Title

Structural Transformation and Natural Disasters: Evidence from the 2008 Sichuan Earthquake

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Abstract

Despite the disruptive side of natural disasters, their expected effects on economic structural transformation are ambiguous. Combining data from the Chinese Household Income Project, the Chinese Statistical Yearbook, and the U.S. Geological Survey, this thesis explores how a tremendous earthquake in Sichuan, China, affected the regional economic structure, using first-difference, OLS, and difference-in-difference with synthetic control method. I find that the earthquake had an immediate impact on the sectoral distribution of both employment and GDP. The shift of labor to the construction and service sectors was stronger in the most severely damaged areas. However, economic structure and industry employment mix of the affected regions showed a trend of convergence after one year of the earthquake. At the same time, compared with non-affected provinces, the earthquake accelerated the decline in the proportion of labor in the primary sector in Sichuan, and this impact is sustained and amplified over time. Labor was more likely to flow to the industries in the secondary and tertiary sectors with higher returns on capital, such as construction and service.

1. Introduction

Many previous articles have studied the correlation between natural disasters and economic outcomes to help policymakers understand the potential benefits from disaster adaptation, especially for issues like income and aggregated growth (Tol and leek, 1999; Skidmore and Toya, 2002; Rasmussen, 2004). Most economists generally accept that an unexpected natural disaster could significantly impact the economy of the affected area both in the short and long term. Besides negative results like economic losses and capital flight, some positive impacts from rapid turn-over of capital have been confirmed in some case-by-case studies, such as 1906 San Francisco Fire (Siodla, 2015) and 2006 Indonesia Earthquake (Kirchberger 2017). Several national or global-scale papers, like V. Loayza and Olaverria (2012) and Noy and Tam (2010), show that disasters do affect economic growth but not always negatively, depending on geographical locations and sectors. However, there is little literature focusing on the relationship between structural transformation and natural disasters. The objective of this thesis is to discover the effect of natural disasters on economic structure from a view of the sectoral distribution of employment and GDP.

In this study, I select the Sichuan Earthquake which happened on 12 May 2008 as my natural experiment. Since different disasters affect growth in various economic sectors differently (Loayza, 2012), the impact of natural disasters on one specific industry is hard to summarize across cities and countries. Though there are two types of structural transformation---industry internal upgrading and changes in sectoral distribution---considering the limitation of the accessibility and detailed degree of industry data in Sichuan, I focus on sectoral distribution of employment and GDP as my main outcomes of interests, because they are observable from the micro, CHIP dataset, and the macro, Chinese Statistics Yearbook. In China, the statistical bureau and research institutes are used to collect data by using the "Three-sector model in economics" (Fisher 1939) for convenience. The three-sector model in economics divides economies into three sectors of activity: extraction of raw materials (primary), manufacturing, construction, and mining(secondary), and services (tertiary) (Wikipedia 2018). To prevent confusion, I use "primary, secondary, and tertiary" terms in the macro analysis and exact sector names like service, construction, and manufacturing in the micro analysis.

Following Kirchberger (2017) does, I use the modified Mercalli intensity (MMI) from U.S. Geological Survey (USGS), a linear exogenous measurement based on recorded ground motions to measure the destruction effect of the earthquake. USGS's website lists this measure for every earthquake that happened around the world. The district-level MMI, obtained from USGS Shakemap, plays a crucial role in this study since the Chinese government does not report the number of houses destroyed or economic loss at the city level but only the aggregated one for the Sichuan earthquake, which indicates that MMI is the only objectively available destruction measurement.

To investigate the short-run and long-run effects of the earthquake on structural transformation, I use both micro- and macro-level panel data. At the micro level, I link MMI with panel data from the end of 2007 and 2008 from the Chinese Household Income Project (CHIP), a large-scale individual level comprehensive survey including labor and income information. Since this dataset perfectly brackets the time of the Sichuan earthquake, we have individual sectoral choices and incomes both before and after the disaster. At the macro level, I integrate the district-level, city-level, and province-level macro data including GDP and employment by sectors from China Statistical Yearbook from 1991 to 2016.

This study's main contribution is that it examines whether natural disasters expedite the process of economic structural transformation, from labor-intensive or resource-intensive sectors to technology-based or productivity-based sectors. I focus on the immediate and lagged effects of the Sichuan earthquake on changes in construction, manufacturing, and service sectors' shares. This study is motivated by an idea, inspired by the previous works, assuming that natural disasters bring not only economic loss and destruction but also a chance for industrial upgrading and a turn-over of capital for later generations if policies and resources could be configurated efficiently and adequately.

The core finding of this study is that after the earthquake, the agriculture sectoral share of employment in Sichuan significantly decreases relative to unaffected provinces, and the earthquake also affected manufacturing, construction, and service differently. Not only were the immediate effects of the quake strong, but its impact on agriculture is still apparent and even more significant today.

More specifically, from micro evidence, I find that a significant portion of the labor force who were in manufacturing and agriculture sectors tends to escape to construction or broadly-defined service sector immediately after the earthquake in the area with a higher level of destruction. From the macro data, even though the effect of the destruction level on city-level employment distribution is not significant, I find a similar pattern in GDP sectoral contribution with the micro result: the GDP contribution rate from manufacturing is negatively correlated with the regional destruction level, while the tertiary sector plays a more prominent role in more damaged areas after the earthquake. However, I do find the effect of the quake on sectoral distribution of employment and GDP diminishes from the second year after the earthquake, and gradually goes to be strongly correlated with the regional development level measured by GDP per capita. I also find two facts in the sectoral wage growth and migrant employment transfer supporting that the earthquake damages the manufacturing sector while construction and service sectors relatively benefit from it. First, I discover that wage growth for the urban workers who are in the higher-destruction-level area is significantly higher, mostly due to income growth in the service sector. Second, I find that there is the same sectoral transition direction of the migrant labor force in villages as the direction from the macro evidence. Sichuan is one of the largest centers of the migrant population in China, and the economical choice from this group is a perfect barometer of the sectors' future. Thus, we could expect this sectoral distribution changes in employment and GDP will continue at least for a middle term.

My findings imply that a massive earthquake, accompanied with a timely capital inflow to the stricken area and a rapid government response, significantly affects the sectoral distribution of regional employment and GDP in both short run and long run. The thesis has four main limitations due to the data constraints: (i) I only have two year district-level GDP data but not employment of Sichuan province which prevents me from conducting robustness test in a more detailed scope. (ii) Moreover, I can only focus on short-run micro effect because of only one-year panel microdata available. (iii) I only look at the sectoral changes but not the internal upgrading of a specific industry, which cannot represent the aggregated structural transformation of an economy. (iv) Finally, the Mercalli intensity index is not a strict interval scale but rather an excellent ordinal scale. The effect of the Sichuan earthquake might be nonlinear with respect to MMI. Thus, if researchers could collect the exact number of loss and death, the results will be more comprehensive.

This thesis is structured as follows: Section 2 contains main literature reviews and the connection between this thesis and previous works; Section 3 describes the Sichuan earthquake context and the data; Section 4 provides the methodology of horizontal and vertical comparisons of this study; Section 5 presents the results and potential mechanisms; Section 6 concludes and discusses.

2. Literature Review

There have been many studies and drastic debates on whether disasters cause significant macro or microeconomic impacts as a potential impediment to economic development (Hochrainer, 2009). In specific, many studies investigate possible effects of natural disasters either on labor market or on capital transfer. Most of the research carried out these topics, starting with Dacy and Kunreuther (1969), tries to find that gross domestic product (GDP) increases after a natural disaster happens. Tol and Leek (1999) presented evidence of the positive effects of natural disasters on macroeconomic in the short run. However, few studies focus on long-term impacts of natural disasters, especially from the view of the sectoral distribution of GDP and employment. This thesis captures both the labor and capital effects to achieve an extensive evidence of structural transformation related to regional development.

Kirchberger (2017) offers a framework for my paper. By analyzing the microdata before and after an earthquake that happened in Indonesia in 2006, the author found that the quake had a positive impact on the wage growth of the agricultural sector. Kirchberger proposed two potential mechanisms to explain this: the first is the rise in food prices from the decline in the food supply in the disaster-stricken area. The other is the decline in the supply of agricultural labor: workers are going from agricultural sector to other industries such as construction or manufacturing, which may increase the marginal product of labor in agriculture. From the analysis of family survey data, Kirchberger found that it was more likely that the second mechanism explained the reality. Also, from Hallegattea and Dumasa (2009), we can see that short-term constraint, like the regional reconstruction capacity, can create "poverty traps" if natural disasters happen, and potentially lead long-run GDP losses to a very high level, preventing economic development. Therefore, the authors argue that it is essential to ensure that the capacity to fund and carry out reconstruction is adapted to the level of disaster risk.

Differently, Caselli and Coleman II (2001) builds a new model to explain the relationship between economic transformation and U.S-wide wage convergence. This model is fundamental, because it distinguishes three phenomena during the same period: "the well-known secular decline in the weight of farm goods in U.S. output and employment; the slightly less well known fact that the relative price of farm goods does not display a clear trend either downward or upward; and least well known of all, the convergence of U.S.-wide agricultural labour incomes to non-agricultural labour incomes" (Caselli and Coleman II 2001). However, traditional explanations of economic transformation (Chenery and Srinivasan 1988-95) are not consistent with the second and third phenomena, and their implications are even contrary to the observed data. Caselli and Coleman II (2001) implicitly point out that the change in wages in one sector is correlated with the employment and capital transfer among industries, which provides a theoretical basis for Kirchberger's work (2017) and my thesis.

However, there are few pieces of literature like Caselli and Coleman II (2001) does, focusing on natural disasters touching the core of long-run regional development: structural change and upgrading. Considering the ambiguity of the long-term impact of unexpected natural disasters on the economy, if we desire to figure out the effect of a particular disaster on a local region with limited time and incomplete data, instead of absolute quantity of economic index, the structure of this economy should be our focusing point. Kuznets (1966) indicates that sustained economic growth cannot happen without structural changes. A recent empirical study also demonstrates that the significant growth difference among developing countries in Latin America and Africa can be attributed to the contribution of structural transformation to aggregate labor productivity (McMillan and Rodrik, 2011). An unpredictable natural disaster like an earthquake can lead to a discontinuity of the development of an economy. More specifically, every country's growth faces some binding constraints based on location and time (Hausmann, Rodrik, and Velasco, 2005). Thus, I infer that random events like natural disasters will disrupt some of these binding constraints in short run, and exert a potential long-run influence, building a good environment for a dynamic optimum instead of standing in a static one. Therefore, a natural disaster with proper policies could expedite the process of creating conditions for "sustainable economic growth." Cuaresma, Hlouskova, and Obersteiner (2008) found that only countries with relatively high levels of development benefit from capital upgrading through trade after a natural catastrophe. However, like Sichuan in China, a least developed region in a moderate developing country with a strong ability of capital transfer could benefit from natural disasters in the aspect of structural transformation of employment and GDP.

3. Context and Data

3.1. Context

To investigate the effects of natural disasters on economic structural transformation, I analyze the effect of an extremely brutal earthquake happened in Wenchuan, Sichuan, China, approximately 1550km southwest of Beijing on May 12th, 2008. This event occurred on one of the tectonically related faults that run along the base of the Longmenshan Mountains marking the boundary of the Tibetan plateau. The fatalities approached 71,000 and millions were injured or left homeless. Thousands of buildings and bridges were destroyed (H.K. Miyamoto, A.S. Gilani, and Akira Wada 2008).

The reason why this natural disaster caused so many deaths and more than 125 billion US dollars direct economic loss is that Sichuan province had previously been considered a moderate earthquake zone by the Chinese Building Code, and hence, the level of damage was not anticipated in the construction of these buildings. Also, according to the data from the analysis report created by United Nations for this earthquake, building and infrastructure destroyed took more than half of the economic loss from the damage of this disaster (United Nations Center of Regional Development 2009).

Admittedly, many factors contributed to the unprecedented level of devastation and fatality. For the collapsed buildings, the lack of ductility, the absence of a clear load path, and the building irregularity were primary contributors. Many schools used a hybrid structural system comprised of masonry columns, concrete beams, and hollow precast decks. This system was responsible for a disproportionate number of collapsed buildings (H.K. Miyamoto, A.S. Gilani, and Akira Wada 2008). Moreover, also, these collapsed buildings were the significant causes of death for the 69226 disaster victims (United Nations Center of Regional Development 2009).

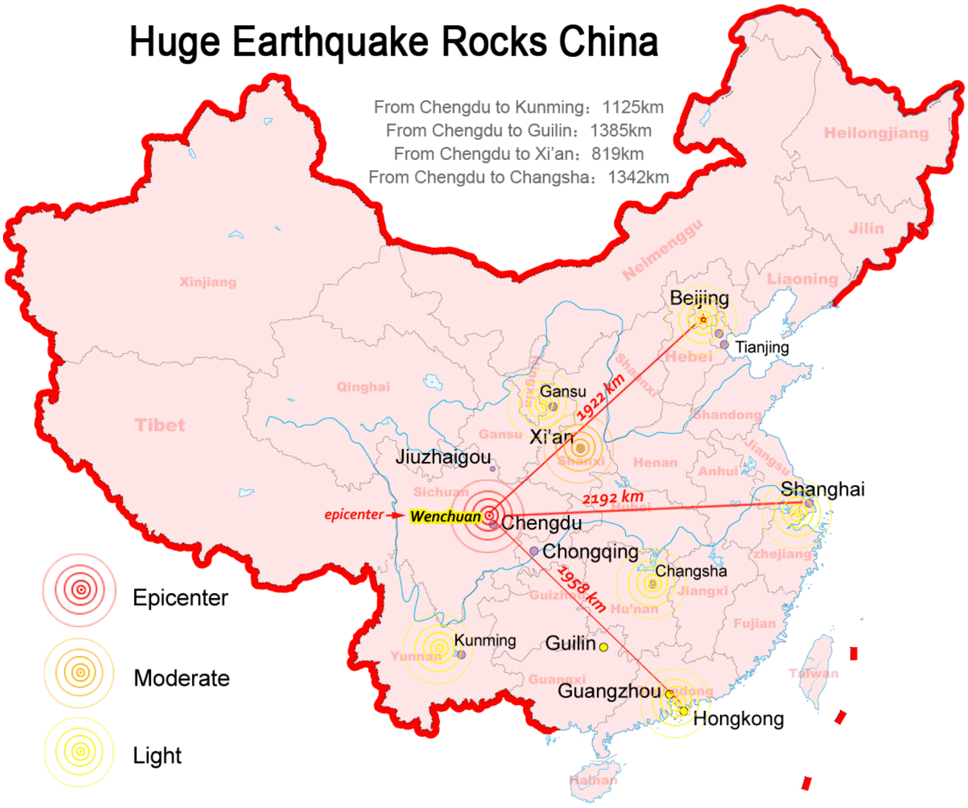

Figure 1. Sichuan Earthquake, 12 May 2008. Source: Google Image

3.2. Data

I integrate data from several sources. First, to measure the destruction severity of the disaster for each district in Sichuan, I use Shake-map data from the United States Geological Survey (USGS) since might be highly correlated with other unobservable variables that also affect structural transformation. Specifically, the Shake-map reports the instrumental intensities of an earthquake, Modified Mercalli Intensity (MMI) scale, ranging from 1 to 10, which has been used by many environmental economists. Therefore, each district in the disaster-stricken area is assigned an MMI scale. I choose MMI instead of commonly-known Richter scale because MMI is a linear measurement but Richter scale is a logarithmic. The Mercalli scale bases its measurement on the observed effects of the earthquake and describes its intensity. Fig. 1 shows the epicenter of the earthquake and the distance between it and major metropolises; Fig. 2 is the Shake-map of the Sichuan Earthquake. The different colors indicate the level of destruction, MMI, in each area, ranging from rare destruction (blue: level 3) up to extreme catastrophe (red: level 9).

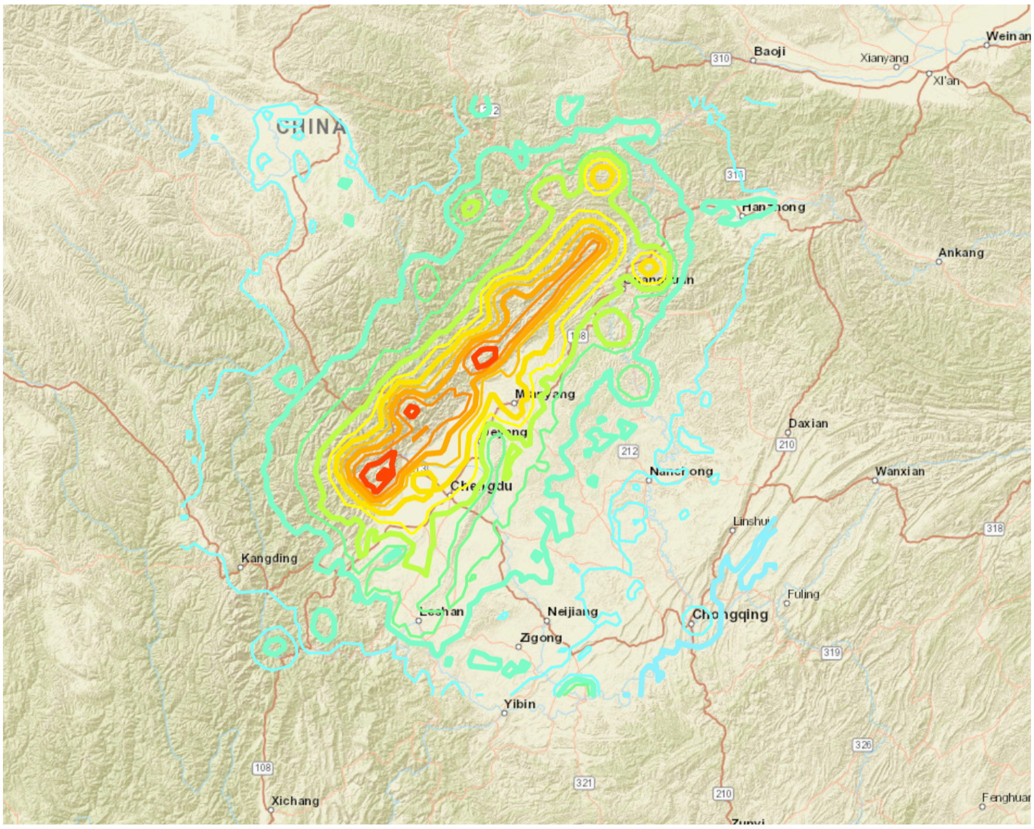

Figure 2. Sichuan Earthquake, 12 May 2008. Source: ArcGIS; date from the U.S. Geological Survey. The colors of the curves indicate the modified Mercalli intensity scale of the earthquake at different cities and towns. Darker (red) color means higher levels of damage.

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest,especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Figure 3. Level Description of MMI. Source: (The Modified Mercalli Intensity Scale 2018)

MMI was developed in 1931 by the American seismologists Harry Wood and Frank Neumann. This scale, composed of increasing levels of intensity that range from imperceptible shaking to catastrophic destruction, is designated by Roman numerals. It does not have a mathematical basis; instead, it is an arbitrary ranking based on observed effects (The Modified Mercalli Intensity Scale 2018).

Both of my micro and macro studies use MMI as the significant explanatory variable, which assigns a destruction-level stamp from the earthquake to the individual, district, and city. Figure 3 shows the standard of each level of the modified Mercalli intensity scale.

I run regressions in several datasets to achieve comprehensive evidence of structural transformation. Table 1 shows the detailed information for each dataset I use, including names, sample size, source, year range, variables included, and whether it integrates the MMI scale. Since I use three different levels of macro data, I create a tree diagram of China and Sichuan Administrative level Explanation shown below in Figure 4, to show the relationship between each level of data.

Table 1
Datasets Description

Source	#	Survey Name	Sample Size	district MMI
CHIP	1	City Questionnaire	1643 city individuals	✓
	2	Rural Questionnaire	4023 rural individuals	✓
	3	Rural Village Survey	110 villages in Sichuan	✓
China Statistical Yearbook	4	Sichuan District-level	181 Districts in Sichuan	✓
	5	Sichuan City-level	21 cities in Sichuan	✓
	6	China Province-level	31 provinces in China	×

Source	#	Year Range	Variables Included
CHIP	1	2007-2008	Employment status, sector info, monthly wage, and weekly working hours
	2	2007-2008	Employment status, sector info, monthly wage, and weekly working hours
	3	2007-2008	Village employment distribution, wage info
China Statistical Yearbook	4	2007-2010	Sectoral distribution of GDP and GDP per capita
	5	2007-2015	Sectoral distribution of GDP and Employment, and GDP per capita
	6	1997-2016	Sectoral distribution of GDP and Employment, and GDP per capita

Note: All my datasets are available for other researchers and the sources are listed in the Appendix B.

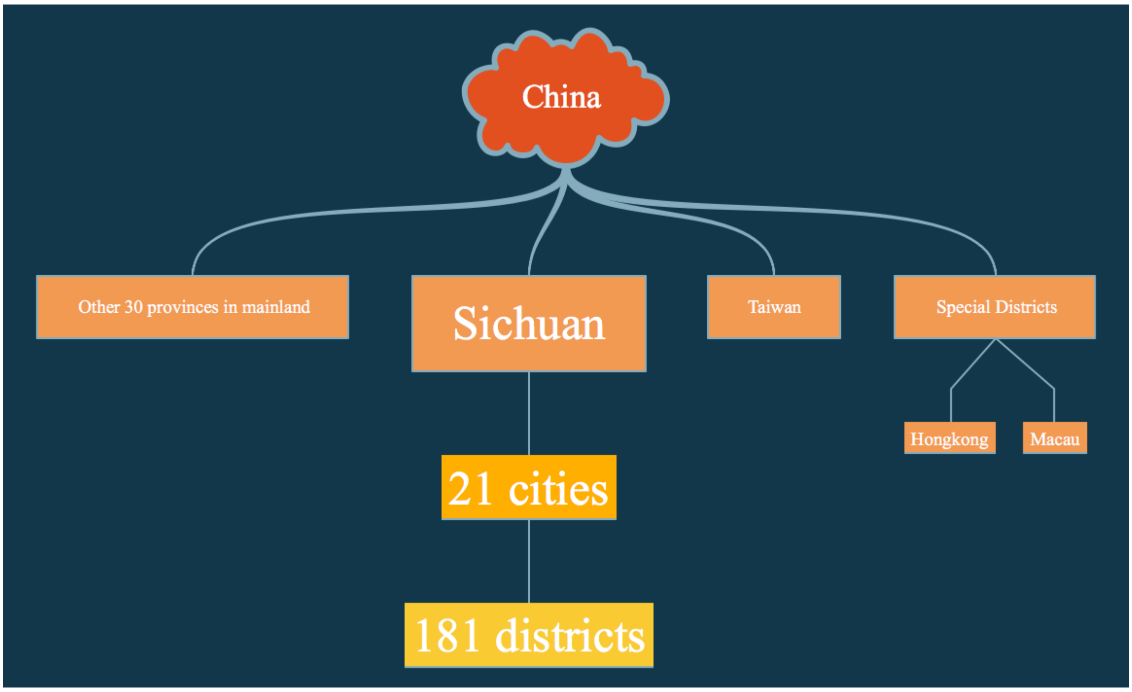

Figure 4. China and Sichuan Administrative level Explanation

In the analysis of individual-level data, I use the Chinese Household Income Projects (CHIP), a large-scale cross-sectional household survey. However, fortunately, since two datasets from CHIP conducted at the beginning of 2008 and 2009, named CHIP 2007 and CHIP 2008, were collaborated and overlapped with the Rural-Urban Migration in China project (RUMiC), they are panel data of individuals, villages, and cities. Besides, they perfectly bracket the Sichuan Earthquake, on May 12th, 2008. CHIP includes the basic situation of the family, underlying conditions of family income-producing members, wage income, the additional income of the whole family, family expenditure and so on. For rural households, the survey also includes the assets and liabilities of farmers, products, sale and consumption, purchasing agricultural produced goods and so on (Ou and Li 2018). The panel dataset in Sichuan for 2007 and 2008 have two parts: the rural sample contains 4023 individuals and 110 administrative villages which represent more than 80% of the rural population, and the urban sample contains 1643 urban individuals in Sichuan province.

Although rural and urban parts of the CHIP survey ask similar questions, there are some differences in employment sector information. First, the rural questionnaire did not ask whether the respondents were employed or not, but only separated them to farm or non-farm category. Hence I classify all individuals without a non-farm job to agriculture sector for simplification. In both rural and urban analysis, the service sector means all industries except for agriculture, manufacturing, and construction, which is slightly different from the classification in macro study when I look at aggregate statistics. Therefore, in the micro-level rural analysis, the results of employment and wages in agriculture are not very meaningful, but they do not affect the outcomes of labor transition of other sectors.

When computing individual hourly wages for complement tests, following Strauss (2004), I divide monthly reported earnings by the approximate total number of hours worked per week, multiplied by 4.33. Since some individuals in my sample reported no earning or negative earning for some reasons, as Kirchberger does, I restrict my sample to those with positive earnings in 2007 and use the change in earnings as a percent of earning in 2007 as the dependent variable, only keep from 1st to 99th percentiles to eliminate outliers and extreme cases. This operation gives me a rural sample of 858 individuals and an urban sample of 641 individuals, for whom I have full information both at the end of 2007 and 2008. In the study of rural villages, 45 of them did not report migrant employment data either in 2007 or 2008 or both, so the observation number for village migrant analysis is only 65 villages, compared to the full sample size of local analysis.

In the macro-level study, I would clarify the different classification of sectors of an economy first. In China, the statistical bureau and research institutes are used to collect data by using the "Three-sector model in economics" (Fisher 1939) for convenience. The three-sector model in economics divides economies into three sectors of activity: extraction of raw materials (primary), manufacturing, construction, and mining(secondary), and services (tertiary) (Wikipedia 2018). To prevent confusion, I use "primary, secondary, and tertiary" terms in the macro analysis and exact sector names like service, construction, and manufacturing in the micro analysis. The relationship between three-sector classification and standard sector classification is shown in Figure 5 below.

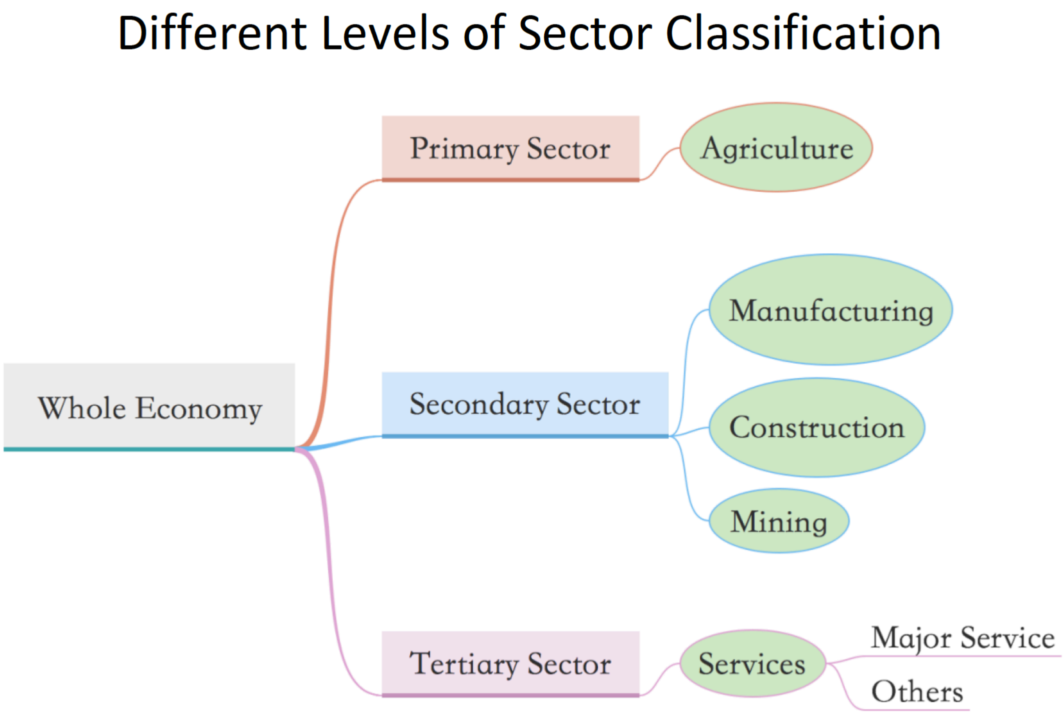

Figure 5. Different levels of sector classification

I use data from China Statistical Yearbook (CSY) between the year 1997 and 2016, an annual statistical publication, which reflects the macroeconomic and social development of mainland China (Ou and Li 2018) comprehensively. It includes statistics from 31 provinces in mainland China. Specifically, the numbers of employed persons and wages by types of sectors for each district and city are grabbed to conduct a fixed effects analysis. It is worth mentioning that in Sichuan Statistical Yearbook, the employment sectoral distribution data is only available at the city level but not the district level. The GDP contribution data is available both for the city and district level. Therefore, I use GDP data by industry as a supportive evidence for observing structural changes. Observations include all 22 cities and 181 districts in Sichuan province. Since annual data from CSY is collected at the end of each year, I set the year 2007 as the baseline year when one and half years before the Sichuan earthquake happened. As a convention, in the synthetic control provincial analysis, I use Sichuan data collected at the end of 2007 as the treatment period since the earthquake happened before the collecting date of the 2008 data.

There are two manipulations of data I have to remark here: in the province-level analysis by using the synthetic control method, the observations from CSY includes all 30 administrative provinces of mainland China, except for Qinghai province since there was another severe earthquake happened there in 2010. In the city-level analysis, because the Mercalli index is only accurate at the district level, I create a new GDP-weighted MMI for each city, weighted by the district GDP contribution to city GDP.

4. Conceptual framework and Methodology

This section presents a framework showing the potential effects of natural disasters on structural transformation and the methodology I use in this thesis. I conduct this study by using both horizontal and vertical comparisons. In the horizontal comparisons, I compare the effect of the Sichuan earthquake on different districts and cities in the affected area in the same year. In the vertical comparisons, I show the macro impact of the Sichuan earthquake on one region in both short-term and long-term periods.

There are three assumptions in this study. First, I assume that while the location of an earthquake is non-random since some areas are more earthquake-prone than others, the timing of an earthquake is relatively random so that nobody including governments could predict them. Therefore, individuals, firms, and powerful entities cannot pre-arrange or change their capital, assets, and physical status before the earthquake strikes. Second, though we cannot see the productivity increase from technology explicitly from employment distribution data, they reveal the willingness of labor to switch sectors which could implicitly reflect sectoral demand for labor, the current and future capacity, and the potential development momentum. Third, I assume that the sectoral distribution of GDP shows the current economic structure. Taking into account China's national conditions, the Central Government in Beijing would take active measures to ensure the employment of the people in the disaster areas, hence sometimes employment data collected at the end of the year cannot represent the real structural changes. Therefore, an analysis of the sectoral distribution of GDP would be a good complement, giving us a more comprehensive picture. If employment and GDP shift toward the same sector, this is a reliable indicator of structural transformation.

To capture the structural transformation due to the earthquake, I first look at the effect on aggregated labor supply and demand. Secondly, I examine this effect on each sector and whether there is an inter-industry transfer of labor. At the same time, I focus on how the disaster affected sectoral GDP contribution in both short and long terms. Finally, I explore the potential relationship and mechanisms in the sectoral distribution of employment and GDP and structural transformation.

A direct intuition emerges as the fact that the earthquake makes both aggregated supply and demand for labor decrease because of the massive amount of deaths and injuries. However, in most cases, the effect on demand during the reconstruction period is ambiguous since we cannot determine the trade-off between the aid-capital inflow and the direct loss of capital. Besides the direct data of employment, the behavior of wages---the price of labor---could also tell us how the employment exactly goes. I would find supportive evidence of employment transition from wage changes in a robustness test.

$$Sector_k\_Post_c = \beta_0 + \beta_1 M_c + \varepsilon_c$$

Equation (1)

For individuals in CHIP c = 1, …, N
and sectors include agriculture, manufacturing, construction, and service where

$Sector_k\_Post_c$ is the dummy variable of post-earthquake employment sector, which is 1 if individual c in the sector k after the earthquake and is 0 if he or she is not.
M_c is a measure of destruction from the earthquake, MMI, and
ε_c is the error term.

Before studying the effect of the degree of damage from the earthquake on a particular sector, I would examine whether there exists an inter-industry employment transfer among different industries by creating employment transition matrices with simple OLS regression in Eq.(1) on Mercalli intensity for each sector of pre-earthquake employment. For each of k sector of origin, I ran linear probability regression for each destination sector. Each regression gives the probability of being in the destination sector after the earthquake, conditional on origin sector and earthquake intensity. Since the panel individual-level data are only available from 2007 to 2008 and separated to rural and urban parts, I mainly explore the instantaneous effect of the earthquake shock separately on two kinds of areas.

To estimate the impact of the Sichuan earthquake on the share of the labor force in each sector, first I would use simple ordinary least squares (OLS) model with MMI as the major independent variable for both micro and macro-level analysis. The results from this regression should therefore always be interpreted as the effect of the destruction severity from the earthquake on individuals, cities, and districts of a particular sector and period. First

$$\Delta Prop_{v2} = \beta_0 + \beta_1 M_v + \varepsilon_{v2}$$

Equation (2)

For villages in CHIP v = 1, …, N and
For districts and cities in CSY v = 1, …, N where

Prop is the proportion of individuals employed in a particular sector or a sectoral contribution to the GDP,
M is a measure of destruction from the earthquake, MMI, and
ε_{v2} is the error term.

I picked two years, 2007 and 2008, and I denoted the pre-earthquake data in 2007 at t=1 and the post-earthquake in 2008 at t=2. Then I computed the changes of the proportion of labor or sectoral GDP contribution between these two years, to run the regression on MMI across geographical units on the following specification in Eq.(2) as Kirchberger (2017) does:
I expect that the aid money and foreign labor from other provinces would be concentrated in construction and service sectors when the agriculture and manufacturing sectors would suffer most in the earthquake due to the destruction in factories and infrastructure. If we assume that labor is a complement of capital, I expect that the agriculture and manufacturing sectoral shares in both GDP and employment would decrease while the construction and service sectoral shares would increase. I would conduct this simple OLS regression in Eq.(2) on GDP and employment for every sector, by using both CHIP and CYS data.

However, intuitively we know that sector distribution is highly correlated with development level, especially the portions of secondary and tertiary sectors in an economy. Furthermore, the adverse effect of the earthquake on a more developed area is likely to be much severer since a more substantial portion of infrastructure and labor is destroyed and the direct economic loss is more prominent than less developed region. Therefore, in the empirical process, I add the regional development level, measured by the natural logarithm of GDP per capita to the independent variable group, specified as follows:

$$\Delta Prop_{v2} = \beta_0 + \beta_1 M_v + \beta_2 D_{v1} + \varepsilon_{v2}$$

Equation (3)

For districts and cities in CSY v = 1, …, N where

Prop is a certain sector contribution to the GDP as a percent of whole Sichuan GDP,
M is a measure of destruction from the earthquake, MMI, and
D is the development level measured by the log of GDP per capita on the baseline year 2007, and
ε_{c2} is the error term.

After the studies within the Sichuan province, jumping into the bigger picture, I would use synthetic control method (SCM) to compare the evolution of the aggregate distribution over time between Sichuan, as a treated unit by the earthquake, and other provinces in mainland China. There are two reasons why I use synthetic control: in the traditional difference-in-difference comparative study, there is always some degree of ambiguity about how comparison units are chosen (Abadie, 2010). Second, after considering every other province on the same earthquake prone, I concluded that no single one could be a proper control unit since their economy structures before the earthquake are all different.

The primary interest of this study is whether natural disasters would expedite the process of structural transformation. The primary sectoral share of employment is known as one of the major indicators of regional development. I would choose the primary sectoral share of employment as the dependent variable to construct the synthetic Sichuan as the convex combination of provinces from the rest provinces in mainland China. The predictors are average employment distribution shares of the other two sectors, secondary and tertiary, GDP contributions of the primary and secondary sectors, and the natural logarithm of GDP per capita. These variables are averaged over the 1997-2006 period and enhanced by adding two years (1997 and 2001) of the lagged primary sectoral share of labor. Therefore, I construct a synthetic Sichuan that mirrors the economic structure status in Sichuan before the 2008 earthquake happened. It would reflect both short-term and long-term effect of the quake on macro employment and GDP at the provincial level, which complements the micro results in vertical comparison over time. I then estimate the impact of the earthquake on primary, secondary, and tertiary sectoral shares of employment as the difference in sectoral shares between Sichuan and its synthetic versions in the nine years after the earthquake happened.

Integrating all these approaches, I would discover the combined effect of the destruction and redevelopment shock on an economy's structural transformation. Though in the long term, overall productivity per capita is the fundamental engine of the economic development, countries---provinces in this thesis---at different levels of development tend to have different structural distributions due to differences in their endowments (Lin, 2012). I say that those provinces with high-level of development often have sufficient capital, not natural resources or labor, which is revealed in the prosperity of secondary and tertiary sectors. GDP and employment, two major macroeconomic indexes, play substantial roles related to economic endowments. Specifically, to some extent, employment distribution represents the current structure of labor and GDP sectoral contribution reflects the future structure of capital flow. Thus, I expect to see same trends and directs in GDP sector contribution changes and employment distribution changes from the earthquake in levels of destruction, which likely implies the existence of structural transformation due to natural disasters.

Finally, observed from other empirical studies, the effect of natural disasters tends to diminish over time. However, typically, if individuals experience higher levels of income or industries, they are less likely to move downward and so do the government. This consistent expectancy between market entities and government probably leads to create a time-persistent effect on economy's structure. In particular, Sichuan is a province with significant amounts of migrant population, which is greatly emphasized by the central government to maintain the stability of the society. Hence more resources and aid capital inflow to Sichuan so that it is more likely to keep the effect of natural disasters on structural transformation over time.

5. Empirical Results

I would describe the results on the order of the datasets I use. First, I present the results from micro CHIP dataset, in which I focus on the effect of the earthquake destruction level on employment sectoral distribution and the inter-industry transfer of labor. Then I show that the results from macro CSY dataset show the consistency to the results from micro eyes. Besides, I investigate the effect of natural disasters on sectoral GDP contribution of each city or district. Further, I test whether these effects diminish over time, considering the latter resilience ability of Sichuan province aimed by China's central government. I proceed by presenting the broader result from comparing the employment distribution of the Sichuan province with that of the synthetic control group. I explore the potential mechanisms that cause the effects throughout the whole section.

Table 2
Rural Employment Transition Matrix.
Dependent variable:
Independent variable: Modified Mercalli intensity (MMI)

	Post-earthquake employment sector			
	Agriculture	Manufacturing	Construction	Services
Pre-earthquake employment sector				
Agriculture	-0.009	0.003	0.001	0.005
Obs.	2865	2865	2865	2865
Manufacturing	0.025*	-0.039**	0.013	0.001
Obs.	407	407	407	407
Construction	0.019	-0.042**	0.061**	-0.038*
Obs.	259	259	259	259
Services	-0.002	-0.030**	-0.002	0.034*
Obs.	492	492	492	492

Notes: I classify all rural individuals who do not have a non-farm job to agriculture sector for simplification since the rural questionnaire neither ask whether an individual is employed or not nor ask whether they belong to farm works or agriculture sector.
* significance at 10% level.
** significance at 5% level.
*** significance at 1% level.

5.1. Micro results

Table 2, a rural employment transition matrix, shows the detailed effects of the earthquake's destruction level on the inter-industry transfer of labor, focusing on the rural area from the CHIP dataset. Rows in the matrix depict sub-samples for pre-earthquake employment categories when Columns represent individual's post-earthquake employment sectoral status in each sub-sample. Every entry shows the result from the independent ordinary least squares (OLS) regression on modified Mercalli intensity, in which the dependent variable is the dummy variable of each post-earthquake employment categories (as described in Eq.(1)). I classify all rural individuals who do not have a non-farm job to agriculture sector for simplification since the rural questionnaire neither ask whether an individual is employed or not nor ask whether they belong to farm works or agriculture sector. Also, I created a similar employment transition matrix for urban individuals sampled in CHIP, but the sectoral distribution of the urban dataset is abnormal which cannot represent the population. I put the results from the urban sample in Table A-5 in the appendix.

We could see that for the labor force who were in manufacturing sector at the end of 2007 before the earthquake, because of the earthquake, the labor retention rate of the higher-damage areas is significantly lower than that of the lower-stricken areas for both rural and urban, with decreasing probability of 0.039 and 0.135 per level of Mercalli intensity (MMI), respectively. The loss of labor in the manufacturing industry further confirms the direct damage of natural disasters to this industry. On the contrary, as we expect, the labor retention rate of the construction sector is positively correlated with the MMI, increasing probability of 0.061 and 0.036 per level of MMI for rural and urban respectively. At the same time, the urban unemployed group before the earthquake also significantly began to engage in working at the construction industry after the earthquake, positive 0.011 per level of MMI. Moreover, the labor force who engaged in the service industry in the more affected areas is more inclined to stay in the industry, especially significantly for rural individuals with increasing probability of 0.034 per level of MMI. After the earthquake, the least popular working destination is the manufacturing industry since all people tend to leave or not choose to go to this sector when they experience a higher level of destruction. A little surprisingly, I do not find a significant effect of the intersectoral transfer of labor in the agriculture sector, in either rural or urban area.

I next further explore more evidences from another survey in CHIP dataset, the village-level interview. This survey asks village heads or administrative officers in 110 villages in Sichuan province, which provides employment data separated to local and migrant categories.

Table 3 shows the results from this village-level interview as outlined in Eq.(2). Column (1)-(2) represent information of local and migrant labor force. Each row depicts the effect on each sector. Due to the economic endowment structure of Sichuan before the earthquake and China's unique fixed household registration system, the degree of earthquake destruction has no significant effect on the distribution of local rural employment. The growth in the village-level share of the population employed in the major service sector decreased significantly, implying that one level increase in Mercalli intensity led to a 0.742% lower growth in the percentage of individuals employed in major service. We can reasonably say that this is caused by the reduction in the local labor supply to the service industry from the population reduction in the higher-destruction area.
On the other hand, Sichuan Province is one of the largest gathering places for China's migrant population whose natural mobility is relatively responsive to natural disasters. I do find the impact of the Sichuan earthquake on the sectoral employment transition. First, the earthquake made migrants flee from agriculture and manufacturing. One level increasing in MMI reduces the share of employment in agriculture by 10.997 percentage points and in manufacturing by 5.285 percentage points. It is also remarkable that the proportion of labor in the construction sector has increased by about 12.368% per level of MMI. This suggests that most of the migrant population has moved to the industry which focuses on the redevelopment and reconstruction, which is consistent with the results of previous empirical analysis: a large number of economic losses increase the labor force demand for the construction and service industries and a large amount of foreign aid capital is concentrated here, resulting in an increase in the number migrant labor force.

Table 3
Dependent variable: Employment changes in sectoral shares
Independent variable: Modified Mercalli intensity (MMI)

	Local types by origins	
	Locals	Migrants
% Agriculture	0.865	-10.997**
	(1.249)	(4.177)
% Manufacturing	-0.649	-5.285*
	(0.668)	(2.715)
% Construction	0.150	12.368***
	(0.617)	(3.669)
% Major service	-0.742**	2.055
	(0.360)	(2.379)
% Other	0.376	1.859
	(0.823)	(2.506)
Observations	110	65

Notes: 45 villages did NOT report migrant employment distribution either in 2007 or 2008 or both, so the observation number for migrant analysis is only 65 villages. Major service includes wholesale trade, retail trade, and catering.
* significance at 10% level.
** significance at 5% level.
*** significance at 1% level.

The main result so far is that the earthquake leads to a significant decreasing portion of the labor force in the manufacturing sector and an increasing portion in the construction and service sectors. To further confirm the findings, I study the effect of the earthquake destruction level on changes in hourly wages as a percent of baseline wages as Kirchberger does, shown in Table 4. Though it is not significant in the rural area, it suggests that workers in urban who were employed in service sector at 2008 affected by the higher level of destruction from the earthquake has significantly higher wage growth (6.998% increase per level of MMI) than those who were affected less. So do all workers in all sectors (7.345% increase per level of MMI). Through the employment transition matrix, we know that the labor retention rate of the service industry in the severely affected areas is higher than that of other industries. The wage growth is also higher than other industries. Hence we can infer that after the Sichuan earthquake, most of the government and private aid capital not only flow into the redevelopment of infrastructure and housing but also turn to services that may provide the basis for "software reconstruction," such as medical care, food retailing, and so on.

Table 4
Changes in hourly wages as the percentage of baseline wages.

		Pre-earthquake employment sector			
	Full sample	Agriculture	Manufacturing	Construction	Services
Rural	(1)	(2)	(3)	(4)	(5)
Mercalli intensity	-0.368	19.710	-1.777	2.288	-0.121
	(1.146)	(13.64)	(1.907)	(2.454)	(1.825)
Observations	858	11	184	317	341
R^2	0.001	0.188	0.003	0.005	0.003
Urban	(6)	(7)	(8)	(9)	(10)
Mercalli intensity	7.345***	-5.832	10.430	2.803	6.998**
	(2.679)	(20.373)	(7.380)	(23.216)	(2.956)
Observations	641	12	72	19	538
R^2	0.012	0.008	0.028	0.001	0.010

Notes:
* significance at 10% level.
** significance at 5% level.
*** significance at 1% level.

Till now, from the micro evidence, I find that in the short term, due to the immediate damage caused by the earthquake, the probability that the labor force will escape from manufacturing and agriculture to the construction industry or a wide range of service industry is significantly higher in higher damaged areas. Similarly, the manufacturing and agriculture sectoral employment shares decrease with the level of destruction while the construction and service sectoral employment shares increase. In addition, this effect is especially amplified among the migrant labor force.

5.2. Macro results

From the macro perspectives, I start by presenting the results of the effects of the natural disaster on district-level GDP sectoral contribution. Since I only have accurate Mercalli Intensity index at the district level, I mainly discuss the district-level results and outline city-level results and other supportive evidences, which are presented in detail in the Appendix.

Table 5: A district-level analysis
Dependent variable: GDP Changes of Sectoral Shares

	% Primary	% Secondary		% Tertiary
		Total	Manufacturing	
from 2007 to 2008				
Mercalli intensity	0.445***	-0.928***	-0.935***	0.483***
	(0.114)	(0.193)	(0.225)	(0.145)
R^2	0.079	0.115	0.088	0.058
from 2007 to 2009				
Mercalli intensity	0.686***	-0.750***	-0.843***	0.064
	(0.174)	(0.266)	(0.281)	(0.208)
R^2	0.080	0.043	0.048	0.001
from 2007 to 2010				
Mercalli intensity	0.814***	-1.276***	-1.075***	0.462**
	(0.213)	(0.317)	(0.350)	(0.230)
Observations	181	181	181	181
R^2	0.076	0.083	0.050	0.022
Observations	181	181	181	181

Notes:
* significance at 10% level.
** significance at 5% level.
*** significance at 1% level.

Table 5 shows the effect of the earthquake on macro GDP changes of sectoral shares at the district level. The first, second, and fourth columns depict primary, secondary, and tertiary sectors, and the third one represents the second-level sector---manufacturing---within the secondary sector. As shown in the table, I choose the year 2007 as the baseline year and compare the effect of the earthquake on GDP sectoral contribution for three years after the event happened, 2008, 2009, and 2010. According to the micro results I got before, it is not surprising that this table shows districts where experienced severer destruction, on average, have higher first and tertiary sectoral contribution to local GDP and lower secondary contribution, especially decreasing in the manufacturing industry.

However, I was doubtful that whether this effect could last more than two years after the earthquake happened and we know that sector distribution is highly correlated with development level, especially the portions of secondary and tertiary sectors in an economy. Therefore, as introduced in Eq.(3), I added the regional development level, measured by the natural logarithm of GDP per capita, as a control variable. The results of the new model are presented in Table 6.

Table 6: district-level analysis with baseline GDP per capita
Dependent variable: GDP Changes of Sectoral Shares

	% Primary	% Secondary		% Tertiary
		Total	Industry	
from 2007 to 2008				
Mercalli intensity	0.417***	-0.914***	-0.992***	0.497***
	(0.122)	(0.208)	(0.242)	(0.156)
Log(GDP/capita)	0.013	-0.007	0.027	-0.007
	(0.021)	(0.036)	(0.042)	(0.027)
R^2	0.081	0.115	0.090	0.059
from 2007 to 2009				
Mercalli intensity	0.356**	-0.331	-0.538*	-0.025
	(0.175)	(0.274)	(0.297)	(0.223)
Log(GDP/capita)	0.154***	-0.196***	-0.142***	0.041
	(0.030)	(0.047)	(0.051)	(0.038)
R^2	0.198	0.127	0.088	0.007
from 2007 to 2010				
Mercalli intensity	0.318	-0.601*	-0.526	0.283
	(0.206)	(0.313)	(0.361)	(0.245)
Log(GDP/capita)	0.231***	-0.315***	-0.256***	0.083**
	(0.035)	(0.054)	(0.062)	(0.042)
R^2	0.255	0.231	0.133	0.043
Observations	181	181	181	181

Notes: the unit of GDP per capita is thousand RMB.
* significance at 10% level.
** significance at 5% level.
*** significance at 1% level.

Most of the signs of significant coefficients of MMI entries have not changed while the magnitudes of them decrease after I introduce the control variable. For example, the coefficient of the MMI on the primary sectoral share of GDP decreases from 0.445 to 0.417. This phenomenon suggests that the net effect from the earthquake on GDP sectoral distribution shift is not as strong as we expected but toward the same direction. In the meanwhile, the significance of MMI started to diminish from one year after the earthquake and the sectoral contributions to GDP went back to be correlated with the regional development level, measured by the log of GDP per capita. This result suggests that the effects of the earthquake on GDP sectoral contribution within the Sichuan province is temporary and the resilience of districts are immediate. There exists a convergence of the GDP sectoral contribution among districts with distinctive levels of destruction but in similar development levels.

Furthermore, I notice that there might be an interaction between Mercalli intensity and the level of regional development since it is reasonable to infer that a more developed area would suffer more direct economic losses from destroyed buildings and hard capital loss than a less-developed one. Thus, in Table A-1 in the appendix, I include the interaction term of MMI and the natural logarithm of district GDP per capita minus the average of it to the model. Table A-1 suggests that there indeed exists an interaction effect of the earthquake on secondary and tertiary sector GDP contribution changes, especially from 2007 to 2009 and 2010. Hence after two years from the Sichuan earthquake, there were few overall effects of either MMI or GDP per capita, but there is a crossover interaction. The effect of MMI on the GDP sectoral distribution is opposite, depending on the level of regional development, which is consistent with the conjecture above.

Also, Table A-2 shows that even after adding the control variable and the interaction term, the effect of the destruction level of the earthquake on GDP growth ratio, calculated by dividing annual GDP by the baseline year GDP minus 1, is significantly negatively large over time. This result implies that while the effect of the earthquake on aggregated GDP growth is relatively median-term, the convergence of the sectoral contribution does happen across different destruction-level areas.

Besides, I conduct several robustness tests, related to an important concern of whether the macro results we have from the district-level data are consistent with other levels'. The results are briefly described here, and all statistics are available in Table A-3 and A-4 I run the same regressions specified in Eq.(2) and Eq.(3) in city-level data by creating a new GDP-weighted MMI for each city weighted by the district's GDP contribution to its city's GDP. I found there is no significant effect of the earthquake on city-level employment distribution, either in short or medium term. However, the effects on GDP sectoral contribution derived from the city-level data shows the consistency with the ones derived from district-level data: in higher-destruction city, the secondary contribution to Sichuan GDP is fewer and the tertiary contribution is bigger, when the effects of the earthquake destruction on GDP sectoral contribution are only significant in a short term, one year after the earthquake happened. Throughout the instant earthquake-effective window, about two years after the disaster, the sectoral contribution to GDP went back to link with the regional development level again. Overall, the results are similar when I use different levels of macro data in Sichuan province.

5.3. Results of synthetic control

After studying the effects of the earthquake economy structure within the affected areas in Sichuan, besides the traditional difference-in-differences technique, I apply another useful tool, the synthetic control method designed by Abadie, Diamond, and Hainmueller (2010), to examine this kind of effects in a bigger picture, seeing Sichuan province as one treated entity. As I mentioned the conceptual framework and methodology section, since the rest of the provinces in China have different regional economic structures and some of them experienced other kinds of natural disasters before and after the 2008 Sichuan earthquake happened, they may not provide a suitable control group for Sichuan to study the effects of the 2008 earthquake on structural transformation. To evaluate the effect of the earthquake on employment sectoral distribution that we are mainly interested in, the central question is how the employment distribution would have evolved in Sichuan after 2008 in the absence of the earthquake. Imitating the previous studies by Abadie, Diamond, and Hainmueller (2010), I construct the synthetic Sichuan as the linear combination of provinces from the rest provinces in mainland China by choosing primary sectoral share of employment as my major-interested dependent variable. The predictor comparison is presented in Table 7 which compares the pre-treatment characteristics of the real Sichuan with these of the synthetic Sichuan. We can see from Table 7 that the synthetic Sichuan provides a relatively accurate value in predictor variables had in Sichuan prior to the time of the disaster that happened in 2008.

Table 8 gives us the exact weights of each control province in the synthetic Sichuan. The weights in the table point out that the trend of the primary sectoral share of employment in Sichuan before the 2008 earthquake is best reproduced by a mix of Guangxi, Jiangsu, and Jiangxi provinces. All other provinces are assigned zero weights and Qinghai, as explained before, is dropped out of our selecting pool because it experienced another severe earthquake in 2010. Figure 6 is a map of the areas included and excluded in the synthetic control, which provides a detailed visualized version of the results.

Figure 1. Map of the areas used and unused in the synthetic control

Table 7: Primary Sectoral Share of Employment Predictor Means

Variables	Sichuan	Synthetic Sichuan
Secondary sectoral share of employment	18.61	17.26
Tertiary sectoral share of employment	26.05	27.26
Primary sectoral contribution to GDP	22.68	22.65
Secondary sectoral contribution to GDP	41.69	40.25
Ln(GDP per capita)	8.69	8.82
Primary sectoral share of employment 1997	61.9	60.29
Primary sectoral share of employment 2001	55.6	56.73

Note: All variables except the lagged sectoral share of employment are averaged for the 1997-2006 period.

Table 8: Province Weights in the Synthetic Sichuan for Emphasis on Primary

Province	Weight	Province	Weight
Anhui	0	Jiangsu	0.190
Beijing	0	Jiangxi	0.077
Chongqing	0	Jilin	0
Fujian	0	Liaoning	0
Gansu	0	Ningxia	0
Guangdong	0	Qinghai	-
Guangxi	0.733	Shannxi	0
Guizhou	0	Shandong	0
Hainan	0	Shanghai	0
Hebei	0	Shanxi	0
Heilongjiang	0	Tianjin	0
Henan	0	Tibet	0
Hubei	0	Xinjiang	0
Hunan	0	Yunnan	0
Inner Mongolia	0	Zhejiang	0

Figure 7 shows the primary sectoral share of employment for Sichuan and its synthetic counterfactual part during the period 1997-2016. We can find that primary sectoral share of employment in the synthetic Sichuan relatively closely track the trend of this variable in real Sichuan before the earthquake happen.

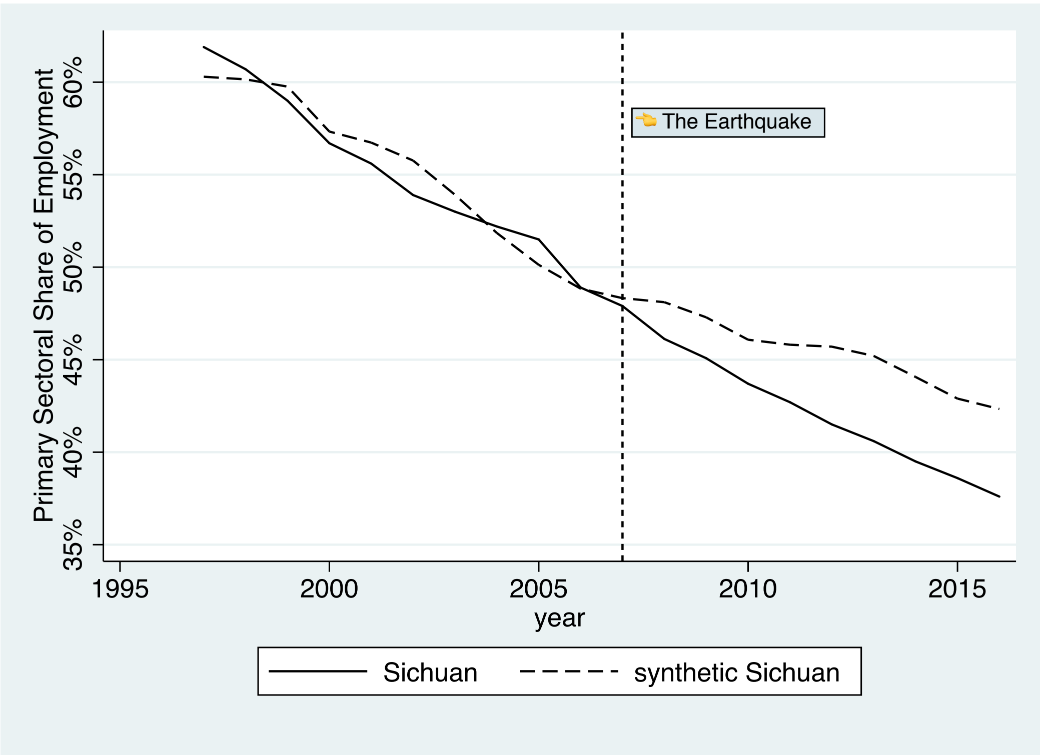

Figure 7. Trends in primary sectoral share of employment: Sichuan vs. synthetic Sichuan

Although there are some fluctuations between the two curves for the pretreatment period, they are generally consistent. Therefore, the synthetic Sichuan gives us a good approximation to the primary share of employment that Sichuan would have from 1997 to 2016 if the disaster never happened. To display the effect of the earthquake on whole economy structural transformation, I use the same synthetic Sichuan to calculate the other two sectoral shares of employment during the whole period from year 1997 to 2016, which is presented in Figure 8 below.

I expect that the differences between sectoral shares of employment in Sichuan and its synthetic version would become more substantial after the earthquake. From Figure 7, I find that immediately after the quake, the two curves of the primary sector begin to diverge obviously, which suggests a noticeable adverse effect of the earthquake on the primary sectoral share of employment. Besides, if we look at the differences over time, they infer that this effect on primary sectoral share gradually increases in time. In specific, the results suggest that for the 1997-2016 period, the primary sectoral share of employment had a decline of approximately five percentage points more compared with the counterfactual situation of Sichuan if no earthquake happened. Relative to the small magnitude of the effect of the earthquake destruction level on agriculture sectoral share of employment, 5% decreasing is more significant. This comparison implies that the impact of the earthquake is more evident between the affected and unaffected areas than between regions with different destruction levels.

To explore the destination of the labor force who move out from the primary sector, I use the same synthetic version of Sichuan to compute the other two sectors' shares of employment during the entire period from 1997 to 2016. Figure 8 depicts all three sectors’ shares of labor in one graphic. Even though we can see from the figure there potentially exists a positive effect of the earthquake on tertiary sector employment shares, I find that the impact of the quake on the secondary and tertiary sectoral employment shares is ambiguous. Because in the pretreatment period, the curve fitting ratio of the two sectors is relatively low compared with the one of the primary sector.

Overall, these results suggest that there is strong evidence that the Sichuan earthquake expedites the decreasing speed of the primary sector employment share, while the proportions of the labor in other two sectors do not display an evident mutation or amplification caused by the disaster.

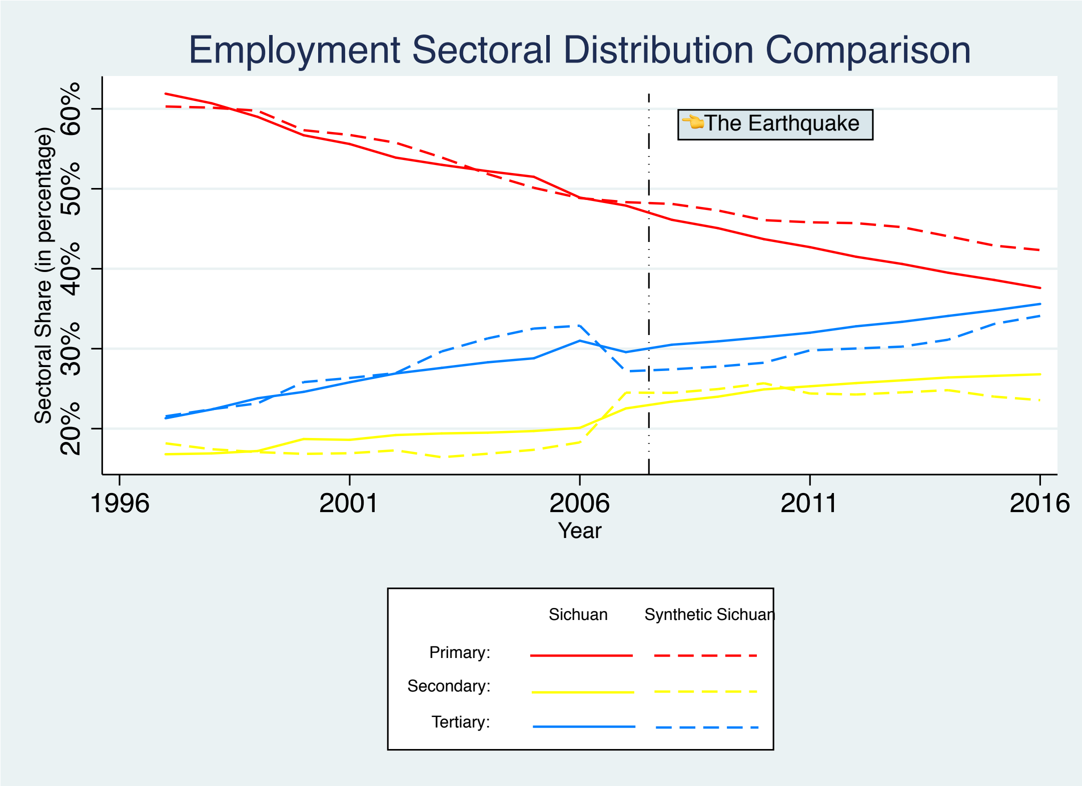

Figure 8. Trends in three sectoral shares of employment: Sichuan vs. synthetic Sichuan

6. Conclusion

Given the divergent positions in the relationship between natural disasters and economic development, this thesis found evidence of the impacts of natural disasters from another point of view: economic structural transformation. My methodology depended on the exogenous nature of a severe earthquake happened in Sichuan province, China, on May 12th, 2008. I mainly studied the effects of the disaster on the sectoral distribution of employment and GDP by using three different levels of data---district, city, and province level---integrated from CHIP and China Statistical Yearbook. I conducted this study not only by analyzing the effect of the damage level from the earthquake but also by exploring the differences on those between the stricken area and non-stricken areas. I linked CHIP and CSY datasets with the modified Mercalli intensity scale of the earthquake from USGS as my primary index of the destruction level.

Overall, I find that the earthquake had an impact on regional structural transformation in the sectoral distribution of employment and GDP. The immediate shift of labor to the construction and service sectors was stronger in the most severely damaged areas. However, the economic structural resilience and industry employment mix of the affected regions showed a trend of convergence after one year of the earthquake. In capital transfer, except the primary sector, the GDP in Sichuan shifted toward the same sectors as the employment did. The primary sector's share of GDP is bigger in the areas with more destruction within the Sichuan province. However, at the same time, compared with non-affected provinces, the earthquake has accelerated the decline in the proportion of labor in the primary sector in

Sichuan, and this impact is sustained and irreversible over time. This seeming contradiction might be caused by a synthetic effect from both changes in the denominator and numerator of the primary sectoral share of GDP. The increase of the relatively individual productivity of the labor in the primary sector made the magnitude of the primary sectoral GDP decline is less than that of the overall GDP decline since the manufacturing suffered most of the losses. Besides, in general, labor is more likely to flow to the industries within the secondary and tertiary sectors with a higher return on capital, such as construction and service industries. However, because there existed the shift out from the manufacturing and the shift into the construction sector at the same time, the internal long-term labor transfer within the secondary sector is ambiguous.

Though this thesis focused on the 2008 earthquake in Sichuan province, China, its findings are salutary for other developing countries as well: natural disasters could significantly positively impact the process of shifting a regional industrial structure from low value-added industries to higher ones. Governments could put more efforts on guiding the aid and capital when enacting redevelopment plan. According to Lin (2012), further research could explore the effect of natural disasters not only on intersectoral shifts but also on structural upgrades within one particular industry. For example, how do disasters impact firms' capital constraints in the service sector? A second area for future researchers is to investigate different effects of other categories of disasters on structural transformation. Emphasizing changes in the economic structure instead of aggregate economic activity might be more relevant for regional redevelopment.

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Appendix A: Tables

Table A-1 (interaction with baseline GDP per capita (unit: thousand))
GDP Changes of Sectoral Shares (district-level analysis)

	% Primary	% Secondary		% Tertiary
		Total	Manufacturing	
from 2007 to 2008				
Mercalli intensity	0.429***	-0.877***	-0.966***	0.448***
	(0.127)	(0.215)	(0.251)	(0.162)
Baseline GDP/capita - mean	0.032	0.053	0.069	-0.084
	(0.055)	(0.094)	(0.110)	(0.071)
Interaction	-0.004	-0.013	-0.010	0.018
	(0.012)	(0.020)	(0.023)	(0.015)
R^2	0.082	0.117	0.091	0.066
from 2007 to 2009				
Mercalli intensity	0.408**	-0.208	-0.443	-0.201
	(0.181)	(0.282)	(0.307)	(0.226)
Baseline GDP/capita - mean	0.238***	0.001	0.010	-0.239**
	(0.079)	(0.123)	(0.134)	(0.099)
Interaction	-0.019	-0.044*	-0.034	0.063***
	(0.017)	(0.026)	(0.028)	(0.021)
R^2	0.204	0.141	0.095	0.057
from 2007 to 2010				
Mercalli intensity	0.336	-0.409	-0.305	0.072
	(0.213)	(0.319)	(0.368)	(0.246)
Baseline GDP/capita - mean	0.260***	-0.008	0.096	-0.252**
	(0.093)	(0.140)	(0.161)	(0.108)
Interaction	-0.006	-0.069**	-0.080**	0.076***
	(0.020)	(0.029)	(0.034)	(0.023)
R^2	0.255	0.255	0.160	0.101
Observations	181	181	181	181

Notes: mean of Baseline GDP per capita among 181 districts is 12.376 thousand RMB.
* significance at 10% level.
** significance at 5% level.
*** significance at 1% level.

Table A-2
Dependent variable: GDP growth ratio (district-level analysis)

Year (based year = 2007)	2008 (1)	2009 (2)	2010 (3)
Mercalli intensity	-5.105***	-3.349***	-3.243**
	(0.811)	(0.899)	(1.357)
Baseline GDP/capita - mean	0.502	-0.038	0.326
	(0.355)	(0.393)	(0.593)
Interaction	-0.086	-0.034	-0.141
	(0.074)	(0.082)	(0.124)
Observations	181	181	181
R^2	0.255	0.255	0.160

Notes:
* significance at 10% level.
** significance at 5% level.
*** significance at 1% level.

Table A-3
Changes in Sectoral Shares (city-level analysis)

Dependent Variables	Employment			GDP				
	%Primary	%Secondary	%Tertiary	%Primary	%Secondary			%Tertiary
					Total	Industry	Construction	
from 2007 to 2008								
Mercalli intensity (GDP weighted)	0.607	0.171	-0.778	0.570	-1.151*	-1.173*	0.249	0.582**
	(0.532)	(0.330)	(0.606)	(0.371)	(0.621)	(0.661)	(0.292)	(0.272)
R^2	0.064	0.014	0.080	0.111	0.153	0.142	0.037	0.194
from 2007 to 2010								
Mercalli intensity (GDP weighted)	0.091	0.088	-0.179	0.654	-1.143	-1.094	1.134	0.489
	(0.773)	(0.512)	(0.579)	(0.517)	(0.698)	(0.734)	(0.835)	(0.459)
R^2	0.001	0.002	0.005	0.078	0.124	0.105	0.088	0.056
from 2007 to 2015								
Mercalli intensity (GDP weighted)	-0.057	-0.279	0.336	0.264	-0.808	-1.094	-0.614	0.544
	(1.041)	(0.955)	(0.672)	(0.977)	(1.116)	(0.734)	(2.428)	(0.527)
R^2	0.000	0.004	0.013	0.004	0.027	0.105	0.003	0.053
Observations	21	21	21	21	21	21	21	21

Table A-4 (with baseline GDP per capita (unit: thousand))
Changes in Sectoral Shares (city-level analysis)

Dependent Variables	Employment			GDP				
	%Primary	%Secondary	%Tertiary	%Primary	%Secondary			%Tertiary
					Total	Industry	Construction	
from 2007 to 2008								
Mercalli intensity (GDP weighted)	0.599	0.221	-0.821	0.567	-1.157*	-1.188*	0.277	0.590**
	(0.548)	(0.312)	(0.614)	(0.382)	(0.641)	(0.681)	(0.292)	(0.280)
Baseline GDP/capita	0.017	-0.115*	0.098	0.007	0.012	0.033	-0.064	-0.019
	(0.110)	(0.063)	(0.123)	(0.077)	(0.129)	(0.137)	(0.059)	(0.056)
R^2	0.065	0.169	0.111	0.111	0.154	0.145	0.096	0.199
from 2007 to 2010								
Mercalli intensity (GDP weighted)	0.060	0.153	-0.213	0.531	-0.993	-0.959	1.107	0.462
	(0.793)	(0.499)	(0.591)	(0.421)	(0.598)	(0.667)	(0.859)	(0.468)
Baseline GDP/capita	0.070	-0.146	0.076	0.278***	-0.340**	-0.306**	0.061	0.062
	(0.159)	(0.100)	(0.119)	(0.084)	(0.120)	(0.134)	(0.172)	(0.094)
R^2	0.011	0.107	0.027	0.425	0.394	0.306	0.095	0.079
from 2007 to 2015								
Mercalli intensity (GDP weighted)	-0.098	-0.175	0.273	0.061	-0.517	-0.959	-0.274	0.455
	(1.068)	(0.946)	(0.672)	(0.853)	(0.852)	(0.667)	(2.336)	(0.490)
Baseline GDP/capita	0.092	-0.236	0.144	0.458**	-0.659***	-0.306**	-0.769	0.201*
	(0.214)	(0.190)	(0.135)	(0.171)	(0.171)	(0.134)	(0.469)	(0.098)
R^2	0.010	0.083	0.072	0.287	0.467	0.306	0.133	0.232
Observations	21	21	21	21	21	21	21	21

Notes:
* significance at 10% level.
** significance at 5% level.
*** significance at 1% level.

Table A-5
Urban Employment Transition Matrix.
Dependent variable:
Independent variable: Modified Mercalli intensity (MMI)

	Post-earthquake employment sector				
	Agriculture	Manufacturing	Construction	Services	Unemployed/retired
Pre-earthquake employment sector					
Agriculture	0.215	0	0.108	-0.323	0
	(0.197)	(0)	(0.150)	(0.222)	(0)
Obs.	13	13	13	13	13
R^2	0.001	0	0.045	0.161	0
Manufacturing	0	-0.135	0.018	0.137*	-0.020
	(0)	(0.087)	(0.017)	(0.082)	(0.063)
Obs.	100	100	100	100	100
R^2	0	0.024	0.011	0.028	0.001
Construction	0	0	0.036	0.252	-0.288**
	(0)	(0)	(0.192)	(0.177)	(0.135)
Obs.	29	29	29	29	29
R^2	0	0	0.001	0.070	0.145
Services	0.004	0.009	-0.001	0.006	-0.018
	(0.003)	(0.008)	(0.006)	(0.017)	(0.014)
Obs.	985	985	985	985	985
R^2	0.002	0.001	0.001	0.001	0.002
Unemployed/retired	0	0.009	0.011*	0.030	-0.050
	(0)	(0.011)	(0.006)	(0.031)	(0.033)
Obs.	516	516	516	516	516
R^2	0	0.002	0.076	0.002	0.005

Notes: if the entry is zero, it means that no one move to this sector after the earthquake.
* significance at 10% level.
** significance at 5% level.
*** significance at 1% level.

Appendix B: Data Sources

Source A: Chinese Household Income Project (CHIP)

1. City Questionnaire

   Google Sheet Link:

   https://docs.google.com/spreadsheets/d/16R85jp3wZkJJvThf9I3XOehUdfglNPFTezLFOdHpraA/edit?usp=sharing

2. Rural Questionnaire

   Google Sheet Link:

   https://docs.google.com/spreadsheets/d/14WkezVX9I6zCYLLFyOsn16FgbCRuJRBuyiVn6i7_nXE/edit?usp=sharing

3. Rural Village Survey

   Google Sheet Link: https://docs.google.com/spreadsheets/d/1cqd4InexaH0XN-25LxruAaU1CbQ43pvstgw-PFQLlfo/edit?usp=sharing

Source B: China Statistical Yearbook

1. Sichuan District-level

   Google Sheet Link:

   https://docs.google.com/spreadsheets/d/1C3_n06sczXXDeViqWXljkJgKCWxBjnj24mpczfZPOWg/edit?usp=sharing

2. Sichuan City-level

   Google Sheet Link:

   https://docs.google.com/spreadsheets/d/1fuFurSAzQjKM6geF2edp_9vrjP6ewEfV0E_kA2828j4/edit?usp=sharing

3. China Province-level for Synthetic Control

   Google Drive Link:

   https://drive.google.com/drive/folders/1KTzyv6k8EQ3XRR3ZTUUgukL-yvBS9yKN?usp=sharing