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# Shock and roam: Migratory responses to natural disasters

Haishan Yuan [a,*], Chuanqi Zhu [b]

[a] Level 6, Colin Clark Building (39), University of Queensland, St Lucia, QLD 4072, Australia
[b] Lingnan (University) College, Sun Yat-sen University, Guangzhou, China

## HIGHLIGHTS

- Use novel data on roaming cellphones to capture post-earthquake migratory responses.
- Higher emigration emerges within a few weeks after the Ludian earthquake.
- Quake-induced emigration peaks in about 14 weeks.

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ABSTRACT

Using novel data on roaming mobile phones and a synthetic control method, we find out-migration in the area affected by the 2014 Ludian earthquake in Southwest China. The induced emigration emerged within a few weeks after the earthquake and persisted for months. We find no evidence that the earthquake drew back migrants who, prior to the earthquake, had emigrated to Guangdong province, which is a manufacturing hub and the primary destination of rural migrant workers in China.



## 1. Introduction

Labor mobility is central to economic development. In less developed countries, migration provides an important means for households to escape from poverty and cope with negative economic shocks. In this paper, we use data on roaming mobile phones to analyze the migratory responses in the area affected by the 2014 Ludian earthquake, which was the deadliest earthquake in China since 2010.

Using a synthetic control method proposed by Abadie and Gardeazabal (2003) and Abadie et al. (2010), we construct a comparison prefecture for the prefecture affected by the earthquake. Taking advantage of the high frequency of our data, we find out-migration from the affected prefecture in the four months immediately following the earthquake. On the other hand, we find no evidence that the affected prefecture drew back existing migrants working in Guangdong province, which is a manufacturing hub and the primary destination of rural migrant workers in China.

The empirical evidence as to whether or not natural disasters induce out-migration has been mixed. Using household panel data from Indonesia, Tse (2012) finds that migration rates decrease following earthquakes, volcanic eruptions, and floods. Halliday (2006) finds that earthquakes in El Salvador caused damages to household assets and reduced the number of household members residing in North America. In contrast, we find out-migration immediately following the Ludian earthquake and no evidence of prior emigrants working in Guangdong province. Our findings are consistent with the recent finding that households in Vietnam sent household members to work in the city after their villages were hit by a severe typhoon (Gröger and Zylberberg, 2016).

* Corresponding author.
*E-mail addresses:* h.yuan@uq.edu.au (H. Yuan), zhuchq3@mail.sysu.edu.cn (C. Zhu).

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## 2. Background and data

Our primary data set consists of daily numbers of users of China Mobile roaming in and outside of Guangdong province. If a China Mobile user travels to or stays in Guangdong with a China Mobile SIM card registered outside of Guangdong and her mobile phone is turned on, her mobile phone would pin its nearby cell tower and one phone would be recorded as roaming in Guangdong for that day. Similarly, if a China Mobile user is physically located outside of Guangdong with a turned-on China Mobile SIM card registered in Guangdong, one phone would be recorded as roaming outside of Guangdong.

We obtain our data set from Guangdong subsidiary of China Mobile, which is the largest telecommunication company in China and accounts for 62% of the Chinese market as of December 2013. Because the other two major telecommunication companies have disproportionately high numbers of 3G users, who concentrate in urban areas, China Mobile's market share in rural areas is even higher. China Mobile operates through its subsidiaries in each of the 31 provinces. Each provincial subsidiary of China Mobile operates independently. They set their own prices and rate plans in their jurisdictions. Unlike in the United States or Australia, where uniform rates apply regardless of which state the mobile user is in, in China, costs for mobile calls, messages and data differ, according to whether the user is in her home province or in another. Therefore, migrants typically switch their mobile subscription to a local one within a few weeks of migrating.

Accounting for about 25% of China's imports and exports, Guangdong is by far the most popular destination for migrant workers from rural areas. In 2012, 52 millions or 20% of the country's stock migrant workers, worked in the Pearl Delta area, where Guangdong's manufacturing industries are located (National Bureau of Statistics, China, 2013). Moreover, the mobile phone penetration rate is high in China. In December 2013, the three major telecommunication companies together had 1.23 billion subscribers, equivalent to 0.91 subscribers per capita. Therefore, though we only observe migration flows as measured by mobile phones roaming in and outside of Guangdong, our data is able to capture the salient features of migration flows in China. However, because migrants switch to local subscriptions, we note that our data could only capture the short-term migration flows, but not migrant stock in Guangdong. To quantify the migratory flows captured by the number of roaming phones in Guangdong, we conduct a survey on mobile phone usage of visitors and migrants to Guangdong. We describe details of this survey in the Online Appendix A.

Our data is at the prefecture level, which is the sub-province level administrative unit. In Fig. 1, we map the average daily number of roaming mobile phone there are in Guangdong province from each prefectures, and plot the daily number of China Mobile users roaming in Guangdong from 2013 to 2015. Over the three-year period, there was an increasing number of China Mobile users roaming in Guangdong.

However, the seasonal patterns are remarkably stable. Each year, the number of mobile phones roaming in Guangdong reaches its lowest point right before the Chinese New Year, which is typically in February or late January and indicated by the orange dash line Fig. 1. Right after the Chinese New Year, the number of mobile phones roaming in Guangdong increases sharply, reaching a peak in one and a half months after Chinese New Year. After the peaks, the number of mobile phones roaming in Guangdong declines until the summer school vocation. Another wave of migration to Guangdong takes places during the summer. Indeed, the all-year peaks are around the end of July or the beginning of August. The number of roaming mobile phones returns to its pre-summer decline on September 1st, which is the first day of the school year through out China. The first days of a school year are indicated by the green dashed lines in right subplot of Fig. 1.

While the numbers of roaming phones in Guangdong reflect short-term personal and business travels, their magnitudes are unlikely to drive the seasonal patterns that are shown in Fig. 1. In Figure A.1, we also plot the daily number of Beijing and Shanghai mobile phones roaming in Guangdong. Beijing and Shanghai together have a population of 44.9 million. The drop in the number of mobiles from these two largest cities being used in Guangdong around the Chinese New Year, is modest, which suggests that the seasonal patterns shown in the right panel of Fig. 1 are driven by migrant workers from rural areas.

Only 20.7% of the 163 million migrant workers working in Chinese urban areas migrated with all members of their households in 2012. Every year, family reunions drive a massive population movement around the Chinese New Year. In Figure A.2, we plot the daily number of Guangdong-registered users of China Mobile's roaming services outside Guangdong. We have the out-roaming data from October 2013 to December 2015. Clear spikes can be seen around Chinese News Year in 2014 and 2015, and they are indicated by the orange dashed lines. During the week surrounding the Chinese New Year in 2015, 23.8 million China Mobile mobile phones roamed outside of Guangdong.

In order to quantify the migratory flows captured by the number of roaming phones in Guangdong, we need to know how long these migrant workers would retain their hometown-registered SIM cards. Therefore, we conduct a survey on mobile phone usage of visitors to Guangdong. Since migrant workers have concerns about mobile phone roaming charge, they usually switch their hometown-registered SIM cards to locally registered SIM cards in Guangdong. The main goal of this survey is to identify the SIM card switching behaviors of visitors to Guangdong, particularly the time frame of SIM card switching of migrant workers.

Since the majority of migrant workers in Guangdong province come to Guangzhou by train, we distributed our survey to those who just arrived at Guangzhou at Guangzhou railways station. We have collected 477 responses for this study from July 20th to July 26th. We focuses on the 47 newly arrived migrant workers who seek jobs in Guangdong and have not switched to a local SIM card. See Online Appendix A for more details about this survey.

## 3. Migratory responses to earthquake

The high frequency of the mobile phone data allows us to investigate the timing and the dynamics of out-migration following a natural disaster. On August 3rd, 2014, an earthquake with a moment magnitude of 6.1 struck Ludian county of the southwest province Yunnan. The earthquake caused 731 deaths and a damage estimated at \$5 billion and affected about 1.1 million people (Guha-Sapir et al., 2016). Most of the affected population were located in Zhaotong prefecture, which has a population of about 5 million and is a low-income area in China. Ludian county is contained in Zhaotong prefecture.

We use a synthetic control method to analyze the migratory responses following the Ludian earthquake. Since proposed by Abadie and Gardeazabal (2003) and Abadie et al. (2010), the synthetic control method has proven to be a powerful tool for comparative case studies. Using a data-driven approach, the synthetic control method constructs a weighted sum of potential controls, known as the donor pool, as the synthetic control. The synthetic control method is particularly suitable for our analysis, because we have one treatment unit, namely Zhaotong prefecture, and a large donor pool, which consists of all prefectures unaffected by the Ludian earthquake.

High frequency may introduce noise in the construction of synthetic controls (Dube and Zipperer, 2015). Thus, we average

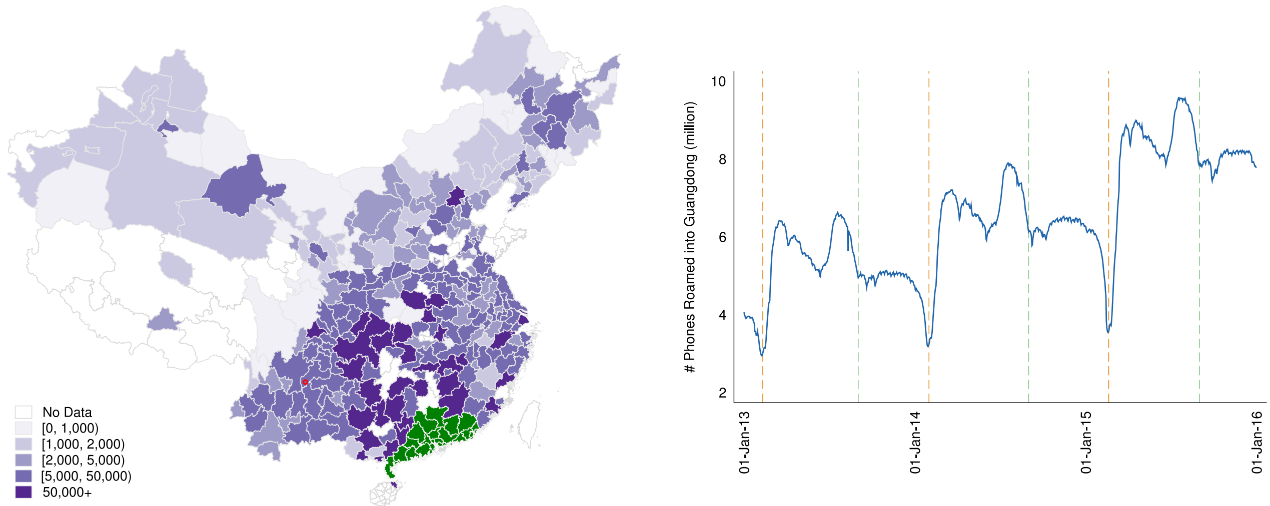


**Fig. 1.** Number of mobile phones roaming in Guangdong. Notes: The map on the left shows the average daily numbers of mobile phones from each prefecture roaming in Guangdong over our sample period. The red circle indicates the epicenter. The green area is Guangdong. The time-series plot on the right shows the average daily number of mobiles roaming in Guangdong. The orange dashed lines indicate Chinese New Year. The green dash lines indicates the first days of school years in China. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

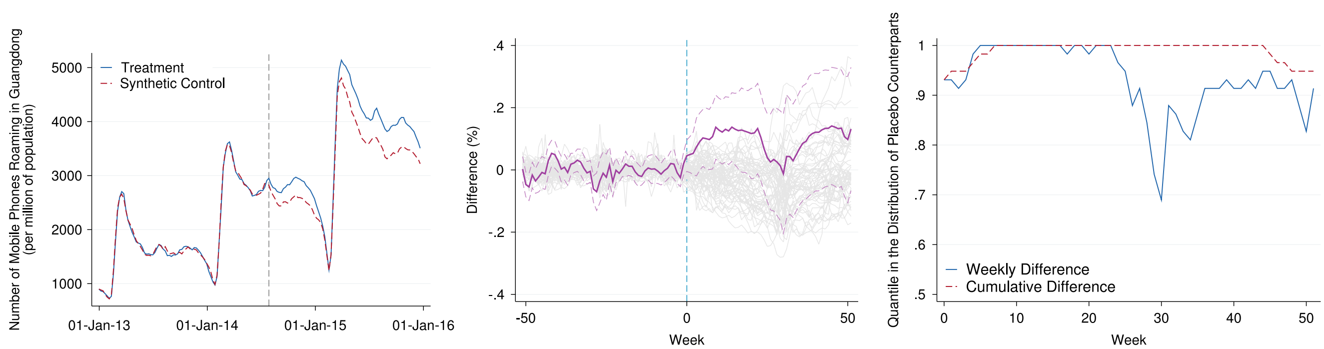


**Fig. 2.** Number of mobile phones from earthquake prefecture roaming in Guangdong and its synthetic control. Notes: The subplot on the left plots the daily numbers of mobile phones from the earthquake-hit prefecture that are roaming in Guangdong, and its synthetic control. In the middle subplot, the thick purple line plots the differences between earthquake-hit prefecture and its synthetic control; the thin gray lines plot the percentage differences of the placebo prefectures and their synthetic controls; and the thin purple dashed line indicates 95% confidence intervals constructed by using the standard deviation of placebo treatment effects in each week. In both plots, the dashed line indicates the week when the Ludian earthquake happened. In the right-hand side subplot, we plot the quantiles of the differences between the treatment and its synthetic controls against the distribution of their placebo counterparts as shown in the middle subplot. The solid blue line indicates weekly differences from week 0 and the red dashed line indicates cumulative differences from week 0. The *p*-values are obtained by taking the differences between 1 and the quantiles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the daily number of phones roaming in Guangdong to a weekly frequency. Moreover, we normalize the number of roaming phones by the prefecture's population in 2012. In left subplot of Fig. 2, we plot the daily number of China Mobile users registered in Zhaotong and roaming in Guangdong using a blue solid line. The horizontal axis indicates the beginning of a week (Monday) and the vertical axis indicates the daily number averaged over a week. With the red dashed line, we also plot the number of China Mobile users registered in the synthetic "prefecture" roaming in Guangdong. The synthetic control is a weighted sum of unaffected prefectures. The weights of each donor prefectures are calculated by minimizing the mean squared prediction error in the pre-treatment (pre-earthquake) period between the outcome variable of Zhaotong prefecture and that of the synthetic predictor. The weights are non-negative and sum to one (see Abadie et al., 2010 for more details).

Fig. 2 shows that the synthetic control matches very well with the treatment prefecture, Zhaotong, on the number of mobile users roamed into Guangdong in the pre-earthquake period. Immediately after the earthquake, however, a gap between the treatment unit, Zhaotong, and its synthetic control emerged. The gap widened over time until a couple months before the Chinese New Year, which, as described before, marks the low out-migrating season. However, in the wave of out-migration following the Chinese New Year, the earthquake-affected prefecture again had an out-migration rate greater than its synthetic control. The gap was even larger than that in the previous year. This finding suggests that the earthquake generated persistently higher out-migration, which took place in seasons typically with high out-migration rates.

The gap between the daily number of roaming phones from Zhaotong prefecture and its synthetic control peaks 14 weeks after the earthquake. At the peak, about 1900 more Zhaotong phones were roaming each day in Guangdong than the synthetic control would suggest.[1] How many migrants from Zhaotong does the higher number of roaming phones imply? The answer depends on how long migrants retain their hometown-registered SIM cards. We survey people moving to Guangdong for jobs about their phone switching behaviors. Of the 47 respondents who move to Guangdong for jobs, 30% of migrants would switch their SIM cards within one week; 19% would switch their SIM cards in one to

1 Zhaotong prefecture had 5.3 million residents in 2012.

two weeks; 19% would switch in three to four weeks; 23% would switch in one to two months; and the reminding 8.5% would take more than two months to switch. This phone-switching pattern suggests that one migrant on average increases the daily number of roaming phones by 25.[2] This conversion rate suggests that the earthquake induced about 14 thousand Zhaotong residents, or 1.3% of estimated quake-affected population, to move to Guangdong in the six months following the earthquake.

For comparison, Gröger and Zylberberg (2016) finds that, in the aftermaths of Typhoon Ketsana, the *net* household-level incidence of domestic long-distance migration is 6.5 percentage points higher in a Vietnamese village that was 50% inundated compared to a village with no inundation. Given that an average household has 4.4 members in their sample, the magnitude of migratory responses in Gröger and Zylberberg (2016) is comparable to ours. However, we note that our estimates may not be directly comparable to the estimates of Gröger and Zylberberg (2016). Gröger and Zylberberg (2016) use a difference-in-differences approach and the relative treatment intensity (post-typhoon inundation) to identify the migratory responses, which may difference out regional impacts affecting both treatment and control villages. In contrast, our estimates capture the aggregate gross migratory responses in the entire affected area.

While we believe that most migrants induced by the Ludian earthquake are economic migrants seeking job opportunities, roaming phones from Zhaotong prefectures may also contain those of temporary migrants who seeks asylums in friends and family in Guangdong. To the extent that asylum seekers may constitute a portion of the phones roaming into Guangdong, our estimates may overstate the migratory responses of economic migrants, which have been the focus of prior literature. On the other hand, unlike the traditional survey-based data, our measure of migratory responses also captures households which move entirely out of the initial residents and therefore would be missed in follow-up interviews. Therefore, this paper adds to a growing literature that uses machine-generated data to complement, and potentially improve, conventional measures of economic activities (see e.g. Henderson et al., 2012; Dong et al., 2016).

To assess the statistical significance, we perform a permutation test by constructing a synthetic control for each untreated prefecture without missing data. In the middle subplot of Fig. 2, each gray line plots the percentage deviation of the placebo prefecture from its synthetic control before and after the week of the Ludian earthquake. Following Abadie et al. (2010), we discard placebos whose synthetic controls have a mean squared prediction error more than two times larger than that of the synthetic control for the treated prefecture in the pre-earthquake period. These placebo prefectures with poor-fit synthetic controls include the largest cities such as Shanghai. The percentage deviation of the earthquake-hit prefecture, as depicted by the thick purple line, is higher than that of most placebo prefectures in the six months after the earthquake.

In the subplot on the right of Fig. 2, we compare the percentage deviation of the treated prefecture against the distribution of the placebo deviation after the earthquake and plot the treatment effect as quantiles in the placebo distribution. The difference between one and the quantile gives the $p$-values of one-side permutation tests against the null that the earthquake induces no migratory responses. As the blue solid line indicates, the migratory responses are mostly significant at the 5% level in the first four months after the earthquake. We also plot the cumulative percentage deviation since the earthquake, against the placebo distribution. In the six months following the earthquake, the responses are significant at the 5% level.

On the other hand, we do not find that there were more migrant workers returning to the earthquake-affected areas. We perform a similar synthetic control analysis using instead the number of Guangdong-registered mobile phone users roaming in Zhaotong and other prefectures as an outcome variable. The synthetic control is constructed similarly to the one above, using the pre-earthquake period. The treatment and its synthetic control are plotted in Figure A.3. Again, the synthetic control matches the movement of the treatment prefecture very well before the earthquake. After the earthquake, only around Chinese New Year in 2015, there were 11% more Guangdong mobile phones roaming in Zhaotong prefecture than roaming in the synthetic prefecture. However, this deviation is not statistically significant. Outside of this period, the synthetic control traces the earthquake-hit prefecture very closely. The findings in Figure A.3 suggest that the Ludian earthquake did not draw back a substantial number of migrant workers living in Guangdong.

## 4. Concluding remarks

Existing studies on natural disasters and migration typically use census or household survey data, which usually measures changes of *net* migration over a period of at least one year. Using novel data on roaming mobile phones, we complement the existing literature in two ways. First, by analyzing both the emigration and return migration flows, our findings suggest that post-disaster economic circumstances prevail over the needs of family support and home rebuilding, resulting greater out-migration but not greater return migration. Second, we shed lights on the timing of the post-disaster migration. Greater out-migration emerged within a few weeks following the earthquake, peaked in about three months and vanished during the lunar new years. This finding suggests that the earthquake-induced emigration is linked to seasonal factors and hence the timing of natural disasters may affect the subsequent migratory responses. To the best of our knowledge, we are also the first to quantitatively document the seasonal patterns of internal migration in China.

## Appendix A. Supplementary data

Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.econlet.2016.09.020.

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[2] We derive this conversion rate in the Online Appendix A.