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Impacts of Earthquakes on Economic Growth and Income Inequality in Independent Turkic States

Burcu Türkcan[1*]

[1] Department of Economics, Faculty of Economics and Administrative Sciences, Ege University, Türkiye

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Abstract

Earthquakes are major natural disasters that occur frequently worldwide. They have several socioeconomic impacts on countries. At first glance, it seems that as if they cause only large volumes of deaths, injuries and destruction. However, in the medium and long run, they cause several other impacts such as income, employment and production losses, increased government expenditures, inflation explosions and income distortions. All of these impacts are critical especially for developing countries that have more vulnerable economies than developed ones. In this respect, this study aims to analyse the impacts of massive earthquakes on economic growth and income inequality in independent Turkic states. With this purpose, two empirical models are estimated by the Generalized Method of Moments (GMM) with panel data covering the period from 1991 – 2022 for 6 countries. Empirical findings exhibit that major earthquakes do not have significant impacts on the economic growth processes of these countries. However, they have significant impacts on income distortions. In this manner, it seems that despite massive earthquakes, Turkic states have been able to sustain their economic growth processes. However, income inequality has increased as a by-product of these disasters. This evidence seems substantial for sustainable development policy formations of Turkic states.

Key words: Earthquakes, Economic growth, Income inequality, Turkic states

1. Introduction

The global climate crisis has been at the scene since the midst of the 20th century. Humanity is about reaching the limits of the globe. This fact has already been declared by The Limits to Growth Report published in 1972. Specifically, with the inefficient use of global resources, it would be impossible to sustain both population and production growth. Even it warns that this would cause drastic decreases in both [1]. Since that time, nothing has changed much in terms of humankind's production and consumption patterns. Global warming has accelerated and despite sustainability efforts, the problem has deepened. Beyond the Limits and The Limits to Growth: The 30-Year Update was published in 1992 and 2004, respectively. At their last update, they warned that 'Overshoot cannot be sustained without collapse.'. However, they have also pointed out that humanity could still reverse the collapse by taking the right actions on resource use and waste management [2].

With the rise of global warming and environmental degradation, the volume and severity of natural disasters have increased [3, 4]. Technological advancements have provided new tools [1]for forecasting natural disasters such as tsunamis, tornadoes and floods. However, there are

* Corresponding Author e-mail: burcu.turkcan@ege.edu.tr

still some disasters that cannot be truly foreseen like earthquakes. Fault zones have been discovered, their historical behaviours have been analysed and possible future earthquakes have been forecasted at all over the World. However, mankind has still inadequate tools to foreseen exactly when an earthquake will occur and at which magnitude will it happen. In this manner, it seems that we, as humankind, need to deeply understand the impacts of major earthquakes and take sustainable policy actions to minimize their socioeconomic costs.

Moreover, transformational changes in international system with the collapse of USSR (Union of Soviet Socialist Republics) in 1989, have reshaped the relationships of all countries across all over the World [5]. Some countries in the South Caucasus and Central Asia declared their independence in 1991. From that time on, historical and ethnic backgrounds of Turkic states have brought them together firstly in the Cooperation Council of Turkic-Speaking States and then in Organization of Turkic States [6]. All these efforts have been important due to creation of a power block in Central Asia. Moreover, the geographical area of these countries has critical importance [7]. With its wide range of landscape and climatic conditions, this area seems to be on the spotlight of climate crisis researchers in the near future. Moreover, this wide geographical area, which includes the main fault zones historically produced massive earthquakes. In this context, the main purpose of this study is to analyse the impacts of major earthquakes on economic growth and income inequality in independent Turkic states. However, there are still inadequate studies on the impacts of earthquakes in this country group. In this respect, the empirical results of this study are expected to make a significant contribution to the related literature. Hopefully, the empirical results will shed light on the socioeconomic impacts of earthquakes in this country group and the development of sustainable policy tools to decrease negative impacts. This country group has a special importance due to the fact that their independencies are relatively new (apart from Türkiye). Hence, their economies are more vulnerable than the similar developing countries. Also, their geography has an important role in the contemporary world. What is more, this role is expected to enhance by Turkic World Vision-2040. Organization of Turkic States has declared Turkic World Vision-2040 as an act focusing on economic and sectoral cooperation in transport. In particular, the use of the Trans-Caspian East-West Corridor has been targeted to widen and the new Zengezur Corridor has been targeted to be jointly built by Türkiye and Azerbaijan. The increase in transportation in the region is expected to increase the macroregional economic development in the near future. This will lead the region to have a more critical role in the global economy. In this respect, the examinations about independent Turkic states have critical importance in the contemporary world [8]. In this context, the first section of the study is devoted to the nexus between earthquakes and sustainable development in terms of economic growth and income inequality. The second section reviews the literature. The third section is devoted to the methodology and empirical results. Finally, in the conclusions, sustainable policy recommendations are proposed.

2. Earthquakes as a Natural Fact in Turkic States

Earthquakes are natural disasters that have several socioeconomic consequences in the short, medium and long-term. In the course of an earthquake, human, capital and infrastructure losses occur. However, this sudden impact is not the only one. From the occurrence of the earthquake through the first 6 months, inflation increases; investments in capital and infrastructure accelerate and government expenditures for disaster victims increase. From 6 months to 3 years, the volume of tourism decreases; foreign direct investments decrease; government expenditures increase and income inequality rises. Even after 3 years, structural changes still occur due to the earthquake [9]. All these impacts can also be classified as direct, indirect and induced impacts. The direct impacts include physical destruction of infrastructure, buildings, machinery

and agricultural assets. However, indirect impacts imply that production and income decrease due to stock losses. Lastly, induced impacts indicate total effects on macroeconomic variables such as GDP (Gross Domestic Product), consumption and inflation [10]. All the aforementioned impacts are critical for all economies and nations. However, there is no doubt that they are more critical for developing countries in which GDP levels are lower and markets are more vulnerable [11].

Independent Turkic states (Azerbaijan, Kazakhstan, Kyrgyzstan, Turkmenistan, Türkiye and Uzbekistan) are developing countries that share the same ethnic historical background [12]. After the end of the 1st World War, Republic of Türkiye has been founded in 1923 in Anatolia. It had a great success against imperial countries and this new country was a secular bridge between Europe and Central Asia [13]. The fundamental notion behind the unity of citizens was the Turkic identity and nationalism as the mainstream policy. After the end of the Cold War, the USSR collapsed and Azerbaijan, Kazakhstan, Kyrgyzstan, Turkmenistan and Uzbekistan announced their liberties one by one in 1991. Hence, the number of independent Turkic states increased worldwide with the emergence of these new countries in Central Asia and the Caucasus [14]. After that time, independent Turkic states followed friendly foreign policies due to their ethno-historical background and linguistic unity. Organization of Turkic States which was first established with the heading of the Cooperation Council of Turkic-Speaking States, has been the most remarkable attempt to provide a union between independent Turkic states [6]. The founders of the organization were Azerbaijan, Kazakhstan, Kyrgyzstan and Türkiye. Then Uzbekistan and Turkmenistan joined the organization. The main object of this union has been declared as fostering comprehensive cooperation among Turkic states. It aims to enhance cooperation in terms of the economy, science, education, tourism and other fields [15]. Although all these efforts are remarkable, there is an underestimated and undiscussable area. Natural disasters are at the spotlight of the contemporary world. The magnitudes and frequencies of these events have increased because of the global climate crises [3]. More importantly, humanity will face more severe disasters. In this sense, it is critical to understand the impacts of these disasters on societies and economies.

It's known that there are several fault zones in Central Asia, the South Caucasus and Anatolia. Although the main earthquake area across these countries is Türkiye, other countries have also experienced massive earthquakes in their histories. The examples include the Azerbaijan Shemakha Earthquake in 1667 (6.9); the Azerbaijan Shemakha Earthquake in 1902 (6.9); the Turkmenistan Ashgabat Earthquake in 1929 (7.4); the Turkmenistan Ashgabat Earthquake in 1948 (7.3); the Turkmenistan Nebitday – Turkmenbashi Earthquake in 2000 (7.0); the Uzbekistan Tashkent Earthquake in 1937 (6.5); the Uzbekistan Tashkent Earthquake in 1966 (6.9); the Uzbekistan Gazli – Bukhara Earthquake in 1976 (7.0); the Uzbekistan Gazli Earthquake in 1984 (7.0); the Kazakhstan Vernensk Earthquake in 1887 (7.3); the Kazakhstan Alma-Ata Earthquake in 1889 (8.3); the Kazakhstan Alma-Ata Earthquake in 1911 (7.7); the Kazakhstan Alma-Ata Earthquake in 1978 (7.1); the Kyrgyzstan Belovodskoje Earthquake in 1885 (6.9); the Kyrgyzstan Earthquake in 1946 (7.6); the Kyrgyzstan Toluk Earthquake in 1992 (7.5). As underlined before, Türkiye is an earthquake country because of its geographical features. Several massive earthquakes have occurred in Turkish history such as the Türkiye Erzincan Earthquake in 1939 (7.9); the Türkiye Samsun Earthquake in 1943 (7.2); the Türkiye Van Earthquake in 1976 (7.5); the Türkiye Golcuk-Kocaeli Earthquake in 1999 (7.8); the Türkiye Van Earthquake in 2011 (7.2) and the Türkiye Kahramanmaras Earthquakes in 2023 (7.8 and 7.6). The values in parentheses are the magnitudes of earthquakes. Table 1 summarizes the main active faults across independent Turkic states. All information in Table 1 were collected from AFEAD [16].

Table 1. Main active faults across independent Turkic States

Country	Fault
Azerbaijan	Main Thrust of Great Caucasus Fault
	Malkamude Thrust Fault
	Kodjashen Fault
	Saliany – Liangabiz Fault
	Apsheron Threshold Fault
	Vandam Fault
Kazakhstan	Chingiz – Tarbagatay Fault
	Tarbagatai Fault
	Chingis – Narym Fault
	Karatau Fault
	Kendaktas Fault
	Sarkand Fault
	Main Dzhungarian Fault
Kyrgyzstan	Talas – Fergana Fault
	Arslanbob Fault
	Issyk – Ata Fault
	Frontal Terskey Fault
	South Chongkemin Fault
	Chonkurchak Fault
	North Naryn Fault
Türkiye	North Anatolian Fault
	East Anatolian Fault
	North Marmara Fault
	Gediz Graben
	Southeast Hellenic Trench
	Great Menderes Graben
	Salt Lake Fault
	Edremit Fault
	Akdag Graben Fault
	Cyprus Trench Fault
Turkmenistan	Main Kopet Dagh Fault
	Kum Dagh Fault
	Isak – Cheleken Fault
	Ghiaur Dagh Fault
Uzbekistan	North Kuldjuktau Fault
	South Atoynok Fault
	Kulkuduk Fault
	Central Ustiurt Fault

All these active faults have produced massive earthquakes in historical manner. Despite providing some examples of massive earthquakes in the history of Turkic states, Table 2 summarizes them with their times and places between 1991 and 2023. This time period was selected due to the independence declaration dates of Azerbaijan, Kazakhstan, Kyrgyzstan, Turkmenistan and Uzbekistan.

Table 2. Massive earthquakes in Independent Turkic States, 1991 – 2023

Date	Place	Magnitude
Azerbaijan		
04.06.1999	Agdas, Ucar, Agali	5.4
25.11.2000	Baku	6.8
07.05.2012	Zagatala	5.7
11.05.2017	Iran-Ardabil	5.1
05.06.2018	Shaki-Zaqatala	5.3
05.02.2019	Shemakha	5.0
Kazakhstan		
13.06.2009	Tekeli	6.3
Kyrgyzstan		
15.05.1992	Osh	6.2
19.08.1992	Toluk	7.5
09.01.1997	Dzhergetal, Koshtebe,Kazarman	5.8
05.09.2002	Not known	5.5
15.12.2006	Kochkor	5.8
08.01.2007	Isfaria	6.0
01.01.2008	Osh	5.6
05.10.2008	Nora	6.6
17.11.2015	Osh	5.6
Turkmenistan		
06.12.2000	Nebitday – Turkmenbashi	7.0
Uzbekistan		
15.05.1992	Andızhan	6.2
19.07.2011	Fargona, Violyati	6.1
Türkiye		
13.03.1992	Erzincan	6.9
01.10.1995	Dinar, Evciler	6.4
27.06.1998	Adana, Ceyhan	6.3
17.08.1999	Istanbul, Kocaeli, Sakarya	7.6
12.11.1999	Bolu, Duzce, Adapazarı	7.2
06.06.2000	Cerkes, Cubuk, Orta	6.0
15.12.2000	Afyon - Bolvadin	6.0
03.02.2002	Afyon	6.5
27.01.2003	Saglamtas, Pulumur	6.1
05.01.2003	Bingol	6.4
08.03.2010	Elazig	6.1
23.10.2011	Ercis, Van	7.1
10.06.2012	Fethiye	6.1
20.07.2017	Bodrum, Datca	6.6
24.01.2020	Elazig, Malatya	6.7
30.10.2020	Izmir	7.0
06.02.2023	Kahramanmaras	7.8 - 7.6
20.02.2023	Kahramanmaras, Malatya	6.3

Note: Since numerous massive earthquakes occurred after 1991, only earthquakes greater than 6.0 in magnitude in Türkiye region are included in the table.

When the magnitudes of earthquakes, number of massive earthquakes and number of active faults are compared, Türkiye is the riskiest country across Turkic states. However, Kyrgyzstan and Azerbaijan are also observed as high risk countries in terms of earthquakes. Given this, earthquakes should be one of the main discussion themes of independent Turkic states. In this context, it is critical to understand the socioeconomic impacts of earthquakes.

3. Literature Analysis

Natural disasters and their impacts received increasing attention in the literature due to the increase in both their frequency and magnitude in parallel with the global climate crises. However, although the socioeconomic impacts of natural disasters have been discussed in more detail over the last 25 years, the macroeconomic impacts of earthquakes have not yet been deeply analysed [17, 18]. It is observed from the literature that natural disasters are discussed as a general phenomenon in most studies, without examining in greater detail the type of disaster. Only few studies have separated these disasters into climatic and geological disasters (please see: [19, 20, 21, 22]).

When the socioeconomic impacts of natural disasters are taken into account, most related studies have focused on the impacts of natural disasters on economic growth (such as [3, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36]). However, very few studies have focused on the income inequality impacts of these disasters (such as; [19, 34, 37, 38]). Moreover, the number of studies focusing on the earthquakes' macroeconomic impacts is very low. These studies can be found in [19, 23, 26, 27, 30, 31, 33, 34, 38, 39, 40, 41].

Another important point in the related literature is the investigations of the studies. It follows from the literature that the most of the related studies have investigated negative impacts of disasters on economic growth (please see: [23, 3; 25, 39, 27, 28, 29; 31, 42, 34, 41, 35, 43, 9, 21, 36, 44]). However, some studies have also investigated positive impacts resulting from different time periods and country groups (please see: [24, 45, 30; 40, 20, 23]). Even some studies have found no significant relationship between natural disasters and economic growth (please see: [26, 46, 32]). Lastly, the studies analysing the impacts of disasters on income inequality have investigated that disasters increase income inequality (please see: [19, 34, 37]).

Since this study focuses on the impacts of earthquakes, it is important to examine the studies having the same axis. In this vein, Huang et al. [23] reported that in Chinese cities, only moderate and strong earthquakes had negative impacts on economic growth from 1999 to 2014. However, Fisker [33] underlined that earthquakes decrease the growth levels of regions where they exist. But when it comes to the nation-level, other regions' growths may neutralize the negative impact at the national level. Similarly, Onuma et al. [39] analysed 173 countries between 1960 and 2010 and they found that earthquakes have negative impacts only in the midterm. Similarly, Skidmore and Toya [22] explored the relationships between natural disasters and macroeconomic indicators. They found that climatic disasters are positively correlated with economic growth, while geological disasters are negatively correlated. Noy [21] analysed different country sets as to their development levels and the results showed that disaster shocks on macroeconomy are handled better in developed countries. Wu and Guo [26] conducted an analysis of 31 Chinese provinces between 2000 and 2010. They found that earthquakes have no significant impact on economic growth in Chinese provinces. However, Best and Burke [27] conducted an analysis of Haiti between 2004 and 2014 and they have investigated that earthquake had negative impact on economic growth. Loayza et al. [20] used a cross-country panel data set for the 1961 – 2005 period and they investigated significant impacts of disasters on economic growth. But they underlined that effects are not always negative. Lackner [30] conducted an analysis for 195 countries between years of 1973 – 2015. Empirical results showed that earthquakes have negative long-run impacts on economic growth in low- and middle-income countries. However, they have positive impacts in high income countries. Zhao et al. [31] conducted a panel data analysis of 181 county-level cities in Sichuan Province in China between 2003 and 2013. They underlined that the Wenchuan Earthquake had

a negative impact on economic growth. However, the recovery period may neutralize this negative impact. Sahin and Yavuz [40] also conducted an analysis of 4 OECD (Organisation for Economic Cooperation and Development) countries between 2005 and 2014 and they found that earthquakes positively affect production in Canada, Chile and Greece. However, they have no impact on Türkiye. Yamamura [19] investigated for 86 countries and the 1965 – 2004 period that natural disasters increase income inequality in short-term. However, this impact disappears in the long-term. Felbermayr and Gröschl [41] conducted an analysis of 108 countries between 1979 and 2010 years and they detected that poor countries are mainly (and negatively) affected by strong earthquakes. Barone and Mocetti [34] analysed impacts of earthquakes occurred in Italy in 1976 and 1980. They underlined that earthquakes may decrease growth and increase inequality in cases of weak institutions and the lack of financial aid. Anbarci et al. [38] estimated a panel data model for 26 countries and the 1960 – 2002 period and they found that developed countries are affected less by earthquakes.

When the aforementioned studies are examined, it seems that there is no study analyzing independent Turkic states in the context of macroeconomic impacts of earthquakes. Although there are several studies in spite of massive earthquakes in this country group (such as [47, 48, 49, 50]), they neither examine their impacts on economic growth and income inequality, nor analyse the related countries as a group. In this context, this paper is the first study analyzing independent Turkic states in terms of macroeconomic impacts of massive earthquakes. Moreover, this paper contributes to the literature on the point that it analyses the period after 1991 for this country group. This starting date was determined as to the independence declarations of Azerbaijan, Kazakhstan, Kyrgyzstan, Turkmenistan and Uzbekistan. Consequently, the empirical findings may have critical importance for policy formation in these countries.

4. Methodology

4.1. Data and Models

Three different types of data sets can be used in econometric analyses as time series data set, cross-sectional data set and panel data set. Panel data has some superiorities over two other data sets. First, they provide more efficient estimations due to higher degrees of freedom [51]. Second, they decrease the possibility of multicollinearity between independent variables. Third, by taking into account both time and cross section dimensions, they make it possible to deepen the analyses [52]. In this study, a panel data set covering the 1991 – 2022 period and 6 independent Turkic states, are used. This time period has been selected due to the declaration of independence of 5 Turkic states (Azerbaijan, Kazakhstan, Kyrgyzstan, Turkmenistan and Uzbekistan).

Two different models are estimated in this panel data context. The first model tries to estimate the determinants of economic growth and the second model tends to estimate the determinants of income inequality. In this sense, the dependent variable of the first model is the economic growth rate and the dependent variable of the second model is the GINI coefficient. The independent variables of the first model are gross fixed capital formation, labour force participation rate, earthquakes and the lagged value of the economic growth rate. Additionally, the independent variables of the second model are the economic growth rate, inflation, unemployment and earthquakes. Table 3 summarizes the variables and their notations.

Table 3. Variables and their notations

Model 1		Model 2	
Notation	**Variable**	**Notation**	**Variable**
GROWTH	Economic Growth Rate	GINI	GINI Index
GFCF	Gross Fixed Capital Formation Rate	GROWTH	Economic Growth Rate
LFPR	Labor Force Participation Rate	INF	Inflation Rate
GROWTH(-1)	One Year Lagged Value of Economic Growth	UNEMP	Unemployment Rate
QUAKE	Earthquakes	QUAKE	Earthquakes
RD	Research and Development		

In the first model, GROWTH is the annual percentage growth of Gross Domestic Product (GDP) and GFCF is the gross fixed capital formation as a percentage of GDP. LFPR is the labor force as a percentage of total population between the ages 15 and 64. RD is research and development expenditures as a percentage of GDP. QUAKE is a dummy variable expressing the earthquakes greater than the magnitude 5.0. Dummy variables are dichotomous variables that are constructed with a qualitative approach. In this sense, they are formed from 1s and 0s [52]. They provide ease to measure the impacts of qualitative variables and hence increase the explanatory power of the regression [53]. In our model, the existence of massive earthquakes is demonstrated by QUAKE dummy variable. In this manner, if at least one earthquake with a magnitude greater than 5.0, has occurred in a year, then it's marked as 1 in the series. Finally, GROWTH(-1) is the one-year lagged value of economic growth rate. This variable is added to the model because the economic growth process expresses path dependency [3, 29, 55, 56, 57]. The first model can be expressed as follows:

$$GROWTH_{it} = \beta 0 + \beta 1 GFCF_{it} + \beta 2 LFPR_{it} + \beta 3 RD_{it} + \beta 4 QUAKE_{it} + \beta 5 GROWTH(-1)_{it} + e_{it} \quad (1)$$

where, i expresses the cross section dimension and t expresses the time dimension. Finally, e is the error term.

In the second model, GINI refers to the GINI coefficient indicating income inequality. It measures the distribution of income across a nation. As much it deviates from 0, income inequality increases so much [57]. Moreover, GROWTH variable is the annual percentage growth of GDP as in the first model. INF is the annual percentage increase in consumer prices. UNEMP is the unemployment rate as a percentage of total laborforce. And lastly, QUAKE is the earthquake dummy as in the first model. Apart from earthquakes data, all other data have been retrieved from World Development Indicators Database [77]. However, earthquakes data have been retrieved from NOAA (National Centers for Environmental Information) [76] and KOERI BOUN (Bogazici University Kandilli Observatory and Earthquake Research Institute) [75]. The expression of the second model where i expressing cross section dimension, t expressing time dimension and e expressing error term, is expressed as follows:

$$GINI_{it} = \beta 0 + \beta 1 GROWTH_{it} + \beta 2 INF_{it} + \beta 3 UNEMP_{it} + \beta 4 QUAKE_{it} + e_{it} \quad (2)$$

Both models were constructed following the related literature. The first model is a basic Solow Growth Model based on Cobb-Douglas Production Function Approach. In this approach, output level is determined mainly by physical capital, labor force and production technology. This model is enhanced by the addition of natural disasters (please see: [24, 3, 30, 41, 33, 20, 21, 59]). However, there are different results in terms of the impacts of earthquakes on economic

growth process. Although most of the studies have found negative impacts of earthquakes on economic growth [3, 30, 41, 33, 21], some of them have found no impact [20] and even some studies have found positive impacts due to the recovery affords in the long-run [24]. Across all these studies, some evidences have pointed out that impacts change as to countries/country groups and time span [24, 20, 59].

The second model is based on the sustainability approach in terms of income inequality (please see: [60, 61; 19, 37, 38, 62, 63]). In this context, following the related literature, the main determinants of the Gini coefficient have been taken into account and earthquakes have been added as another factor affecting income inequality in the model. Again there are contradicting empirical results in the literature. As an example, Keerthiratne and Tol [60] found that earthquakes decrease income inequality in Sri Lanka. However, Yamamura [19] underlined that earthquakes may increase income inequality in the short-run, but this effect may disappear in the long-run.

4.2. Empirical Methods and Results

In this study, two models are estimated via panel data analysis methods to test the impacts of earthquakes on economic growth and income inequality. In this respect, firstly, cross section dependencies of series were checked. This is an important step because if cross sectional dependency exists, then second generation unit root tests should be applied to check the validity of stationarity. First generation unit root tests produce erroneous results when cross sectional dependency ignorance [64, 65]. While checking the cross section dependency, it is critical to select a suitable test for the related data set. There are frequently used different tests as Breush-Pagan LM Test, Pesaran Scaled LM Test, Bias-Corrected Scaled LM Test and Pesaran CD Test. When cross section dimension is low (i=6) and time dimension is long enough (t= 31), Breusch – Pagan LM Test is suitable to apply [66, 67]. Null hypothesis of this test assumes no cross section dependency. Since QUAKE is a dummy variable set, cross section dependency test was not conducted for this series. Table 4 expresses Breusch – Pagan LM Test results for the series in the first model.

Table 4. Breusch – Pagan LM Test results for the growth model

Series	t Statistic	Probability	Evidence
GROWTH	167.5007	0.0000	Cross section dependency
GFCF	33.37421	0.0042	Cross section dependency
LFPR	170.2333	0.0000	Cross section dependency
RD	120.4142	0.0000	Cross section dependency

The Breusch-Pagam LM Test results show that all four series have cross section dependency. In this case, second generation unit root tests should be applied to check the validity of stationarity. Pesaran [67] has proposed the CIPS unit root test which has built upon IPS (Im, Pesaran and Shin) Test and aimed to improve its performance in panel data. The CIPS Test is especially effective when the time dimension is relatively large [68]. Table 5 summarizes the results of the CIPS Unit Root Test.

Table 5. CIPS Unit Root Test results for the growth model

Series	t Statistic	Probability	Evidence
GROWTH	-3.02329	<0.01	Stationary
GFCF	-2.55220	<0.05	Stationary
LFPR	-2.22270	<0.10	Stationary
RD	-1.18906	>=0.10	Not stationary

Table 5 exhibits that GROWTH has no unit root problem at 1% significance level. GFCF and LFPR do not also have unit root problems at the 5% and 10% significance levels respectively. However, RD has unit root problem. In this sense, first difference of the series has been taken and then the CIPS test was applied again. The test results showed that t statistic is 3.73702 indicating stationarity at 1% significance level. Hence, the first difference of RD has been used in our model. After detecting the stationarity of series, the next step is determining the type of the model to estimate. In this manner, a panel data model may either be fixed effects model or random effects model and Hausman Test expresses true type of model to be estimated. The null hypothesis of this test assumes the validity of fixed effects, while the alternative hypothesis assumes random effects [69]. Table 6 exhibits the Hausman Test results for the first model.

Table 6. Hausman Test results for the growth model

Model	Chi-Sq. Statistic	Probability	Evidence
Growth Model	1.647824	0.8954	Random Effects

After determining the type of the model, the GMM technique was used to estimate the first model. The GMM Technique which has a superiority over Maximum Likelihood, has been a widely used technique in panel data [70]. It is widely accepted that Least Squares Procedure produces large biases in panel data and what is more is that Maximum Likelihood Method is also insufficient to estimate true model [71]. Lagged values of the independent variables have been used as instrumental variables. Lag selection were made through AIC criteria [71]. Table 7 shows the GMM estimation results.

Table 7. GMM estimation results of the growth model

Variable	Coefficient	t-Statistic	Probability
Constant	-16.64984	-1.925621	0.0568*
GFCF	0.172461	1.934909	0.0557*
LFPR	0.171951	0.171951	0.0743*
QUAKES	8.140416	8.140416	0.1194
GROWTH(-1)	0.810792	0.810792	0.0000***

Note: * stands for 10% significance level; ** stands for 5% significance level and * stands for 1% significance level.**

The estimation results show that as expected, gross fixed capital formation, the labour force participation rate and one-year lagged value of economic growth are all statistically significant and have positive impact on economic growth rate. However, earthquakes greater than 5.0

magnitude has no statistically significant impact on the economic growth rate. This evidence is consistent with the findings of [24], [20] and [59].

For a more in-depth analysis, the second model is conducted. This model assumes that the existence of massive earthquakes is a determinant of income inequality. Again, the Breusch-Pagan LM Test was conducted as the first step. Since the GINI is an index series and QUAKE is a dummy variable series, their cross section dependencies have not been detected. Table 8 summarizes the results for the series.

Table 8. Breusch – Pagan LM Test results for the income inequality model

Series	t Statistic	Probability	Evidence
INF	65.76880	0.0000	Cross section dependency
UNEMP	217.5324	0.0000	Cross section dependency
GROWTH	167.5007	0.0000	Cross section dependency

Since all the series have cross section dependency, the next step is to check the validity of the stationarity. In this manner, CIPS unit root test was conducted. Table 9 summarizes the results.

Table 9. CIPS Unit Root Test results for the income inequality model

Series	t Statistic	Probability	Evidence
INF	-1.26983	>=0.10	Not stationary
UNEMP	-1.32631	>=0.10	Not stationary
GROWTH	-3.02329	<0.01	Stationary

It is observed from the results that while inflation and unemployment are not stationary at the level, growth is stationary. Therefore, the first difference of both series have been taken and stationarity has been detected. CIPS results have proved that both series are stationary at their fisrt differenced forms. INF had -2.418 t-statistic value and UNEMP had -3.508 t-statistic value indicating statistical significances at 10% and 1% respectively. After handling stationary series, the Hausman Test has been applied to determine the type of the model. Table 10 exhibits the results.

Table 10. Hausman Test results for the income inequality model

Model	Chi-Sq. Statistic	Probability	Evidence
Income Inequality Model	5.144645	0.2728	Random Effects

The Hausman Test Results indicate that Income Inequality Model has also the form of random effects. In this manner, GMM estimation has been conducted with random effects in our model. Table 11 shows the empirical results.

Table 11. GMM estimation results for the income inequality model

Variable	Coefficient	t-Statistic	Probability
Constant	23.29859	8.909452	0.0000***
INF	0.401101	0.784368	0.4366
UNEMP	7.617754	3.222919	0.0023**
GROWTH	1.161668	2.590098	0.0126**
QUAKES	11.90413	5.024242	0.0000***

Note: * stands for 10% significance level; ** stands for 5% significance level and * stands for 1% significance level.**

The estimation results show that unemployment, economic growth and earthquakes are the determinants of GINI coefficients in Turkic states. However, it seems that inflation has no statistically significant effect on income inequality. Moreover, all the significant determinants have positive impacts on the dependent variable. For the sake of clarity, it is important to remember that the higher the GINI coefficient means the higher distortions in income inequality. In this manner, it is observed that as unemployment and economic growth rate increase, income inequality increases, too. Also, the occurrence of massive earthquakes increases income inequality in this country group.

5. Conclusions

Earthquakes are natural disasters of that existences cannot be foreseen all the time and impacts are great in both fatalities and damages. Since the global climate crisis began, the number and magnitude of natural disasters have increased. Recently, two devastating earthquakes occurred in Türkiye on February 6, 2023. This has caused thousands of people to die and numerous buildings and infrastructure to collapse. Other independent Turkic states have also experienced massive earthquakes in recent years. With their destructive results, earthquakes seem critical for all these countries. Moreover, all independent Turkic states are classified as developing countries. Such countries are characterized with less developed industrial structures and lower human development levels.2 Azerbaijan, Kazakhstan, Kyrgyzstan, Turkmenistan and Uzbekistan have gained their independences in 1991. Since they had been under the control of the USSR for a long time period, it is critical for them to establish appropriate public policies for sustainable development. Also, their geography has a strategic role in the contemporary world. Organization of Turkic States has declared Turkic World Vision-2040 for the extended use of the Trans-Caspian East-West Corridor and for the joint construction of new Zengezur Corridor. It’s expected that higher transportation rates will lead to higher strategic importance of this region in the near future. In this respect, the examinations about independent Turkic states have critical importance [8].

Following all these facts, this study tries to shed light on the impacts of massive earthquakes on economic growth and income inequality in Turkic states. Empirical findings suggest that earthquakes have no statistically significant impact on economic growth. However, these findings are in line with the literature. Most of the empirical studies have investigated that earthquakes have no significant impact or they have positive impacts in the long run. This result occurs due to high investments on the earthquake region. If these investments are supported by

structural reforms, excellent planning and strong institutions, it is possible to overcome short-run negative impacts [32, 46, 35]. However, economic growth is a quantitative notion and cannot tell us everything about the sustainability. In this manner, it is important to research the sustainability facts behind the earthquakes. At this point, a basic question arises. What if earthquakes do not affect the growth process but detoriate income distribution? Empirical analyses of this study investigated that the existence of massive earthquakes in Turkic states between 1991 and 2022, causes higher income inequality. Again this result is in the same line with the related literature. Although there are only few studies examining this relationship, the existed ones have underlined that massive earthquakes increase income inequality [37]. However, here there is an important explanation in the literature, too. Nearly all studies examining the impacts of natural disasters on income inequality have underlined that less developed and developing countries have been affected more from disasters [45, 30, 36]. In this sense, there is a policy dilemma for developing countries as choosing to invest in structural reforms in terms of disaster-resilient societies or choosing to invest in growth-oriented policies. The first is probably time-consuming and costly but the latter means greater fatalities and damage in the case of a massive earthquake. Growth-oriented policies may increase GDP per capita in the short-run but it will not sustain welfare in the long-run. In this case, societal well-being would be underestimated and sustainable development would be laid aside.

In summary, massive earthquakes seem critical for the sustainable development journeys of independent Turkic states. Historically, devastating earthquakes have been experienced several times in each country and it seems that the frequency of natural disasters will increase in the near future. In this manner, it is important to take right policy actions in terms of sustainability. Precautions seem critical for earthquake-resilient societies and economies.

Notes

1. In these studies, there is an implicit assumption that earthquakes are independent of the global climate crisis. However, since the world is an integrated complex system [72], actually it is impossible to think earthquakes apart from the climate crisis.

2. For the list of developing countries, please visit [73].

Conflict of Interest

No potential conflicts of interest were reported by the author(s).

Author Contribution

B. T. collected the data, designed the models and wrote the whole manuscript.

References

[1] D. H. Meadows, D. L. Meadows, J. Randers, and W. W. III. Behrens. The limits to growth. Universe Books, First Edition, New York, 1972.

[2] D. H. Meadows, D. L. Meadows and J. Randers. Beyond the limits. Chelsea Green Publications, First Edition, USA, 1992.

[3] M. T. I. Kahn, S. Anwar, S. A. Sarkodie, M. R. Yaseen, and A. M. Nadeem. "Do natural disasters affect economic growth? The role of human capital, foreign direct investment, and infrastructure dynamics". *Heliyon*, 9, 1- 19, 2023. https://doi.org/10.1016/J.HELIYON.2023.E12911

[4] J. Guo, H. Liu, X. Wu, J. Gu, , S. Song and Y. Tang. "Natural disasters, economic growth and sustainable development in China—an empirical study using provincial panel data". *Sustainability*, 7(12), 16783 – 16800, 2015. https://doi.org/10.3390/su71215847

[5] O. Sander. "Turkey and the Turkic world". *Central Asian Survey*, 13(1), 37 – 44, 1994. https://doi.org/10.1080/02634939408400849

[6] Y. Sapiyev. "Turkey and Turkic-speaking states". *Journal of Anadolu Strategy*, 3(2), 1 – 31, 2022.

[7] A. Penck. "Central Asia". *The Geographical Journal*, 76(6), 477 – 487, 1930. https://doi.org/10.2307/1783689

[8] M. Mustofaev. "The Organization of Turkic States: A New Approach to Global and Regional Challenges". *Perceptions*, 27(1), 105 – 120, 2022.

[9] C. R. Jaramillo. "Do natural disasters have long-term effects on growth?" Documento CEDE 2007 – 14, 2007.

[10] R. Mechler. "Macroeconomic impacts of natural disasters". *World Bank*. 2003 http://info.worldbank.org/etools/docs/library/

[11] A. Coburn, and R. Spence. *Earthquake protection*. John Wiley and Sons. 1992.

[12] A. Tokmak, and I. Kara. "Türk devletleri teşkilatı ülkelerinin yurtdışında yerleşik yaşayan vatandaşlarına yönelik uygulamalarının analizi". *MANAS Journal of Social Studies*, 12(2), 677 – 690, 2023. https://doi.org/10.33206/mjss.1251578

[13] I. Bal. "The Turkish model and the Turkic republics". *New Trends in Turkish Foreign Affairs*. Ed. Vedat Yucel and Salomon Ruysdael. Writers Club Press. USA. PP. 211 – 234, 2002.

[14] K. Cinar. "Turkey and Turkic nations: a post-cold war analysis of relations". *Turkish Studies*, 14(2), 256 – 271, 2013. https://doi.org/10.1080/14683849.2013.802925

[15] OTS (Organization of Turkic States). Organization of Turkic States. https://www.turkicstates.org (Accessed 10 November 2023).

[16] AFEAD (Active Faults of Eurasia Database) http://neotec.ginras.ru/index/english/database_eng.html (Accessed 08 October 2023).

[17] M. Cruse. "Place in Haitian literature since the 2010 earthquake". *Geographical Review*, 103(4), 469 – 483, 2013.

[18] B. J. Godfrey. "Urban development and redevelopment in San Francisco". *Geographical Review*, 87(3), 309-333, 1997.

[19] E. Yamamura. "The impact of natural disasters on income inequality: analysis using panel data during the period 1970 to 2004". *International Economic Journal*, 29(3), 359 – 374, 2015. https://doi.org/10.1080/10168737.2015.1020323

[20] N. V. Loayza, E. Olaberria, J. Rigolini, and L. Christiaensen. "Natural disasters and growth: going beyond the averages". *World Development*, 40(7), 1317 – 1336, 2012.

https://doi.org/10.1016/j.worlddev.2012.03.002

[21] I. Noy. "The macroeconomic consequences of disasters". *Journal of Development Economics*, 88, 221 – 231, 2009. https://doi.org/10.1016/j.jdeveco.2008.02.005

[22] M. Skidmore, and H. Toya. "Do natural disasters promote long-run growth?" *Economic Inquiry*, 40(4), 664 – 687, 2002. https://doi.org/10.1093/ei/40.4.664

[23] L. Huang, Q. Liu, and Y. Tang. "Long-term economic impact of disasters: evidence from multiple earthquakes in China". *World Development*, 174, 106446, 2024. https://doi.org/10.1016/j.worlddev.2023.106446

[24] G. M. Idroes, I. Hardi, M. Nasir, E. Gunawan, P. Maulidar, and A. R. R. Maulana. "Natural disasters and economic growth in Indonesia". *Ekonomikalia Journal of Economics*, 1(1), 33 – 39, 2023. https://doi.org/10.60084/eje.v1i1.55

[25] G. S. Atsalakis, E. Bouri, and F. Pasiouras. "Natural disasters and economic growth: a quantile on quantile approach". *Annual Operations Research*, 306, 83–109, 2021. https://doi.org/10.1007/s10479-020-03535-6

[26] X. Wu, and J. Guo. "Natural disasters and economic growth—an empirical study using provincial panel data of China". In: *Economic Impacts and Emergency Management of Disasters in China.* Springer, Singapore. 2021.

[27] R. Best, and P. J. Burke. "Macroeconomic impacts of the 2010 earthquake in Haiti". *Empirical Economics*, 56, 1647 – 1681, 2019. https://doi.org/10.1007/s00181-017-1405-4

[28] N. Baig, S. Khan, N. G. Gilal, and A. Qayyum. "Do natural disasters cause economic growth? An ARDL bound testing approach". *Studies in Business and Economics*, 13(1), 5-20, 2018. https://doi.org/10.2478/sbe-2018-0001

[29] Y. T. Hee, K. V. Kalimuthu, L. C. Yu, C. S. Pong, and F. C. Chew. "Do natural disasters affect economic growth in Bangladesh?" *International Journal of Business and Society*, 19(3), 781 – 792, 2018.

[30] S. Lackner. "Earthquakes and economic growth". *FIW Working Paper*. No. 190. Pp. 1-61, 2018.

[31] R. Zhao, Z. Shihu, and H. Aiping. "Disaster impact, national aid, and economic growth: evidence from the 2008 Wenchuan earthquake". *Sustainability*, 10(12), 4409, 2018. https://doi.org/10.3390/su10124409

[32] E. Cavallo, S. Galiani, I. Noy, and J. Pantano. "Catastrophic natural disasters and economic growth". *The Review of Economics and Statistics*, 95(5), 1549–1561, 2013. https://doi.org/10.1162/REST_a_00413

[33] P. S. Fisker. "Earthquakes and economic growth. Institute for Advanced Development Studies". *Development Research Working Paper Series*. No: 01/2012.

[34] G. Barone, and S. Mocetti. "Natural disasters, growth and institutions: a tale of two earthquakes". *Journal of Urban Economics*, 84, 52 – 66, 2014. https://doi.org/10.1016/j.jue.2014.09.002

[35] K. J. Thomas, F. B. McDermott, and S. J. T. Richard. "Disasters and development: natural disasters, credit constraints, and economic growth". *Oxford Economic Paper*, 66(3), 750–773, 2014. https://doi.org/10.1093/oep/gpt034

[36] M. E. Kahn. "The death toll from natural disasters: the role of income, geography, and institutions". *The Review of Economics and Statistics*, 87 (2), 271–284, 2005.

https://doi.org/10.1162/0034653053970339

[37] E. Yamamura. "Impact of natural disasters on income inequality: analysis using panel data during the period 1965 to 2004". *MPRA Paper No*. 45623, 2013.

[38] N. Anbarci, M. Esceleras, and C. A. Register. "Earthquake fatalities: the interaction of nature and political economy". *Journal of Public Economics*, 89, 1907 – 1933, 2005. https://doi.org/10.1016/j.jpubeco.2004.08.002

[39] H. Onuma, K. J. Shin, and S. Managi. "Short-, medium-, and long-term growth impacts of catastrophic and non-catastrophic natural disasters". *Economics of Disasters and Climate Change*, 5, 53 – 70, 2021. https://doi.org/10.1007/s41885-020-00074-z

[40] I. Sahin, and O. Yavuz. "Econometric analysis of natural disasters' macro-economic impacts: an analysis on selected four OECD countries". *Journal of Business, Economics and Finance*, 4(3), 430 – 442, 2015. https://doi.org/10.17261/Pressacademia.2015313064

[41] G. Felbermayr, and J. Gröschl. "Naturally negative: the growth effects of natural disasters". *Journal of Development Economics*, 111, 92 – 106, 2014. https://doi.org/10.1016/j.jdeveco.2014.07.004

[42] N. Benali, and K. Saidi. "A robust analysis of the relationship between natural disasters, electricity and economic growth in 41 countries". *Journal of Economic Development*, 42(3), 89 – 100, 2017. https://doi.org/10.35866/CAUJED.2017.42.3.005

[43] S. Hochrainer. "Assessing the macroeconomic impacts of natural disasters: are there any?" *World Bank Policy Research Working Papers*. No. 4968, 2009.

[44] T. N. Rasmussen. "Macroeconomic implications of natural disasters in the Caribbean". *IMF Working Paper*. No: 04/224, 2004.

[45] E. A. Asyahid, and I. S. Pekerti. "Economic impact of natural disasters, spillovers, and role of human development: Case of Indonesia". *Letters in Spatial and Resource Sciences*, 15, 493 – 506, 2022. https://doi.org/10.1007/s12076-022-00307-7

[46] Y. Okuyama. Disaster and economic growth: theoretical perspectives. In: Okuyama, Y., Rose, A. (eds) Advances in Spatial and Economic Modeling of Disaster Impacts. *Advances in Spatial Science*. Springer, Cham, 2019.

[47] T. C. Zajicek. "The seismic colony: earthquakes, empire and technology in Russian-ruled Turkestan, 1887–1911". *Central Asian Survey*, 41(2), 322 – 346, 2021. https://doi.org/10.1080/02634937.2021.1919056

[48] R. Umaraliev, R. Moura, H – B. Havenith, F. Almeida, and A. G. Nizamiev. "Disaster risk in central asia: socio-economic vulnerability context and pilot-study of multi-risk assessment in a remote mountain area of the Kyrgyz Republic". *European Journal of Engineering Research and Science*, 5(3), 234 – 244, 2020.

[49] D. Iakubowskii, N. Komendantova, E. Rovenskaya, D. Krupenev, and D. Boyarkin. "Impacts of earthquakes on energy security in the Eurasian economic union: resilience of the electricity transmission networks in Russia, Kazakhstan, and Kyrgyzstan". *Geosciences*, 9(1), 54, 2019. https://doi.org/10.3390/geosciences9010054

[50] E. Durukal, and M. Erdik. "Physical and economic losses sustained by the industry in the 1999 Kocaeli, Turkey earthquake". *Natural Hazards*, 46, 153 – 178, 2008. https://doi.org/10.1007/s11069-008-9218-6

[51] J. P. Elhorst. Spatial panel data models. *Handbook of Applied Spatial Analysis: Software Tools, Methods and Applications*. M.M. Fischer ve A. Getis (Eds). Springer-Verlag

Berlin Heidelberg, 2010.

[52] C. Hsiao. "Panel data analysis – advantages and challenges". *Test*, 16(1), 1 – 22, 2007. https://doi.org/10.1007/s11749-007-0046-x

[53] M. A. Hardy. *Regression with dummy variables.* Sage Publications. California. USA, 1993.

[54] D. B. Suits. "Use of dummy variables in regression equations". *Journal of the American Statistical Association*, 52(280), 548 – 551, 1957. https://doi.org/10.1080/01621459.1957.10501412

[55] J. Bellaiche. "On the path-dependence of economic growth". *Journal of Mathematical Economics*, 46(2), 163 – 178, 2010. https://doi.org/10.1016/j.jmateco.2009.11.002

[56] T. Harada. "Path-dependent economic growth with technological trajectory". *Economics of Innovation and New Technology*, 19(6), 521 – 538, 2010.

[57] A. K. Dutt. Path dependence, equilibrium and economic growth. in Arestis, P., Sawyer,M. (eds): *Path Dependency in Macroeconomics*. International Papers in Political Economy, Macmillan Palgrave, Houndmills and New York, 2009.

[58] EUROSTAT. (2023). Glossary: Gini coefficient. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Gini_coefficient (Accessed 04 October 2023).

[59] J. M. Albala-Bertrand. "Natural disaster situations and growth: a macroeconomic model for sudden disaster impacts". *World Development*, 21(9), 1417 – 1434, 1993. https://doi.org/10.1016/0305-750X(93)90122-P

[60] S. Keerthiratne, and R. S. J. Tol. "Impact of natural disasters on income inequality in Sri Lanka". *World Development*, 105, 217 – 230, 2018. https://doi.org/10.1016/j.worlddev.2018.01.001

[61] M., Mehrara, and M. Mohammadian. "The determinants of gini coefficient in Iran based on bayesian model averaging". *Hyperion Economic Journal*, 1(3), 20 – 28, 2015.

[62] E. Abounoori. "Unemployment, inflation and income distribution: A Cross-Country Analysis". *Iranian Economic Review*, 8(9), 1 – 11, 2003. https://doi.org/10.22059/IER.2003.30925

[63] T. P. Schultz. "Secular trends and cyclical behaviour of income distribution in the United States: 1944 – 1965". In Six papers on the size distribution of wealth and income. *NBER*. Pp. 75 – 106, 1967.

[64] M. H. Pesaran. "General diagnostic tests for cross section dependence in panels". *Cambridge Working Papers in Economics*, 435, 2004.

[65] M. H. Pesaran. "A simple panel unit root test in the presence of cross section dependency". *Cambridge Working Papers in Economics*, 0346, 2006.

[66] M. H. Pesaran. "General diagnostic tests for cross-sectional dependence in panels". *Empirical Economics*, 60, 13 – 50, 2021. https://doi.org/10.1007/s00181-020-01875-7

[67] T. S. Breusch, and A. R. Pagan. "The lagrange multiplier test and its application to model specifications in econometrics". *Review of Econometric Studies*, 47, 239–253, 1980. https://doi.org/10.2307/2297111

[68] M. H. Pesaran. "A simple panel unit root test in the presence of cross-section dependence". *Journal of Applied Econometrics*, 22, 265 – 312, 2007. https://doi.org/10.1002/jae.951

[69] J. A. Hausman. "Specification tests in econometrics". *Econometrica*, 46(6), 1251 – 1271,

1978. https://doi.org/10.2307/1913827

[70] D. Harris, and L. Matyas. “Introduction to the generalized method of moments estimation. Ed. Laslozo Matyas. Generalized Method of Moments Estimation”. USA: Cambridge University Press, 1999.

[71] J. D. Sargan. “The estimation of economic relationships using instrumental variables”. *Econometrica*, 26, 393 – 415, 1958. https://doi.org/10.2307/1907619

[72] C. A. Hidalgo, and R. Hausmann. “The building blocks of economic complexity”. *PNAS*, 106(26), 10570 – 10575, 2009. https://doi.org/10.1073/pnas.0900943106

[73] IMF. https://www.imf.org/en/Publications/WEO/weo-database/2023/April/groups-and-aggregates (Accessed 10 November 2023).

[74] EM-DAT. The International Disaster Database. https://public.emdat.be/ (Accessed 04 October 2023).

[75] KOERI BOUN (Bogazici University Kandilli Observatory and Earthquake Research Institute). http://www.koeri.boun.edu.tr/new/ (Accessed 11 November 2023).

[76] NOAA (National Centres for Environmental Information). https://www.ngdc.noaa.gov/hazard/earthqk.shtml (Accessed 10 November 2023).

[77] WDI (World Development Indicators). https://databank.worldbank.org/source/world-development-indicators (Accessed 10 November 2023).