Do natural disasters cause an excessive fear of heights? Evidence from the Wenchuan earthquake

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\begin{abstract}
This paper uses the 2008 Wenchuan earthquake in China to examine if the occurrence of a natural disaster can cause an excessive fear of living in upper floors. We rely on potential variations in earthquake risk perceptions by floor level to assess whether the pricing of apartments in lower versus upper floors is consistent with a disproportionate fear of heights. We use a unique transaction dataset for new apartment units in the affected area. We find that the relative price of low to high floor units, particularly units located in the first and second floor, considerably increased for several months after the earthquake and then returned back to the levels observed prior to the tremor. This temporal increase in relative prices is in line with a higher risk perception and fear, triggered after the earthquake, of living in upper floors, which gradually dissipated over time. The results are robust to alternative model estimations.
\end{abstract}

\section{Introduction}

The occurrence of natural disasters provides a unique setting to examine the potential overreaction of individuals to large, disruptive and generally unexpected events. According to the prospect theory, rare events tend to be overweighted in the absence of a risk-learning process with repeated experience (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). Glaeser (2004) also notes that people may put enormous weight on ephemeral situations. Even under low-risk circumstances, a rare but "sharp" event can induce individuals to overestimate risk and exaggerate perceived risk (Tversky and Kahneman, 1974; Slovic, 1987; Viscusi, 1989, 1990). In this paper, we use the 2008 Wenchuan earthquake in China to analyze if the occurrence of the tremor results in an excessive fear of living in upper floors.

An earthquake is a traumatic event that increases the awareness of potential damages and risks among all residents in the affected area. The level of perceived risk, however, may be further dictated by the floor level where you live as people may feel safer at lower floor apartments in the occurrence of another earthquake. Individuals may prefer to live in lower floors as shocks are felt stronger in upper floors. Similarly, although individuals in the first floors may exit the building faster, people in lower floors are not always more likely to not get injured or survive. Our identification strategy relies on these likely variations in earthquake risk perceptions by floor level to evaluate the pricing behavior of units in lower versus upper floors and assess whether the observed pricing patterns are in line with an excessive fear of heights. Consistent with this overreaction hypothesis, risk perception biases should trigger a rise in the relative price of lower to upper floor units after the earthquake, but this increase should fade over time as the fear of risk gradually dissipates when people realize that the recurrence probability of a high magnitude tremor is small (Kreps, 1984; Wood et al., 1992).

The Wenchuan earthquake, measured at 7.9M (surface wave magnitude scale), occurred at 2:28 p.m. on May 12, 2008 along the Longmen Shan Fault in Sichuan province. The epicenter was located 90 kilometers northwest of the city of Chengdu, the provincial capital with about ten million residents. The earthquake caused severe damage to Chengdu and was felt across most of mainland China.\textsuperscript{1} The State Council designated Chengdu as an earthquake-stricken area.

\textsuperscript{1} According to official figures, the earthquake resulted in 69,197 deaths (68,636 in Sichuan province), 18,222 missing and 374,176 injured (\url{www.sina.com}). The earthquake also left more than 4.8 million people homeless. For additional details of the Wenchuan earthquake refer to EERI (2008a).
The progression of relative prices after the tremor resembles the evolution of stock prices after major unanticipated events, which has been extensively documented in financial markets (e.g., De Bondt and Thaler, 1985; Ederington and Lee, 1993 and 1995; Brooks, Patel and Su, 2003). In this literature, the psychological biases of investors under risky and uncertain situations result in abnormal investing behavior. Prices follow a “normal-abnormal-normal” progression in the occurrence of a rare event: prices first decrease after a negative event as agents tend to overweight new information; when agents fully understand the situation, prices revert and ultimately return back to their normal levels.

Our study is also related to the studies of Beron et al. (1997), Wong (2008), and Abadie and Dermisi (2008), which follow different approaches to examine the response of the housing market to extreme events and find mixed results. Beron et al. use a hedonic model to analyze sale prices for single-family dwellings before and after the 1989 Loma Prieta earthquake and find results consistent with the notion that individuals initially overestimate the probability of damage from earthquakes. Wong uses a panel of housing estates in Hong Kong and does not find evidence, when compared to the predictions of a standard asset-pricing model, of an excessive reaction of prices in secondary residential properties after the 2003 Severe Acute Respiratory Syndrome (SARS) epidemic. Abadie and Dermisi use a quarterly panel of buildings in downtown Chicago and conclude that office location decisions (vacancy rates) appear to have been affected by the increased perception of terrorist risk after the 9/11 attacks.

In contrast to these papers, we exploit a unique transaction dataset of new apartment units in residential buildings to examine if the occurrence of an earthquake can cause an excessive fear of living in upper floors. These data allow us to concentrate on price differentials before and after the earthquake of comparable housing units located in lower- versus upper-floor levels and assess whether the observed relative pricing patterns can be linked to likely variations in the level of perceived earthquake risk and fear. Focusing on relative price differences further helps us to better control for other unobserved changes (if any) in housing demand and supply factors affecting prices, provided that these changes occur across all apartments and not in units located at specific floor levels. For instance, we do not expect systematic variations in the quality of the structures and the amenities of units located in lower versus upper floors. Still, we recognize that our analysis is based on a before-after comparison such that we cannot completely rule out alternative explanations to the results obtained, but we are also unaware of other plausible explanations.

The remainder of the paper is organized as follows. Section 2 further discusses earthquake risks by floor level and the potential fear of living in upper floors. Section 3 describes the data and methodology. Section 4 presents the estimation results. Section 5 concludes.

2. Earthquake risks and fear of living in upper floors

Large disruptive events such as high magnitude earthquakes may have an important psychological effect on people in the affected areas and raise their awareness of potential risks. “High-signal” events, however, may also induce individuals to overestimate risk and amplify perceived risk. As noted by Slovic (1987), the level of perceived risk will increase with how unusual, uncontaminable and fatal the risk is as well as with the degree of exposure to the risk. In the case of an earthquake, the level of perceived risk may depend on the floor level where you are located as people may feel safer in lower floors, although the likelihood of getting injured or not surviving does not necessarily increase with height.

One reason why individuals may feel more exposed to earthquakes in upper levels is that shocks are felt more strongly in upper floors, thereby increasing their fear. Side-to-side shaking is felt stronger in upper floors because most of the mass in buildings is typically lumped at the floor levels, such that a significant inertia force is added at each floor level with the shaking of the building’s foundation (Murty, 2007). Taller buildings may also undergo several modes of vibration besides their “natural period” of vibration (rate at which they move back and forth), although these additional vibrations are less critical (FEMA, 2006). Another reason for preferring lower floors is the possibility of exiting the building faster. In several situations, being able to exit a building in a faster and easier way can significantly increase your chances of survival; for example, when there is a fire or gas leak in the building or in the case of an explosion or terrorist attack such as the 9/11 events where height was a crucial determinant of surviving. In the case of earthquakes, however, people in lower floors are not always more likely to not get injured or survive. First, as pointed by the Earthquake Country Alliance, research on injuries and fatalities during earthquakes and the experiences of search and rescue teams, indicate that building collapse is generally less of a danger as a small number of buildings partially or completely fail. You are safer finding shelter inside your apartment rather than trying to run for exits, doorways or jumping from a window; moving during a tremor puts you at more risk as the shaking can be so strong that it is very difficult to move far enough without falling down and objects also fall (areas near the exterior walls of a building are actually the most dangerous places). Second, even if a building fails, dynamic forces and the direction and frequency of shaking are unpredictable such that displacements and structure failures can occur at any floor. Similarly, while some buildings may collapse sideways others may collapse downwards (“pancaking”) where the first floors get demolished.

See also Kahneman and Riepe (1998), Hirshleifer (2001) and Baker and Nofsinger (2002).

Related to this study, Davis (2004) examines the effect of health risks, resulting from an outbreak of pediatric leukemia in a county in Nevada, on local housing values and finds a decrease in housing prices.

Other studies that analyze the impact of natural events (earthquakes) on housing markets include Brookshire et al. (1985), Murdoch, Singh and Thayer (1993), Bin and Polasky (2004), and Nakagawa, Saito and Yamaga (2007, 2009).
by the weight of the upper floors falling and this occurs over a very short period of time.\textsuperscript{10} Overall, in several cases you are equally safe (or unsafe) no matter the floor you are located at.

Articles from the local media and online forums (chatter websites) in the days following the Wenchuan earthquake also indicate that many people got injured or died because of panic and desperation, including people jumping from windows, and not only by partial or total building collapse.\textsuperscript{11} Several residents in the area further expressed their concerns and fears of living in upper floors where shakes were felt more strongly, while interviewed experts indicated that it is normal for taller buildings to vibrate more.\textsuperscript{12} The reports and information collected by the Earthquake Engineering Research Institute–EERI (2008b) show different types of building damages and failures in the disaster areas, including numerous ground floor collapses. In addition, several buildings that collapsed buried all people inside the building.\textsuperscript{13}

Hence, although subjective risks are difficult to quantify, to the extent that earthquake risks are more subjective than objective as we move to upper floors, an increase in the relative price of lower to upper floor units after the tremor can be interpreted as an excessive fear of heights. In line with this overreaction hypothesis, the rise in relative prices should be temporal as the higher risk perception and fear of living in upper floors, triggered after the earthquake, slowly dissipates when people recognize that the likelihood of recurrence of a similar high magnitude tremor is small. While the Sichuan region is located in a seismic zone, the previous major earthquake in the province occurred back in 1933 (7.3M). Burchief et al. (2008) have also estimated the average recurrence interval of the Wenchuan earthquake in the general range of 2,000–10,000 years.

3. Empirical approach

3.1. Data

The data used for the study is based on real estate transactions for new housing units purchased across nine (out of fourteen) county districts and the downtown area of Chengdu, as shown in Fig. 1.\textsuperscript{14} The data is obtained from the Housing Authority transaction system of Chengdu. The sample period covers May 1, 2007 through May 31, 2009, approximately one year before and one year after the Wenchuan earthquake. The dataset contains information on purchase date, transaction price, unit area and floor, location, building developer, and building type and status.

We restrict our analysis to residential apartments with elevator in the building, which represent 88% of the total transactions in our full sample. This permits us to examine the pricing behavior of comparable housing units located in different floor levels. We further restrict our sample to forward contract transactions, i.e. sales where the buyer has to wait for a period of time before moving in because the building is still under construction, as most of new house purchases in China are made through forward contracts (89% in our sample).\textsuperscript{15} Focusing on residential apartments with elevator in the building and forward contracts also helps us to better account for potential different types of buyers looking for a new house as these may differ by building and purchase type. Our final working sample includes 313,805 observations.

Table 1 reports summary statistics of some key variables for the full sample and for the periods before and after the earthquake. The average price per square meter of a new apartment bought during the sample period is roughly 4870 RMB (700 US dollars). We observe that average prices significantly dropped by about 712 RMB (13.5%) after the earthquake. There is also a decrease in the percentage of purchased units built by a major developer (6 percentage points), the national housing price index (one point), and the average size of units (3 square meters).

Table A.1 in the Supplementary Appendix presents, in turn, average prices before and after the earthquake for the West and East side of Chengdu (see Fig. 1) and for units located in floors 1–2, 3–6 and 7 or above.\textsuperscript{16} Interestingly, we observe a higher and statistically significant decrease in prices after the earthquake in the West (of 655 RMB), which was relatively more exposed to the tremor than the East because it was closer to the epicenter. By floor level, units in upper floors show, on average, a higher drop than units in lower floors and the differences are clearer in the West. We analyze in more detail below the results across the West and East.

Fig. 2 provides additional insights about the potential impact of the Wenchuan earthquake on the price of new apartments by floor level. We compare the evolution of monthly prices before and after the earthquake (May 2007 through December 2010) of units in floors 1–2, floors 3–6, and floor 7 or above. Prices seem to move in a similar fashion over time across the different floor levels. However, two interesting patterns occurred after the earthquake. First, units in the first and second floor experienced a temporary and substantial increase in their prices after the earthquake (around 10%). For about three months (July through September 2008), the price of units in the first two floors were even similar to the price of units in the seventh floor or above, a pattern that was never observed prior to the earthquake. Second, there was a general decrease in the average price differences between upper and lower level units during the entire second half of 2008. The average differences between prices in floors 7 or above versus floors 1–2 and 3–6 reduced from 450–490 RMB to 230–340 RMB per square meter; the price differences did not return to previous levels until February 2009 and then remained through December 2010.

These pricing trends are further corroborated in Figure A.1, which present the evolution of daily prices based on separate data-driven regression discontinuity plots for apartment units in floors 1–2 and 7 or above.\textsuperscript{17} We find an important jump of about 9% (438 RMB) in the prices of units located in floors 1–2 after the earthquake versus a decrease of 3% (128 RMB) in the prices of units in floor 7 or above. Hence, a preliminary overview of the data suggests that after the tremor there was a differentiated variation, by floor level, in the price of new apartments, which seems in line with an apparent excessive fear of living in upper floors in the months following the earthquake.

\textsuperscript{10} A building may fail due to different factors, including the failure of the soil, foundation, “soft floor” or building joints or simply because of the type of materials the structure is made of. For details of structural damages during earthquake see also Okada and Takai (1999) and Day (2012).


\textsuperscript{13} The Urban Real Estate Administration Law of China requires the building construction investment to be at least 25% of the total investment for a forward contract sale to occur. The results are though not sensitive to the inclusion of non-forward transactions.

\textsuperscript{14} The county districts without information are mainly rural counties with a small number of housing transactions.

\textsuperscript{15} We group units in floors 7 or above together because the price of units in these floors show a very similar behavior pattern as opposed to the price of units in the first six floors. Similarly, the floor divisions (1–2, 3–6 and 7 or above) capture major price differences across floor levels and provide a better model fit compared to other floor groupings. It is also worth noting that all buildings with an elevator in our sample have at least seven floors (based on more than half of the buildings for which we have this information). According to the China Building Code, buildings with seven or more floors should have at least one elevator.

\textsuperscript{16} The estimated plots are based on Calonico, Cattaneo and Titunik (2014a, 2014b, 2015).
The epicenter of the Wenchuan earthquake was located along the Longmen Shan Fault, 90 kilometers northwest of the city of Chengdu. The West area, closer to the fault, comprises six county districts (Dayi, Chongzhou, Wenjiang, Dujiangyan, Pixian and Pengzhou); the East area, farther away from the fault, comprises three county districts (Shuangliu, Longquanyi and Xindu) plus the six downtown districts (Wuhou, Qingyang, Jinniu, Chenghua Jinjiang and Gaoxin). The five county districts not included in the analysis (Pujiang, Qionglai, Xinjin, Qingbaijiang and Jintang) are mainly rural counties with a small number of housing transactions.

Note: The epicenter of the Wenchuan earthquake was located along the Longmen Shan Fault, 90 kilometers northwest of the city of Chengdu. The West area, closer to the fault, comprises six county districts (Dayi, Chongzhou, Wenjiang, Dujiangyan, Pixian and Pengzhou); the East area, farther away from the fault, comprises three county districts (Shuangliu, Longquanyi and Xindu) plus the six downtown districts (Wuhou, Qingyang, Jinniu, Chenghua Jinjiang and Gaoxin). The five county districts not included in the analysis (Pujiang, Qionglai, Xinjin, Qingbaijiang and Jintang) are mainly rural counties with a small number of housing transactions.

**Fig. 1.** Map of areas included in the study.

**Fig. 2.** Evolution of monthly average prices for different floor levels, May 2007–December 2010.

Note: Data for the period May 2007 through May 2009 corresponds to the working sample, while data for the period June 2009–December 2010 corresponds to additional price data (by floor level) obtained from the Chengdu Housing Authority.
Table 1
Summary statistics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
<th>Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel A: full sample (313,805 observations)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price (RMB per meter square)</td>
<td>4,869</td>
<td>1,612</td>
<td>304</td>
<td>28,000</td>
<td></td>
</tr>
<tr>
<td>Unit size (square meters)</td>
<td>97.1</td>
<td>30.7</td>
<td>20.1</td>
<td>735.4</td>
<td></td>
</tr>
<tr>
<td>Floor level</td>
<td>11.9</td>
<td>7.8</td>
<td>1.0</td>
<td>36.0</td>
<td></td>
</tr>
<tr>
<td>1–2 floor unit</td>
<td>0.08</td>
<td>0.27</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>3–6 floor unit</td>
<td>0.23</td>
<td>0.42</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>7–above floor unit</td>
<td>0.70</td>
<td>0.46</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>If top developer</td>
<td>0.36</td>
<td>0.48</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Housing price index (base year = 2010)</td>
<td>100.51</td>
<td>0.71</td>
<td>99.30</td>
<td>101.90</td>
<td></td>
</tr>
<tr>
<td>Panel B: Before the earthquake (139,901 observations)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price (RMB per meter square)</td>
<td>5,263</td>
<td>1,553</td>
<td>590</td>
<td>21,830</td>
<td></td>
</tr>
<tr>
<td>Unit size (square meters)</td>
<td>98.8</td>
<td>32.2</td>
<td>20.1</td>
<td>735.4</td>
<td></td>
</tr>
<tr>
<td>Floor level</td>
<td>12.0</td>
<td>7.6</td>
<td>1.0</td>
<td>36.0</td>
<td></td>
</tr>
<tr>
<td>1–2 floor unit</td>
<td>0.07</td>
<td>0.25</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>3–6 floor unit</td>
<td>0.22</td>
<td>0.41</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>7–above floor unit</td>
<td>0.71</td>
<td>0.45</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>If top developer</td>
<td>0.40</td>
<td>0.49</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Housing price index (base year = 2010)</td>
<td>101.06</td>
<td>0.60</td>
<td>100.20</td>
<td>101.90</td>
<td></td>
</tr>
<tr>
<td>Panel C: After the earthquake (173,904 observations)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price (RMB per meter square)</td>
<td>4,551</td>
<td>1,588</td>
<td>304</td>
<td>28,000</td>
<td>−712**</td>
</tr>
<tr>
<td>Unit size (square meters)</td>
<td>95.7</td>
<td>29.4</td>
<td>20.1</td>
<td>613.1</td>
<td>−3.1*</td>
</tr>
<tr>
<td>Floor level</td>
<td>11.9</td>
<td>7.9</td>
<td>1.0</td>
<td>36.0</td>
<td>−0.1</td>
</tr>
<tr>
<td>1–2 floor unit</td>
<td>0.08</td>
<td>0.27</td>
<td>0.00</td>
<td>1.00</td>
<td>0.01</td>
</tr>
<tr>
<td>3–6 floor unit</td>
<td>0.23</td>
<td>0.42</td>
<td>0.00</td>
<td>1.00</td>
<td>0.02</td>
</tr>
<tr>
<td>7–above floor unit</td>
<td>0.69</td>
<td>0.46</td>
<td>0.00</td>
<td>1.00</td>
<td>−0.03</td>
</tr>
<tr>
<td>If top developer</td>
<td>0.33</td>
<td>0.47</td>
<td>0.00</td>
<td>1.00</td>
<td>−0.06**</td>
</tr>
<tr>
<td>Housing price index (base year = 2010)</td>
<td>100.07</td>
<td>0.43</td>
<td>99.30</td>
<td>100.70</td>
<td>−0.99**</td>
</tr>
</tbody>
</table>

Note: The top panel reports summary statistics for the full sample (May 1, 2007 through May 31, 2009), the middle panel for the subsample prior to the earthquake (May 1, 2007 through May 12, 2008), and the bottom panel for the subsample after the earthquake (May 13, 2008 through May 31, 2009). The reported differences between the two subsamples in the last column are based on least squares regressions of each continuous variable on a dummy variable distinguishing the period before and after the earthquake. For the discrete variables, the reported differences are the marginal effects resulting from a Probit model.

** Denote significance at the 5%.
* Denote significance at the 10% level.

Although we focus on prices, the progression of the share of transactions by floor level and building height also provide an interesting pattern. As shown in Fig. 3, there was an important temporary decrease after the earthquake in both the number of purchases of units in floors 7 or above relative to purchases in lower floors and the number of purchases of units in high-rise buildings (i.e. buildings with more than 18 floors) relative to purchases in low-rise buildings. In particular, the share of transactions in upper floors and high-rise buildings decreased up to 6–7 percentage points until September 2008. These findings further support the seeming disproportionate fright of heights in Chengdu’s housing market after the earthquake.18

3.2. Methodology

This section describes the empirical model used to examine the effect of the Wenchuan earthquake on prices of new apartments located in different floor levels. We follow a hedonic approach to evaluate average and dynamic patterns of relative housing prices after the earthquake, as compared to prior to the tremor. We are particularly interested in examining whether apartment units in lower floors exhibited a different pricing behavior than units in upper floors after the earthquake, and assess whether these relative price differences are in line with a potential overreaction of consumers in terms of an excessive fear of heights after an extreme natural event.

We first estimate the following log-linear price equation,

$$
p_{ijt} = \alpha + \beta_1 \text{Quake}_t + \beta_2 \text{Floor}_{12i} + \beta_3 \text{Floor}_{36i} + \beta_4 (\text{Quake}_t x \text{Floor}_{12i}) + \beta_5 (\text{Quake}_t x \text{Floor}_{36i}) + X_{ijt}' \gamma + \kappa_j + \eta_i + \epsilon_{ijt}$$  

where $p_{ijt}$ is the price per square meter of apartment unit $i$ located in building $j$ and purchased at day $t$. Quake$_t$ is a dummy variable equal to one if the transaction occurred after the earthquake; Floor$_{12i}$ and Floor$_{36i}$ are dummy variables indicating whether the apartment is located in floors 1–2 and 3–6 respectively (floors 7 or above is the base category); and $X_{ijt}$ is a vector of apartment unit controls such as apartment size (in square meters). We specify the error term to have a building effect $\kappa_j$ common to all units in the same building, a time effect $\eta_i$ representing common shocks to Chengdu’s market, and a white noise error $\epsilon_{ijt}$. The building fixed effects account for all characteristics shared by units in the same building such as the quality of the building structure, the reputation of the developer (constructor), property amenities and location attributes, while a time trend (and its squared) capture overall economic and housing trends in Chengdu during the period of our study. We also include the housing price index obtained from the National Bureau of Statistics to control for the national real estate market trend and dummy variables to account for the housing subsidy period and variations in the policy by unit size, which was implemented by the city government after the earthquake to help displaced people.

We then estimate a second log-linear price equation given by,

$$
\ln p_{ijt} = \alpha + \sum_{S=0}^{12} \beta_3 S \text{Quake}_{MSt} + \beta_2 \text{Floor}_{12i} + \beta_1 \text{Floor}_{36i} + \sum_{S=0}^{12} \beta_4 S (\text{Quake}_{MSt} x \text{Floor}_{12i}) + \sum_{S=0}^{12} \beta_5 S (\text{Quake}_{MSt} x \text{Floor}_{36i}) + X_{ijt}' \gamma + \kappa_j + \eta_i + \epsilon_{ijt}
$$  

where $\text{Quake}_{MSt}$, $S=0, ..., 12$, are dummy variables for 30-day windows after the earthquake.

We refer to Eq. (1) as the average-effect model, which permits to assess average changes in relative prices of units located in lower versus upper floors. Parameters $\beta_4$ and $\beta_5$ capture variations after the earthquake in the price of units located in floors 1–2 and 3–6 relative to units located in floors 7 or above. Eq. (2) is the dynamic-effect model that allows us to analyze the progression of relative prices over the months following the tremor. The parameters of interest in this case are $\beta_4$ and $\beta_5$, $s=0, ..., 12$. We also estimate below a more flexible model that permits to recover the evolution of relative prices over the entire period of analysis.

4. Estimation results

Table 2 reports the estimation results of the average-effect model. The first two columns show the results using the full sample while the other two columns show the results for the West and East of Chengdu. In column (1) we measure the unit floor using an ordered variable from one to 36 and in columns (2)–(4) we use categorical variables to distinguish units in floors 1–2 and 3–6 (floors 7 or above is the base category). Building fixed effects and the trend terms are omitted for ease of presentation. The reported standard errors are robust and clustered at the district level.

Several interesting patterns emerge from the full-sample results. First, housing prices generally decreased after the earthquake, which is consistent with previous studies evaluating the impact of hazardous events on property values (e.g., Brookshire et al., 1985; Murdoch, Singh and Thayer, 1993; Bin and Polasky, 2004; Nakagawa, Saito and Yamaga, 2009). This negative effect is associated with the direct risks and self-insuring behavior of consumers for living in hazardous areas. Second, from column (1), we find that the earthquake seems to have had a higher (negative) impact on the prices of upper than lower floor units. On average, prices decreased by additional 0.2 percentage points for each additional floor level. The floor-level premium of 0.2% essentially vanished after the earthquake. Third, from column (2), we observe a general and significant increase after the earthquake in the prices of units in floors 1–2 and 3–6 relative to units in floors 7 or above. Prior to the earthquake, the price of apartments in floors 1–2 was not statistically different from the price of units in floors 7 or above; after the earthquake, the price of lower-level units were on average 2.6% higher. We also find an important increase in the relative price of units in floors 3–6 (from −3.1% to −0.2%). Under the premise that the floor level serves as a basis to measure perceived earthquake risk, these relative price changes are in line with an increased risk perception and fear, triggered after the tremor, of living in upper floors.

Regarding the control variables, we observe a negative correlation between prices (per square meter) and unit size as well as a positive correlation between housing prices in Chengdu and other cities. Prices in smaller size units also decreased with the temporary housing subsidy implemented after the earthquake. These effects generally hold across all model specifications.

If the fear of living in upper floors is driving the relative price changes after the earthquake, we would also expect higher price variations in areas located closer to the Longmen Shan Fault where the earthquake occurred. Conditional on the magnitude of the earthquake, ground shaking intensities decrease with distance from the fault or segments of faults where the earthquake occurs (ABAG, 2003). Hence, people living closer to this thrust fault should perceive a higher risk and fear of living in upper floors in the event of

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19 Unfortunately, we do not have additional information on unit attributes, like number of bedrooms/bathrooms or balconies, although apartment unit plans in China are relatively more homogenous than in other countries (Kong, Wu and Ma, 2008). Similarly, there are very small differences between units in the same building (Guo et al., 2014).

20 The results are not sensitive to using district by quarter fixed effects, district specific time trends or (annual) socioeconomic characteristics by district such as per capita disposable income and population density.

21 The subsides started on June 2008 and ended on December 2009. The amount of the subsidy depended on the size of the housing unit: 1.5% of the sale price for units of 90 square meters or less; 1% for units between 91 and 144 square meters; and 0.5% for units between 145 and 180 square meters.

22 The floor-level premium generally observed in residential apartments can be associated with the additional attributes provided by upper-floor units in terms of, for example, a better view, less noise and fresher air than lower-floor units (Benson et al., 1998; Chau, Wong and Yu, 2004; Glaeser, Gyurok and Saks, 2005).

23 Another important factor in determining shaking intensity is directivity, where areas located along the fault axis (in the direction of rupture) will experience stronger shaking. The intensity boundaries also extend farther from the fault source the larger the magnitude of the earthquake.
another earthquake, as there is a significant amplification of shaking near the fault rupture. When segmenting the sample between the West and the East of Chengdu in columns (3) and (4), we effectively observe a higher relative price increase in the West, which is closer to the fault (see Fig. 1). The relative price of units in floors 1–2 and 3–6 to floors 7 or above increased from –3.1% and –5.7% to 3.7% and 0.1% in the West, while in the East prices increased from –0.2% and –2.9% to 2.5% and –0.8%.

4.2. Dynamic-effect model

Table A.2 presents the estimation results of the dynamic-eff ect model. We are also interested in examining the progression of relative prices of units in lower versus upper floors over the months following the earthquake; in particular, if the increase in relative prices was temporal. Columns (1) and (2) show the results using the full sample and columns (3) and (4) the results for the West and East areas. To save space, we report the estimated coefficients (and standard errors) of the floor-level categorical variables (floors 1–2 and 3–6) and their corresponding interactions with the dummy variables for each 30-days window after the earthquake.24

The full-sample results show interesting patterns in the evolution of prices in lower- versus upper-floor units, which are better illustrated in Fig. 4. The figure reports estimated relative prices before the earthquake and for every 30-days window after the tremor. We observe that the relative price of units in floors 1–2 over floors 7 or above started to increase approximately 60 days after the earthquake and the increase lasted for about a year.25 During several months, the relative price reached values above 2.5% (with a peak of 7.9%) and returned back to the pre-earthquake level after 360 days, i.e. around May 2009. Second, the relative price of units in floors 3–6 followed a similar path and increased after the earthquake, but to a lower extent than in floors 1–2. In this case, the relative price reached levels close to zero percent (with a peak of 3.8%) and returned back to negative values towards the end of the sample period.26

24 The full estimation results are available upon request.

25 There was an important decline in the total number of house purchases over the 6–8 weeks after the earthquake, which could be linked to different market factors, including a general supply and demand contraction, as well as potential delays in the transaction and registration process (which generally take between 5–10 working days). During the second half of May 2008 there were a total of 3,330 transactions versus 4,261 transactions during the first half of the month, totaling 7,591 purchases compared to 9,195 purchases in April; in June, the number of transactions further decreased to 7,158 and recovered back in July with a total of 8,404 transactions.

26 As robustness, we excluded all transactions in the downtown area as the city center is likely less comparable to the other areas, although it was still affected by the tremor; the results are qualitatively similar when excluding this area (see Figure A.2.). A separate analysis of the evolution of relative prices of units in each of the first six floors also indicates that units in the first floor showed a much higher relative price increase. This suggests that consumers could have had a particular preference for living in the first floor—for example, the notion of being able to exit the building in an easy way in the case of an earthquake.
We also examined if the price reaction differed among districts with a high versus low per capita income. Prices on average decreased more in higher income areas after the earthquake, in line with the higher life valuation of high-income consumers and the direct risks of living in hazardous areas. Yet, relative prices of lower to upper floor units followed a similar progression in both high- and low-income areas and showed a rather larger relative increase in the latter, although this could be linked to the higher concentration of low-income areas in the West (see Figure A.3).

Similar to Brooks, Patel and Su (2003), we observed some delay in the price reaction after the tremor. The authors associate the delay in the price reaction of the US equity market after an unforeseen day event to an initial drop in the trade volume. The delay of about 60 days in our case is also correlated with a decline in the sales volume. The author also links her results to specific market restraints including credit constraints and high transaction costs; while in the case of Chengdu, the years around the tremor were in fact periods with a very dynamic housing market.

Finally, we cannot rule out potential unobserved factors driving the relative pricing behavior of units in lower versus upper floors after the earthquake. However, since we focus on relative prices, likely unobserved changes on housing demand or supply factors would be accounted for as long as these changes occurred across all apartment units and not among units located in specific floor levels. For example, agents’ overall expectations towards property values in disaster (hazardous) areas should be controlled for. Similarly, we do not expect systematic variations in the amenities included in upper versus lower units, although we cannot directly account for this. The subsidy policy did not affect the size distribution and relative prices of units across different floor levels. Even the apparent decrease in the available stock of new upper-level units, relative to lower-levels units, due to the slowdown in the construction of high-rise buildings in Chengdu after the earthquake, should have moved relative prices
in the opposite direction to what we observe, which provides additional support to our findings.33

4.3. Alternative dynamic model

As an additional exercise, we estimate a partially linear smooth coefficient model, which models the relative price differences of units in lower to upper floors as a function of time. In particular, we estimate the following log-price equation,

\[ \ln p_{ijt} = g_0(Ti_{et}) + g_1(Ti_{et}) \cdot Floor_{12} + g_2(Ti_{et}) \cdot Floor_{36} + X_i \gamma + \kappa_j + \epsilon_{ijt} \]

(3)

where \( Ti_{et} \) is a time variable accounting for 30-days windows before and after the earthquake and \( g_k (\cdot), k = 0, \ldots, 2 \), are unspecified smooth functions. The estimation is performed over a five percent random sample of the data due to the computational burden of the methodology.34

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33 A similar opposite effect on relative prices is expected if developers temporarily delayed the selling of upper floor units given the observed pricing patterns. In addition, the economic growth of the city around the time of earthquake could also have lessen the price discount for upper floor units after the tremor as we would expect an increasing demand for upper units with a higher income, as these units provide a better view or offer less noise than lower floor units (i.e. are of better “quality”).

34 The bandwidth of \( Ti_{et} \) is estimated using least-squares cross-validation and a Gaussian kernel function. This bandwidth estimation accounts for a daily time trend and the housing price index, which are then smoothed out to derive the unspecified functions \( g_k (\cdot), k = 0, \ldots, 2 \). See Li and Racine (2007) for further details on the method.

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Fig. 5. Estimated relative prices of lower- to upper-floor units, dynamic-effect model West versus East side.

Note: The upper figure corresponds to the West of Chengdu, which was closer to the earthquake epicenter, and the lower figure to the East of Chengdu, which was farther way from the epicenter (see Fig. 1). The relative prices for every 30-days window are based on the estimated coefficients of the dynamic-effect model reported in columns (3) and (4) in Table A.2 in the Appendix for the West of Chengdu and columns (5) and (6) for the East of Chengdu. The base category is upper-floor units in floors 7 or above. ** and * indicate that the estimated relative prices are statistically different from zero at the 5% and 10% level.

Fig. 6 shows how the relative price differences of units in floors 1–2 and 3–6 to floors 7 or above vary over the entire sample period. Prior to the earthquake, the relative price of units in the first two floors fluctuated between −3% and −1%; after the earthquake, the relative price experienced an important increase with positive values of 2% to 6% between July and January 2009, and then started to return back to the (negative) values exhibited prior to the tremor. The relative price of units in floors 3–6 followed a similar pattern with somewhat more stable negative values of −5% to −4% prior to the tremor, and a temporary increase up to 1–2% after the tremor; these prices also started to decrease towards the beginning of 2009. In sum, the evolution of relative prices after the earthquake was not similar to the one observed prior to the event.35
5. Concluding remarks

This paper analyzes if the occurrence of a natural disaster, such as the Wenchuan earthquake, results in a disproportionate fear of living in upper floors. The tremor not only caused severe property damage and casualties, but raised the awareness of potential earthquake risks among Chengdu residents. We rely on likely variations in the level of perceived risk by floor level, triggered after the earthquake, to evaluate the relative pricing patterns of apartment units in lower versus upper floors and assess whether the observed pricing behavior is consistent with an excessive fear of heights. We use an extensive transaction dataset of new residential apartments purchased across Chengdu over a period of one year before and one year after the earthquake.

The estimation results show that average housing prices decreased after the earthquake, which is consistent with the documented negative impact of hazard events on property values. However, the relative price of units in lower to upper floors, especially units in the first two floors, significantly increased for several months after the earthquake and then returned back to the levels observed prior to the tremor. We find this temporal increase in relative prices supportive of an increased risk perception and fear of living in upper floors, which eventually dissipated over time. The results are robust to alternative model estimations. Overall, the results suggest an apparent excessive fear of heights after the tremor.

The findings of this paper should stimulate additional studies regarding potential behavior anomalies in markets driven by agents’ risk perceptions and their effects on market efficiency. The fact that the relative price increase carried on for several months casts doubts on the efficiency of the housing market and the extent of no-market arbitrage, and should not be overlooked given the importance of housing in the Chinese household wealth portfolio (41% of total household assets according to the Chinese Household Finance Survey (2011)). In the event of a future similar disaster, a public program that stimulates the demand for units in upper floors (instead of only offering subsidies for smaller units) could probably help to address this unusual relative price behavior. Certainly, this price behavior can be regarded as irrational to the extent that there is an overestimation of perceived risks relative to actual risks as we move to upper floors, although we admit that subjective risks are difficult to quantify. Finally, we acknowledge that our study relies on a before-after comparison in the affected areas so we cannot fully discard alternative interpretations to our results, but we are also unaware of other probable explanations.

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Supplementary materials

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References


