed and open countries. The interaction terms are not significant in both groups either, showing that moderate earthquakes do not have a significant economic effect in countries with moderate institutions. This lack of significant results could be a result of the way open and closed countries are defined, as the most open country in the closed group and the least open country in the open group do not differ much, because the data are divided into two groups based on the median. It is possible that comparing, for example, the 10% least open with the 10% most open countries gives significant results. However, as the effect that earthquakes have on economic growth also depends on several other factors, it is possible that the amount of trade is not a dominant factor that influences how moderate earthquakes affect economic growth.

Severe earthquakes have a less negative effect in closed countries and this effect is significant with a CI of 95%. When an additional severe earthquake occurs in a closed country, economic growth increases by 0.17 percentage point[14]. Additionally, economic growth increases further by 0.13 percentage point, when an additional earthquake occurs in a country with median institutional quality and this effect is significant with a CI of 95%[15]. The total effect is an increase of 0.30 percentage point in countries with median institutions. This does not follow the hypothesis of earthquakes having a more negative effect on economic growth in closed countries. A reason why the results differ from the hypothesis could be that the regressions examine the short-term effect, while the effect on economic growth is likely to change over time. It is also possible that closed countries are more independent and are therefore better able to process the shock of an earthquake quicker than open countries, thereby experiencing a less negative effect of earthquakes on economic growth. It is possible that the amount of trade is not a dominant factor that determines the economic effect of an earthquake. A country with a low amount of trade that suffers from an earthquake, but has advanced technology and financial means to use for the recovery phase is likely

[14] (Coefficient(earthquakes)*100) / mean (land area, less trade): (0.318*100) / 187.0596 = 0.170
[15] (Coefficient(earthquakes) + Coefficient(interaction)*median(institutional quality)) / mean(land area less trade) * 100 = (0.318 + 0.179*-.4296) / 187.0596 * 100 = 0.1289

to experience a less negative effect from an earthquake, compared to a low income country that has less financial means, although this country could have a higher trade level. This explains why closed countries can experience less negative effects of earthquakes on economic growth than open countries.

Severe earthquakes also have a significant effect in open countries, but this effect is negative with a CI of 95%. For an additional severe earthquake in an open country, economic growth decreases by 0.24 percentage point[16]. The corresponding interaction term is not significant, which means that institutional quality does not influence this effect. This negative effect contradicts the hypothesis that technology transfer and inflow of aid cause the effect of earthquakes on economic growth to be less negative in open countries, as open countries benefit from better access to new technologies. However, the extra time that is required to train new workers and to adapt to the new technology leads to productivity loss in the short run and a negative effect on economic growth in the short run (Kellenberg and Mobarak, 2011). Another reason for this negative effect is that earthquakes disrupt the production process by breaking supply lines (NRC, 1992). When this affects the production of export goods, the result is a decline in export and an increase in import and this disrupts a country's balance of trade (Klomp and Valckx, 2014). The size of this effect depends on the magnitude of the contribution of trade to a country's economy. Moreover, Ahlerup (2013) finds that open countries are more likely to receive aid, but an inflow of aid that is too high can have a damaging effect on economic growth. This was the case in Sri Lanka, which received a high aid inflow after the 2004 Tsunami, which was meant to be used to provide fishing boats for the population in order to provide a means for income (WNL, 2017). However, this resulted in an abundance of competition and in overfishing and the problem was not solved.

The negative effect of severe earthquakes in open countries could also be a result of exaggeration of the damage and losses by the government. An example where this has happened is the Haiti earthquake in 2010 (Ahlerup, 2013; van den Berg, 2017). Van den Berg (2017) explains that the government wanted to attract more media attention, while journalists and NGOs were reluctant to accept the lower numbers of casualties, as journalists want to cover the biggest disaster while NGOs aim for money. Van den Berg (2017) believes a structural disaster fund could improve the effectiveness of aid (van den Berg, 2017). Countries with a high level of institutional quality are less likely to exaggerate the damage, which should show in an interaction term that is not significantly positive, but this interaction term is insignificant. However, the negative effect of severe earthquakes in open countries supports the finding that severe earthquakes usually have a negative effect on economic growth (Felbermayr and Gröschl, 2014).

6.4.3 Short run effect based on level of financial development

The fifth and sixth column of table 13 show the output of the regressions for countries that supply less and countries that supply more credit to the private sector. Moderate earthquakes do not have an effect in countries that supply less credit and this effect is not significant for countries with median institutions. Countries that supply more credit to the private sector experience a less negative effect of moderate earthquakes on economic growth and this effect is significant with a CI of 99%. An additional moderate earthquake increases economic growth by 0.17 percentage point[17].

[16] (Coefficient(earthquakes)*100) / mean (land area, more trade): (-0.467*100) / 192.5876 = -0.2425
[17] (Coefficient(earthquakes)*100) / mean (land area, more domestic credit): (0.332*100) / 201.6647 = 0.1646

This is in line with the hypothesis that unconstrained economies have better access to credit, which results in an increase in investment following an event that is sufficient to compensate for the losses (McDermott, et al., 2014). This shows how the economy of countries that supply more credit is more resistant to shocks. Institutional quality does not influence the effect of moderate earthquakes in countries that supply more credit, as the interaction term in not significant.

Severe earthquakes do not affect economic growth in countries that supply less or supply more credit to the private sector. However, the interaction term for countries that supply more credit is significant with a CI of 99%. An additional severe earthquake in a country that supplies more credit and has median institutional quality, decreases economic growth by 0.11 percentage point[18]. This is not in line with the hypothesis of countries that supply more credit experiencing a less negative economic effect of earthquakes, as the increase in investment caused by earthquakes is sufficient to cover for the losses in unconstrained countries (McDermott, et al., 2014). However, this concerns a long run effect and it is likely that severe earthquakes cause a negative short-term effect, even when a country has a developed financial system. This also accounts for the first two factors, as the effects of earthquakes in the short and long run can differ completely. This negative results is also likely to be a result of bureaucratic rules that delay the recovery process as bureaucracy is also common in countries with better institutions. It is also possible that severe earthquakes have a larger effect on financial systems, resulting in a negative effect on economic growth, independent on the quality of the financial system.

6.4.4 Summary

Table 1 Overview of the regressions using splits

	Moderate earthquakes		Severe earthquakes	
		Inst. qual		Inst. Qual
Low-middle income				
High income		+	+	
Less trade			+	+
More trade			-	
Less credit to the private sector				
More credit to the private sector	+			-

An overview of the result of the regressions is shown in table 1. To sum up, the regressions show how moderate and severe earthquakes affect economic growth differently when taking differences based on their income, amount of trade and amount of credit to the private sector into account. Moderate earthquakes have a less negative effect on economic growth in countries that supply more credit to the private sector and in high income countries with median institutions. Severe earthquakes have a less negative effect in high income countries and in closed countries but a more negative effect in open countries. They also have a less negative effect in countries with median institutions when they are closed or supply more credit to the private sector. The result for high income countries is in line with the hypothesis, but the effects for the closed countries and for countries that supply more credit are not. Closed countries are likely to be more independent and therefore able to deal with a shock quicker. Furthermore, this hypothesis is based on open countries having better access to new technology, which they can use to increase productivity of destroyed production capacities. However, this effect will only be visible in the long run, while these regression

[18] Coefficient(interaction)*median(institutional quality) = 0.248* -.4296 = -0.1065

examine the short run. Additionally this can show how aid, which is received more by open countries, can have a negative effect on economic growth when received in abundance. Concerning severe earthquakes in countries that supply more credit to the private sector, this result shows that severe earthquakes always have a negative effect on economic growth. furthermore, it also shows how bureaucratic rules delay the recovery process and thereby increase the damage. Moreover, this regressions examine the short run and these effects are likely to develop over time.

7 Conclusion

This thesis presents the results of a study on the economic effects of earthquakes by answering the research question; "*How do earthquakes affect economic growth and how does institutional quality influence this relationship?"* The sub questions that complement the research question are; *"How do earthquakes affect the short and long run economic growth conditional on institutional quality?"* and *"How does this effect rely on income level, openness and the level of financial development?"* The long run effect of earthquakes on economic growth differs across countries, as this effect is influenced by several country-specific factors, including the levels of development, income inequality, openness to trade and level of financial development. Institutional quality is another key factor that influences this effect, for which the WGIs are used as indicator. A regression analysis is performed to examine how earthquakes that occurred over the period 1996-2014 affect real GDP per capita in the short and long run and how institutional quality influences this effect. The magnitude of an earthquake is another factor that determines how earthquakes affect economic growth and this is examined in three different settings: by adding earthquakes as one variable that includes all earthquakes, as seven variables consisting of seven magnitude categories and as two variables that separate moderate earthquakes from severe ones. The overall earthquake variable does not give a significant result, while using seven categories shows that earthquakes with scores between 5.1-6.0 and 6.1-7.0 on the Richter scale cause a less negative effect on economic growth than earthquakes in the other categories. Furthermore, countries with median institutions experience a less negative effect of earthquakes with a score between 5.1-6.0 and 6.1-7.0, while earthquakes with a score of 4.1-5.0 cause a worse effect in countries with median institutions. Dividing the observations into moderate and severe earthquakes shows that moderate earthquakes cause a less negative effect on economic growth, while countries with median institutions experience a more negative effect of severe earthquakes. It was expected that institutional would have a positive influence on this effect, but this result shows how bureaucracy can cause a delay in the recovery process which increases the negative effect on economic growth. The regression examining the effect of earthquakes in the long run shows that earthquakes have a positive effect on economic growth in the fourth year and this shows that it takes four years before the benefits due to replacing destroyed technology with more advanced technology outweigh the short-term costs related to the implementation of the new technology. However, examining for five years is not sufficient to draw conclusions concerning the long term effect, as the long run is usually considered to be longer than five years. Furthermore, the strength of an earthquake was not taken into account, while the previous regression shows that strength matters. It was not possible to examine the long run more extensively, due to time limitations. Another series of regressions examine how external factors influence the effect of earthquakes on economic growth by comparing countries based on their income level, level of openness which is measured by amount of trade, and level of financial development which is measured by amount of domestic credit supplied to the private sector. The results show that high

income countries experience a less negative effect of moderate earthquakes when they have median institutions, which shows the positive effect of higher quality building codes and engineering structures that are a result of better institutions. Furthermore, countries that supply more credit to the private sector experience a less negative effect of moderate earthquakes, which supports the hypothesis of moderate earthquakes causing a less negative economic effect than severe earthquakes. High income countries experience a less negative effect of severe earthquakes, which is in line with the hypothesis. However, it was not expected that this effect would be less negative for severe earthquakes compared to moderate earthquakes, but this shows how earthquakes with a higher score on the scale of Richter do not necessarily cause more damage, as the quality of buildings and structures has a large influence on the damage as well. Closed countries experience a less negative effect of severe earthquakes and countries with median institutions experience less negative effects as well. This is not in line with the hypothesis, but shows how closed countries are able to deal with shocks independently. It also suggests that the trade level is not a dominant factor that determines the effect of earthquakes on economic growth. Open countries with median institutions experience a less negative economic effect, which does not follow the hypothesis, but shows that it requires time for new technologies to be implemented and for workers to be trained, causing initial productivity loss which has a negative effect on economic growth. Another reason could be an abundance of aid, as open countries are more likely to receive aid, which can harm economic growth. Severe earthquakes cause a more negative economic effect in countries with median institutions that supply more credit to the private sector. This supports the hypothesis of severe earthquakes causing a more negative effect than moderate earthquakes, but deviates from the hypothesis of countries that supply more credit to the private sector experiencing a less negative effect than countries that supply less credit to the private sector. However, this is likely to be cause by bureaucratic rules, which are also common in countries with better institutions, that delay the recovery process. Furthermore, these set of regressions examine the short run and these effects will develop over time. In conclusion, these results show how earthquakes with different scores on the Richter scale affect economic growth differently and that these effects depend on institutional quality and differ between countries with different levels of income, openness and financial development. Due to the number of country-specific factors that influence economic growth and how this is affected by earthquakes, the development of economic growth after an earthquake is difficult to predict.

However, this study is limited to data that cover the period 1996-2014, which is a short time frame. Additional research could examine the effect of earthquakes over a longer period, although a different indicator for institutional quality should be used, as the WGIs do not contain data from before 1996. Moreover, the regression that examines the effect of earthquakes in the long run includes only five lags, while the long run usually refers to a period beyond five years. This regression also only uses the overall earthquake variable, while regressions using multiple variables for earthquakes of different magnitudes show how earthquakes with different scores on the Richter scale affect economic growth differently. In addition, this regression does not examine the influence levels of income, openness or financial development, while the other regressions show how earthquakes affect countries differently when they are divided into groups based on these characteristics. Additional research could focus on examining the long run effects of earthquakes on economic growth more elaborately and over a longer time period. Furthermore, the effect of earthquakes on economic growth in closed and open countries is not in line with the hypothesis and

should be examined more elaborately as well. Future research could examine if this is caused by the way openness is defined, for example by comparing countries in the highest 10% with the lowest 10%, instead of comparing two groups based on the median. Future studies could also examine the effect of the amount of credit supplied to the private sector in more detail, by comparing the highest 10% with the lowest 10%. The regressions based on income classification could be elaborated by dividing the countries over more groups according to the complete income classification, and compare high income, upper-middle, lower-middle and low income countries with each other. Furthermore, the regressions that compare countries by dividing them by levels of income, openness and financial development could be extended to the long run to examine how the short run differs from the long run and to examine if the results that differ from the hypothesis continue to differ.

Another limitation of this study refers to possible endogeneity. Although the occurrence of an earthquake is exogenous, the effect earthquakes have on economic growth is not. Countries with a higher income are likely to have a higher level of institutional quality, and both income and level of institutional quality have a positive effect on the impact of earthquakes on economic growth. As a consequence, countries with higher income and better institutions do not experience fewer earthquakes, but they do experience less earthquake-related damage and therefore a less negative effect on economic growth. Furthermore, countries with better institutions are likely to receive more aid, which can also limit the negative effect of earthquakes on economic growth.

It is possible for countries to limit the effect of earthquakes on economic growth. Countries in which bureaucratic rules affect the impact of earthquakes, which can be democratic institutions as well, should adapt measures that prevent bureaucratic rules from hindering the recovery process. An example is limiting the amount of paperwork required in case of a natural disaster. In the case of natural disasters, it is important to send emergency care as soon as possible in order to limit the damage. An affected area is vulnerable, especially when aftershocks hit this area again. When a large amount of paperwork is required to be filled in before financial flows and other types of aid become available or other action takes place, this will delay the emergency aid and the recovery process, thus increasing the negative effect of the earthquake on economic growth. Furthermore, the regressions show that closed countries experience a less negative effect of earthquakes in the short run, while most literature conclude that open countries experience a less negative effect in the long run. Therefore, future research is needed to determine how this short run effect develops over the long run and, depending on the outcome, which factors cause the effect of earthquakes on economic growth to be positive or negative in the long run and how open or closed countries can learn from each other. However, when a country experiences economic growth, it does not mean that all citizens profit equally, therefore it could be valuable to examine the level of inequality in closed countries with a high level of economic growth. When economic growth increases it is important that also the poor profit, especially as they are affected the worst by earthquakes, since they live in vulnerable houses and lack the financial resources to recover from the shock. Additionally, countries with lower levels of institutions should make the elimination of corruption in the building sector a priority, as it is likely that there is a strong relation between corruption on the one hand and the death toll and damage on the other, as corruption can lead to badly constructed houses and buildings that are more likely to collapse during a shock. However, countries where corruption is common are not likely willing to invest in the elimination of corruption and the quality of building, therefore they should be stimulated to do so. For example, the UN can provide a fund for improving

the quality of buildings in low income countries near tectonic plate boundaries. Selected countries for this fund should be transparent in order to prevent these funds from disappearing into corruption. Furthermore, countries that receive other forms of aid should also be transparent on their use, in order to motivate other countries to give aid, to decrease the chance of aid disappearing into corruption and to protect the institutional quality. This could also stimulate donors to give to non-democratic countries as well, as democratic countries are more likely to receive aid. In order to give citizens in other countries equal chances, aid programs need to be monitored in these countries in order to motivate donors to donate to these countries as well. People living in high risk areas should be educated on how they can prepare themselves, what to do during an earthquake and what to do in the aftermath. Houses and building in these areas should have emergency kits and companies should not concentrate their buildings in high risk areas in order to limit the effect on economic growth. As an earthquake cannot be prevented, measures such as these can limit damage and number of deaths.

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9 Appendices

9.1 Appendix A – Variable list

Table 2, definitions and sources of the variables

Variable	Definition	Source
Economic growth	The log difference of real GDP per capita.	World Bank , 2016b
Real GDP per capita	(Gross value added by all residents producers in the economy + taxes – subsidies not included in the value of the products) / midyear population Data are in constant 2005 US dollars.	World Bank , 2016b
Institutional quality	Created by means of factor analysis and consists of the six dimensions of the WGIs, which are 'voice and accountability', 'political stability and absence of violence', '' government effectiveness', 'regulatory quality', 'rule of law', 'control of corruption'.	World Bank, 2015b
Earthquakes	Score the Richter scale of earthquakes that are recorded in the NOAA data base. The data are categorized in three ways: as one overall magnitude variable, as seven separate magnitude categories and divided into a moderate and a severe variable.	NOAA's Significant Earthquake Database (2016)
Earthquakes * Institutional quality	Score the Richter scale of earthquakes * factor resulting from factor analysis on the WGIs	
Income level	The levels divide the countries into groups, based on their income level, according to the 2012 income classification. Low- and middle income countries have a gross national income (GNI) per capita below $12,615, high income counties have a GNI per capita above $12,615.	World Bank , 2016a
Financial development	Financial resources provided to the private sector by financial corporations as percentage of GDP. Examples are loans and trade credits.	World Bank , 2016b
Population total	Total of all residents regardless of legal status or citizenship that were present in a certain geographical area at a certain time.	World Bank , 2016b
Population growth	The log difference of population total	World Bank , 2016b
Inflation	Annual growth rate of the ratio of GDP in current local currency to GDP in constant local currency (the GDP implicit deflator)	World Bank , 2016b
Aid	Aid is represented by the net official development assistance per capita, which is defined by government aid designed to promote the economic development and welfare of developing countries divided by the midyear population estimate.	World Bank , 2016b
Investment	Gross capital formation, which consists of outlays	World Bank , 2016b

	on additions to the fixed assets of the economy plus net changes in the level of inventories as percentage of GDP	
Government consumption	General government final consumption, which includes government current expenditures for purchases of goods and services and most expenditures on national defense and security, with exception of government military as percentage of GDP	World Bank , 2016b
Trade	Sum of exports and imports of goods and services as percentage of GDP	World Bank , 2016b
Net barter terms of trade*	Percentage ratio of the export unit value indexes to the import unit value indexes, measured relative to the base year 2000.	World Bank , 2016b
Inequality*	Represented by the Gini index, which is measure by the area between the Lorenz curve and a hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line. The Lorenz curve shows the income distribution by plotting the cumulative percentages of total income received against the cumulative number of recipients	World Bank , 2016b
Secondary school enrolment*	Total enrolment in secondary education, regardless of age, as a percentage of the population of official secondary education age.	World Bank , 2016b

***** These variables are excluded due to a low number of observations.

9.2 Appendix B – Histograms of the Control Variables

9.2.1 Control variables that are used for the regressions

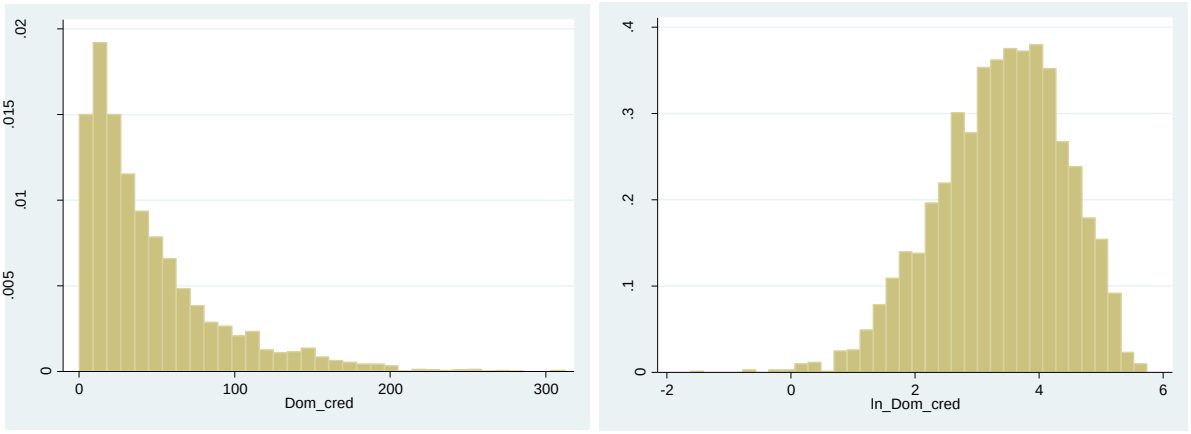


Figure 3, Financial development

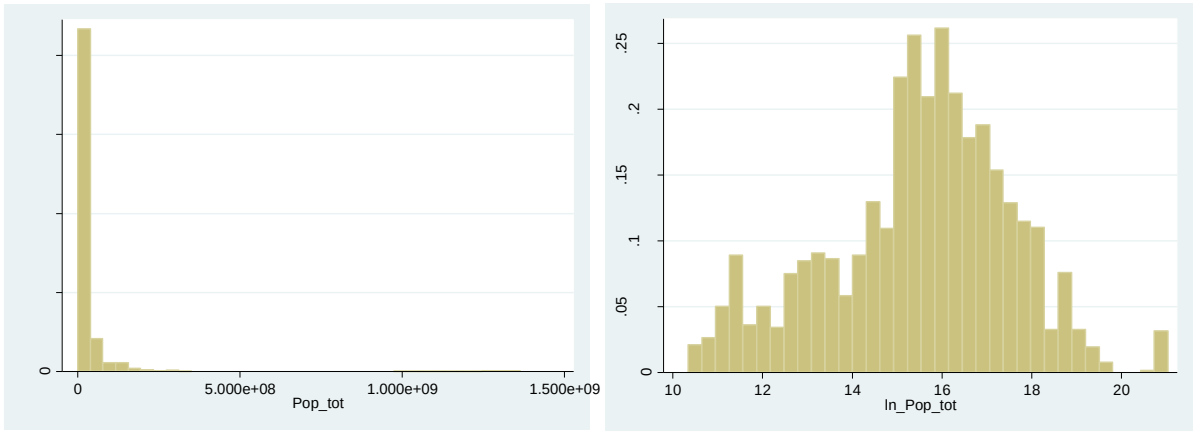


Figure 4, Population total

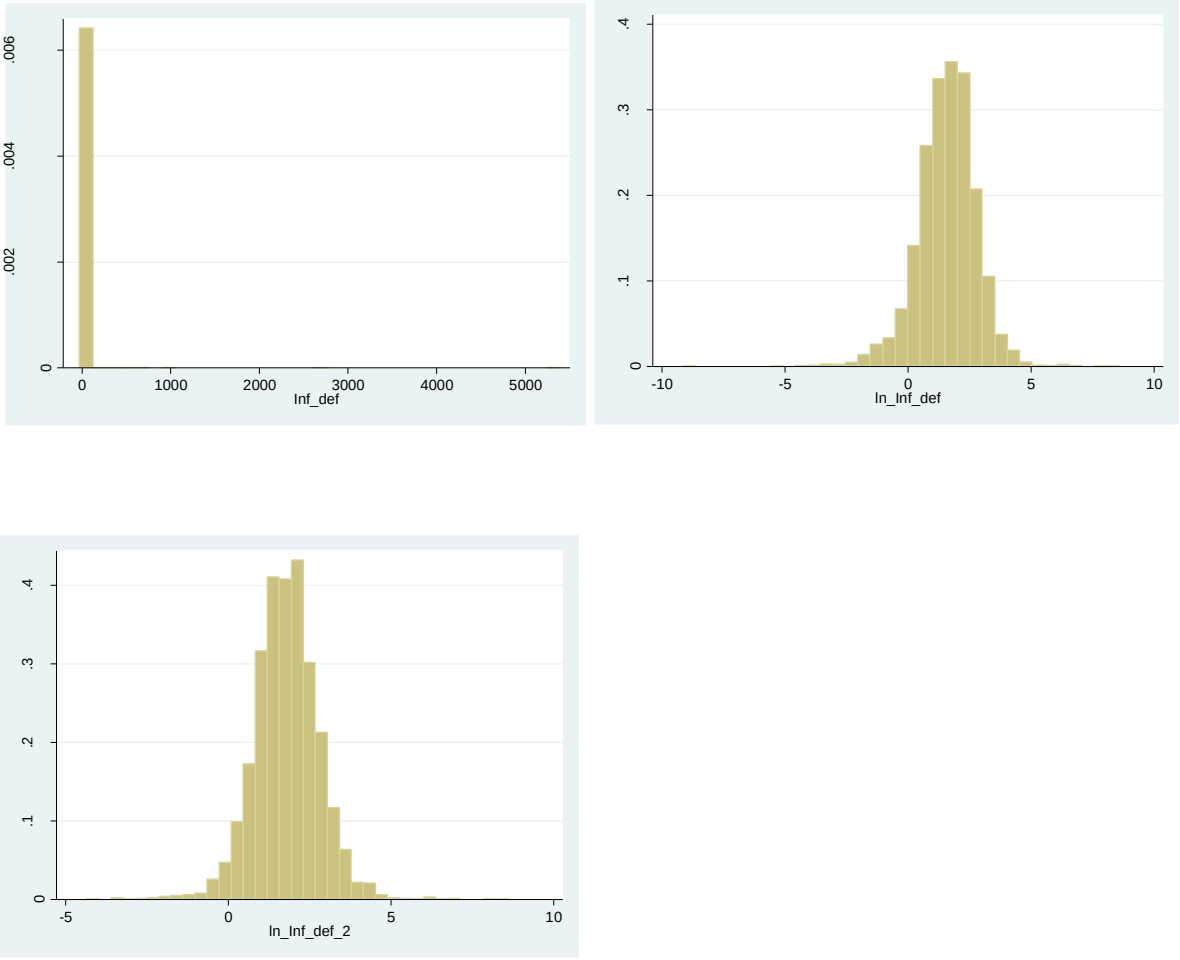
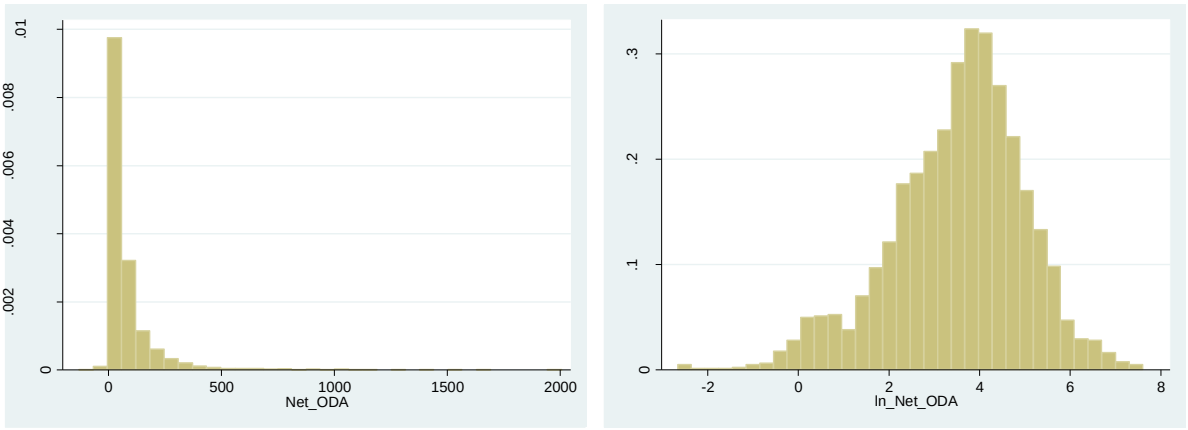
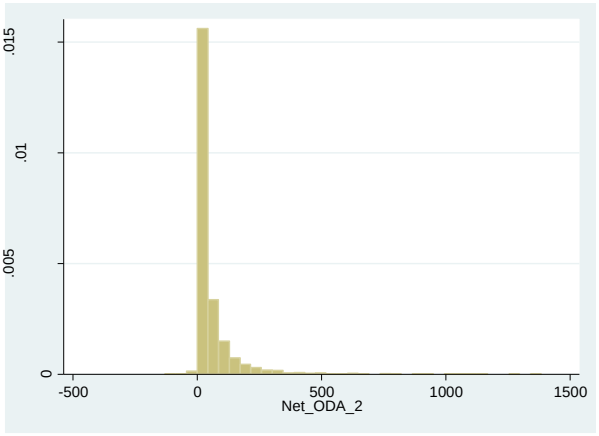


Figure 5, Inflation





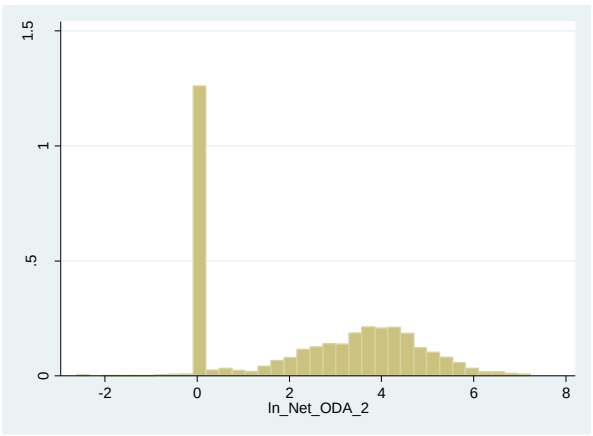


Figure 6, Aid

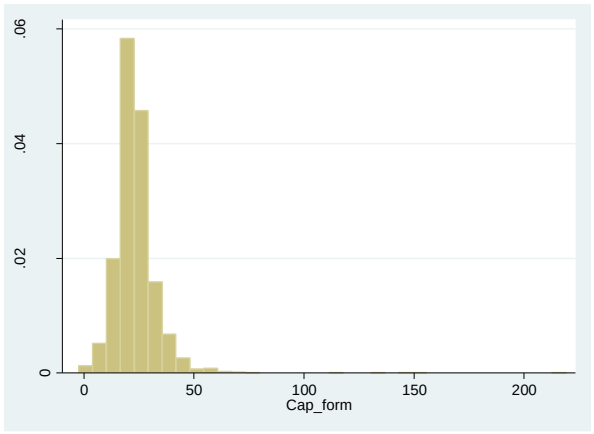


Figure 7, Investment

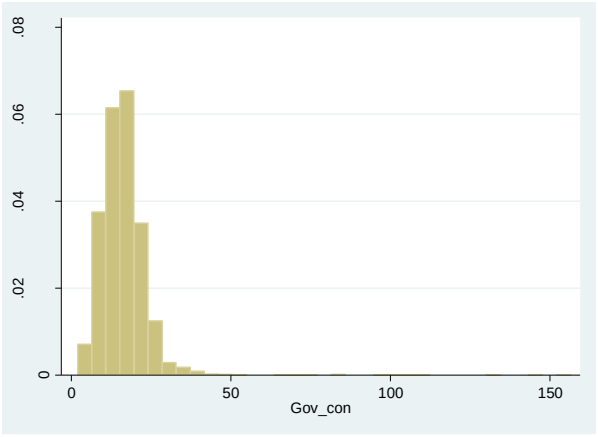
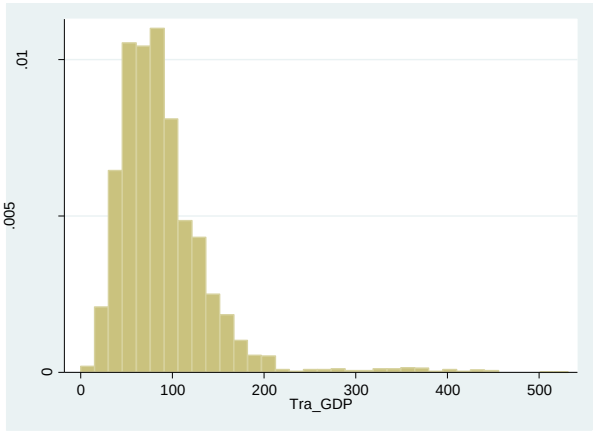


Figure 8, Government consumption



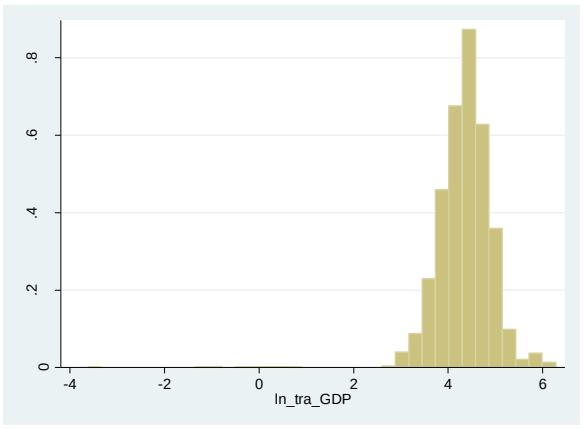


Figure 9, Trade

9.2.2 Rejected control variables due to low number of observations

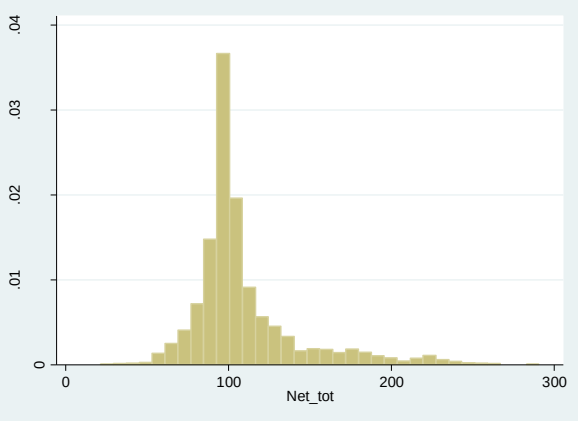


Figure 10, Net barter terms of trade

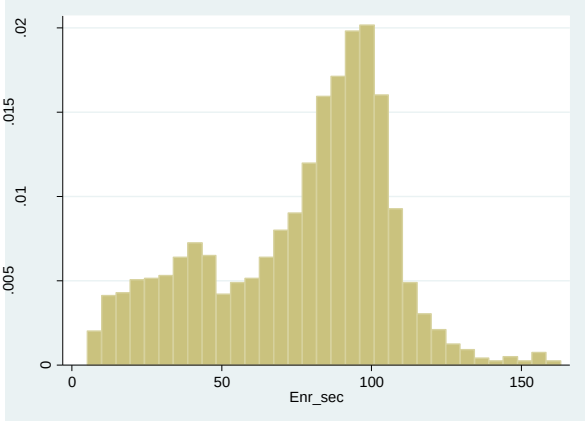
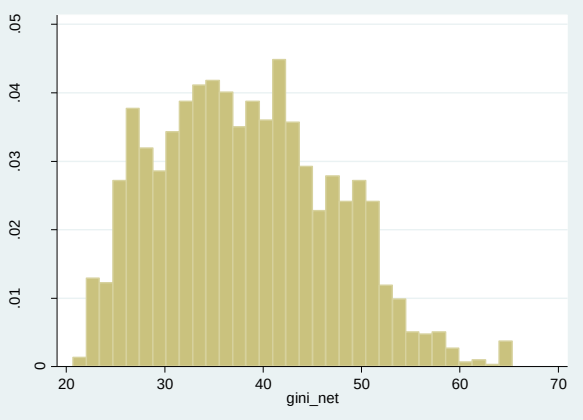


Figure 11, Secondary school enrolment



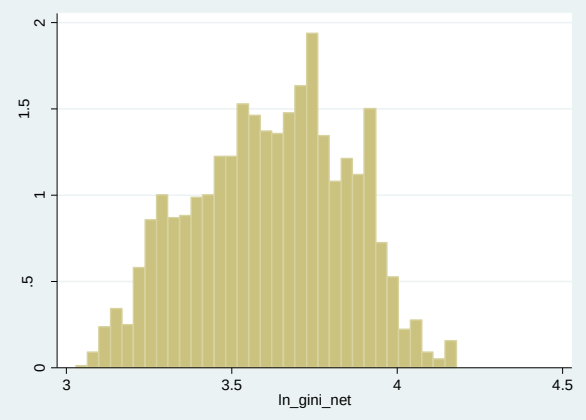


Figure 12, Level of inequality

9.3 Appendix C - Tables

Table 3, Number of observations per category

Magnitude category	Number of observation
2.1-4.0	16
4.1-5.0	103
5.1-6.0	151
6.1-7.0	152
7.1-8.0	89
8.1-9.0	14
9.1-10.0	1
2.1-6.0	327
6.1-10.0	292

Table 4, Hausman specification test

	Coëfficiënt			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	fe_model1	re_model1	Difference	S.E.
Log of real GDP per capita (lag)	-0.06310	-0.00760	-0.05550	0.00609
Earthquake magnitudes	0.12599	0.14219	-0.01620	0.04982
Institutional quality (lag)	0.01163	0.00354	0.00808	0.00243
Log of Financial development (lag)	-0.00632	-0.00837	0.00205	0.00198
Population growth (lag)	-0.72041	-0.62651	-0.09390	0.08606
Log of inflation (lag)	-0.01474	-0.01408	-0.00066	0.00209
Log of aid (lag)	0.00551	-0.00091	0.00643	0.00183
Investment (lag)	0.00060	0.00095	-0.00035	0.00010
Government consumption (lag)	-0.00051	-0.00039	-0.00012	0.00025
Trade (lag)	0.00023	0.00009	0.00014	0.00005

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(10) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 131.80
Prob>chi2 = 0.0000

Table 5, FE model (xtreg)

Variables	(1) FE model	(2) FE model robust
Real GDP per capita (lag)	-0.0631***	-0.0631***
	(0.0063)	(0.0098)
Earthquake magnitudes	0.1260	0.1260*
	(0.0959)	(0.0710)
Institutional quality (lag)	0.0116***	0.0116***
	(0.0027)	(0.0040)
Log of financial development (lag)	-0.0063**	-0.0063*
	(0.0026)	(0.0037)
Population growth (lag)	-0.720***	-0.7200***
	(0.1170)	(0.2230)
Log of inflation (lag)	-0.0147	-0.0147
	(0.0091)	(0.0135)
Log of aid (lag)	0.0055***	0.0055**
	(0.0021)	(0.0026)
Investment (lag)	0.0006***	0.0006**
	(0.0002)	(0.0003)
Government consumption (lag)	-0.0005*	-0.0005*
	(0.0003)	(0.0003)
Trade (lag)	0.0002***	0.0002***
	(5.26e-05)	(7.63e-05)
Constant	0.5290***	0.5290***
	(0.0491)	(0.0718)
Observations	2,170	2,170
R-squared	0.113	0.113
Number of cid	174	174

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: economic growth

Table 6, Correlation matrix

	ln_Dom~d	pop_gr	ln_Inf~l	ln_Net~2	Cap_form	Gov_con	Tra_GDP
ln_Dom_cred	1						
pop_gr	-0.282	1					
ln_Inf_defl	-0.2842	0.0689	1				
ln_Net_ODA_2	-0.4287	0.1436	0.0728	1			
Cap_form	0.0468	0.0107	-0.0537	-0.0425	1		
Gov_con	0.1278	-0.1031	-0.0801	0.0083	0.054	1	
Tra_GDP	0.1909	-0.0245	-0.0906	-0.1318	0.2925	0.0797	1

Table 7, Autocorrelation test

Wooldridge test for autocorrelation in panel data

H0: no first-order autocorrelation		
F(1, 171)	=	51.334
Prob > F	=	0.0000

9.3.1 Model with Driscoll-Kraay standard errors

Table 8, Driscoll-Kraay model without and with interaction term

VARIABLES	(1) Driscoll-Kraay model No interaction term	(2) Driscoll-Kraay model Interaction term
Real GDP per capita (lag)	-0.0631*	-0.0631*
	(0.0295)	(0.0295)
Earthquake magnitudes	0.126*	0.190***
	(0.0629)	(0.060)
Earthquakes*institutional quality		0.0597
		(0.0413)
Institutional quality (lag)	0.0116***	0.0114***
	(0.0022)	(0.0021)
Log financial development (lag)	-0.0063*	-0.0063*
	(0.0034)	(0.0034)
Population growth (lag)	-0.720***	-0.721***
	(0.120)	(0.120)
Log of inflation (lag)	-0.0147	-0.0151
	(0.0126)	(0.0127)
Log of aid (lag)	0.0055	0.0056
	(0.0036)	(0.0036)
Investment (lag)	0.0006*	0.0006*
	(0.0003)	(0.0003)
Government consumption (lag)	-0.0005	-0.0005
	(0.0006)	(0.0006)
Trade (lag)	0.0002**	0.0002**
	(7.96e-05)	(7.95e-05)
Constant	0.5290**	0.5290**
	(0.2410)	(0.2410)
Observations	2,170	2,170
Number of groups	174	174

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: economic growth

Table 9, Driscoll-Kraay model

VARIABLES	(1) Driscoll-Kraay model one magnitude	(2) Driscoll-Kraay model Separate	(3) Driscoll-Kraay model two categories
Real GDP per capita (lag)	-0.0631*	-0.0632*	-0.0632*
	(0.0295)	(0.0295)	(0.0294)
Earthquake magnitudes	0.190***		
	(0.060)		
Earthquakes*institutional quality	0.0597		
	(0.0413)		
Earthquakes with a score of 2.1-4.0		-0.729	
		(0.639)	
Earthquakes with a score of 4.1-5.0		-0.066	
		(0.174)	
Earthquakes with a score of 5.1-6.0		0.451**	
		(0.154)	
Earthquakes with a score of 6.1-7.0		0.232**	
		(0.107)	
Earthquakes with a score of 7.1-8.0		-0.101	
		(0.133)	
Earthquakes with a score of 8.1-9.0		-0.356	
		(0.617)	
Earthquakes with a score of 9.1-10.0		0	
		(0)	
Earthquakes (2.1-4.0)*institutional quality		-0.372	
		(0.520)	
Earthquakes (4.1-5.0)*institutional quality		-0.188**	
		(0.0791)	
Earthquakes (5.1-6.0)*institutional quality		0.217**	
		(0.0812)	
Earthquakes (6.1-7.0)*institutional quality		0.145**	
		(0.0647)	
Earthquakes (7.1-8.0)*institutional quality		0.0972	
		(0.161)	
Earthquakes (8.1-9.0)*institutional quality		-0.702	
		(0.539)	
Earthquakes (9.1-10.0)*institutional quality		-0.378	
		(0.409)	
Moderate earthquakes (with a score of 2.1-6.0)			0.287*
			(0.159)
Severe earthquakes (with a score of 6.1-10.0)			0.110
			(0.082)
Moderate earthquakes*institutional quality			0.0567
			(0.084)
Severe earthquakes*institutional quality			0.107*
			(0.0512)
Institutional quality (lag)	0.0114***	0.0113***	0.0114***
	(0.0021)	(0.002)	(0.002)
Log financial development (lag)	-0.0063*	-0.0063*	-0.0063*
	(0.0034)	(0.0034)	(0.0034)
Population growth (lag)	-0.721***	-0.717***	-0.719***

	(0.120)	(0.121)	(0.119)
Log of inflation (lag)	-0.0151	-0.0148	-0.015
	(0.0127)	(0.0126)	(0.0127)
Log of aid (lag)	0.0056	0.00577	0.0056
	(0.0036)	(0.0035)	(0.0035)
Investment (lag)	0.0006*	0.0006*	0.0006*
	(0.0003)	(0.0003)	(0.0003)
Government consumption (lag)	-0.0005	-0.0005	-0.0005
	(0.0006)	(0.0006)	(0.0006)
Trade (lag)	0.0002**	0.0002**	0.0002**
	(7.95e-05)	(8.01e-05)	(7.89e-05)
Constant	0.529**	0.529**	0.529**
	(0.241)	(0.240)	(0.240)
Observations	2,170	2,170	2,170
Number of groups	174	174	174

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: economic growth

Table 10, Multiple lags

VARIABLES	(1) Driscoll-Kraay model multiple lags
Lag of real GDP per capita	-0.0959***
	(0.0235)
Earthquakes magnitude	0.100
	(0.0567)
Earthquake magnitude (first lag)	0.023
	(0.0207)
Earthquake magnitude (second lag)	0.0146
	(0.0357)
Earthquake magnitude (third lag)	0.0272
	(0.0269)
Earthquake magnitude (fourth lag)	0.0926***
	(0.0268)
Earthquake magnitude (fifth lag)	0.0297
	(0.0289)
Institutional quality (lag)	0.0125***
	(0.0026)
Log of financial development (lag)	-0.003
	(0.0024)
Population growth (lag)	-0.740***
	(0.120)
Log of inflation (lag)	-0.0204**
	(0.0092)
Log of aid (lag)	0.0035
	(0.0026)
Investment (lag)	0.001*
	(0.0005)
Government consumption (lag)	-0.0001
	(0.0006)
Trade (lag)	0.0002*
	(0.0001)
Constant	0.778***
	(0.208)
Observations	2,014
Number of groups	174

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: economic growth

9.3.2 Splits

Table 11, Observation, income

Variable		Obs	Mean	Std. Dev.	Min	Max
Low level of income	Earthquake magnitudes	2468	0.270259	1.047849	0	15
High level of income	Earthquake magnitudes	1252	0.218051	0.775047	0	8

Table 12, Observations, openness

Variable		Obs	Mean	Std. Dev.	Min	Max
Low level of openness	Earthquake magnitudes	1695	0.467847	1.347085	0	15
High level of openness	Earthquake magnitudes	2025	0.072593	0.347442	0	3

Table 13, Observations, financial development

Variable		Obs	Mean	Std. Dev.	Min	Max
Low level of financial development	Earthquake magnitudes	1632	0.204657	0.830018	0	12
High level of financial development	Earthquake magnitudes	2088	0.29023	1.057096	0	15

Table 14, Splits using income, openness and financial system

VARIABLES	(1) Low income	(2) High income	(3) Less trade	(4) More trade	(5) Less credit	(6) More credit
Lag of real GDP per capita	-0.0494	-0.100**	-0.0309	-0.0732**	-0.0723**	-0.053
	(0.0291)	(0.0396)	(0.0234)	(0.0314)	(0.0312)	(0.0316)
Moderate earthquakes (2.1-6.0)	0.0132	0.200	0.284	0.449	-0.259	0.332***
	(0.307)	(0.291)	(0.175)	(0.454)	(0.446)	(0.0879)
Severe earthquakes (6.1-10.0)	-0.0143	0.771***	0.318**	-0.467**	0.166	0.0025
	(0.152)	(0.175)	(0.124)	(0.181)	(0.293)	(0.144)
Moderate earthquakes*institutional quality	-0.0909	0.212**	0.0825	0.0788	-0.159	0.0575
	(0.165)	(0.095)	(0.0892)	(0.208)	(0.220)	(0.0682)
Severe earthquakes*institutional quality	0.033	0.0197	0.179**	0.171	-0.0481	0.248***
	(0.0881)	(0.0647)	(0.0751)	(0.175)	(0.212)	(0.0649)
Institutional quality (lag)	0.0089***	0.0167***	0.0083**	0.0086***	0.0122***	0.0102***
	(0.0021)	(0.005)	(0.0033)	(0.0028)	(0.0035)	(0.0022)
Log of financial development (lag)	-0.0018	-0.0142***	-0.0137***	-0.0057	-0.0026	-0.0208**
	(0.0042)	(0.0029)	(0.0037)	(0.0034)	(0.0047)	(0.0085)
Population growth (lag)	-0.6660*	-0.745***	-0.044	-0.757***	-0.105	-0.754***
	(0.317)	(0.111)	(0.363)	(0.128)	(0.391)	(0.155)
Log of inflation (lag)	-0.0256***	0.0456	-0.0301***	0.0133	-0.0089	-0.0321
	(0.0078)	(0.0738)	(0.008)	(0.0392)	(0.0123)	(0.0362)
Log of aid (lag)	0.0039	0	0.00124	0.0063**	0.0073	0.0022
	(0.0031)	(0)	(0.005)	(0.0023)	(0.0051)	(0.0018)
Investment (lag)	0.0003	0.0007	-0.0005	0.001**	0.0004	-3.46e-05
	(0.0004)	(0.0006)	(0.0003)	(0.0004)	(0.0003)	(0.0006)
Government consumption (lag)	-0.0002	-0.002**	-2.29e-05	-0.0005	-0.0008	-0.0002
	(0.0007)	(0.0008)	(0.0006)	(0.0007)	(0.0009)	(0.0011)
Trade (lag)	0.0003*	0.0002**	0.0005*	4.63e-05	0.0004***	-9.16e-06
	(0.0001)	(7.31e-05)	(0.0003)	(5.22e-05)	(0.0001)	(0.0001)
Constant	0.370	1.0360**	0.289	0.643**	0.5090**	0.585*
	(0.213)	(0.388)	(0.188)	(0.272)	(0.229)	(0.276)
Observations	1,404	766	1,050	1,120	985	1,185
Number of groups	115	59	119	122	108	125

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 Dependent variable: economic growth

9.3.3 Driscoll-Kraay using two magnitude categories

Table 15, Driscoll-Kraay model with interaction terms

VARIABLES	(1) Driscoll-Kraay model interaction term
Lag of real GDP per capita	-0.0632*
	(0.0294)
Moderate earthquakes (2.1-6.0)	0.287*
	(0.159)
Severe earthquakes (6.1-10.0)	0.110
	(0.082)
Moderate earthquakes*institutional quality	0.0567
	(0.084)
Severe earthquakes*institutional quality	0.107*
	(0.0512)
Institutional quality (lag)	0.0114***
	(0.002)
Log of financial development (lag)	-0.0063*
	(0.0034)
Population growth (lag)	-0.719***
	(0.119)
Log of inflation (lag)	-0.015
	(0.0127)
Log of aid (lag)	0.0056
	(0.0035)
Investment (lag)	0.0006*
	(0.0003)
Government consumption (lag)	-0.0005
	(0.0006)
Trade (lag)	0.0002**
	(7.89e-05)
Constant	0.529**
	(0.240)
Observations	2,170
Number of groups	174

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variable: economic growth