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ABSTRACT

This paper uses the 2008 Wenchuan earthquake in China as a natural experiment to examine how the housing market reacted to this unforeseen, extreme event. We use a unique transaction dataset for new (under construction) apartment units to analyze the pricing behavior of units in lower versus upper floors before and after the earthquake. We observe that average housing prices decreased after the tremor. However, 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. This relative pricing pattern is in line with a higher risk perception and fear, triggered after the tremor, of living in upper floors. Additional robustness checks support the apparent overreaction of individuals to a dramatic event.

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1 Introduction

Research in experimental psychology suggests that people may overreact to new, unpredictable events. In particular, individuals will often violate Baye's rule when responding to new information as people tend to overweight recent information and underweight prior data (Kahneman and Tversky, 1973, 1982). Prospect theory further predicts that rare events tend to be overweighed in the absence of a risk-learning process through repeated experience (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). As noted by Glaeser (2004), individual decisions may also be highly context-dependent, based on local influences, and people may put enormous weight on ephemeral situations (what he refers to as "situationalism"). Even under low-risk circumstances, the occurrence of a rare but "high-signal" or "sharp" event will cause individuals to overestimate risk and exaggerate perceived risk (Tversky and Kahneman, 1974; Slovic, 1987; Viscusi, 1989, 1990). The level of perceived risk will particularly increase with the degree of exposure to the risk and how unusual, unpredictable, uncontainable and fatal the risk is.

While the excessive reaction of agents to major news events has been extensively examined in financial markets (e.g., De Bondt and Thaler, 1985; Ederington and Lee, 1993 and 1995; Brooks, Patel and Su, 2003), studies regarding potential overreaction of individuals to unexpected, dramatic events in other markets like the housing market are still scarce. This paper uses the 2008 Wenchuan earthquake in China as a natural experiment to analyze how individuals in the real estate market reacted to this unexpected, extreme event. We use an extensive transaction dataset for new (under construction) apartment units purchased across different affected areas over a period of one year before the earthquake and one year after the earthquake. We follow a hedonic price model approach to evaluate the pricing behavior of units in lower to upper floors after the earthquake, as compared to prior to the tremor, and assess whether the observed relative pricing patterns are in line with a potential overreaction in the housing market after an extreme event.

The Wenchuan earthquake, measured at 8.0M (surface wave magnitude scale), occurred at 2:28pm 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, which lasted for about two minutes, caused severe damage to

Chengdu and was felt across most mainland China.[2] The State Council designated Chengdu as an earthquake-stricken area after the earthquake.[3] Strong aftershocks, some exceeding 6.0M, continued to hit the area even months after the main tremor.

The occurrence of the earthquake provides a unique setting to evaluate market responses to a dramatic, exogenous event. Unlike most studies in financial markets which focus on reactions to major news releases, the Wenchuan earthquake of 2008 was a fully unforeseen, traumatic event that increased the awareness of potential earthquake damages and risks among all residents in Chengdu.[4] If the level of perceived earthquake risk is further dictated by the floor level where a unit is located, focusing on the relative price differences of apartment units in lower to upper floors permits us to examine if variations in these relative prices after the earthquake can be characterized as an overreaction driven by changes in the perceived risk. In particular, individuals may prefer to live at lower floors since they feel safer in the occurrence of an earthquake, as shocks are felt stronger in upper floors, and may also believe that their chances of surviving are higher at lower floors, as they can exit the building faster, although no evidence shows that people at lower floors are more likely to survive.[5] This should trigger an increase in the price of units in lower floors relative to units in upper floors after the earthquake, while controlling for other factors. The relative price increase should also fade across time as the fear of risk slowly dissipates when people eventually realize that the probability of recurrence of an event of such magnitude is very small (Kreps, 1984; Wood et al., 1992).

The results show that the average housing prices of new apartment units decreased after the Wenchuan earthquake, consistent with previous studies evaluating the impact of hazardous events and risks on property values (e.g., Brookshire et al., 1985; Murdoch, Singh and Thayer, 1993; Bin and Polasky, 2004; Wong, 2008). We also find, however, that the relative price of low to high floor units, specifically units located in the first and second floor, considerably increased

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[2] According to official figures, the Wenchuan earthquake resulted in 69,197 deaths (68,636 in Sichuan province), 18,222 missing and 374,176 injured (www.sina.com). The earthquake also left more than 4.8 million people homeless.

[3] Although Chengdu is located in a seismic zone, the previous major earthquakes around the area occurred back in 1974 in the neighboring province of Yunnan (7.1M) and in 1933 in Sichuan province (7.5M).

[4] Brooks, Patel and Su (2003) is among the few studies in financial markets that focus on unexpected, rare events (accidents) that occurred on specific firms like plane crashes and plant explosions.

[5] Side-to-side shacking is felt stronger in upper floors because most of the mass in buildings is typically lumped at the floor levels, thereby a significant inertia force gets added at each floor level due to the earthquake shacking at the building's foundation. The shearing of the whole structure, in turn, may concentrate stresses on weak walls or joints in the structure resulting in failure and partial or total collapse. For other details on earthquake effects refer to http://earthquake.usgs.gov.

for several months after the earthquake and then returned back to the levels observed prior to the tremor. We interpret our results as evidence of an increased risk perception and consequent fear of locating in upper floors. Additional robustness checks help to reduce the possibility of explanations other than an apparent overreaction of individuals to the observed relative pricing behavior of lower- to upper-level units after the natural event.

Other studies on real estate markets related to ours include Beron et al. (1997), Wong (2008) and Abadie and Dermisi (2008), which find mixed evidence regarding the reaction of housing markets to extreme events. Beron et al. (1997) 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 unlikely events. Wong (2008) does not find evidence of an excessive reaction of prices in secondary residential properties in Hong Kong after the 2003 Severe Acute Respiratory Syndrome (SARS) epidemic. Abadie and Dermisi (2008) conclude that office location decisions (vacancy rates) in downtown Chicago appear to have been affected by the increased perception of terrorist risk after the 9/11 attacks.

In contrast to these papers, our analysis is based on a unique transaction dataset of new (under construction) residential apartment units. These data allows us to exclusively concentrate on price differentials before and after the earthquake of comparable housing units located in lower- versus upper-floor levels. As noted above, the different floor levels permits us to exploit likely variations in the level of perceived earthquake risk. The focus 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 for all apartments and not for units located in 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; people's general expectations towards property values in affected (hazardous) areas should also be accounted for. We recognize, however, that our study 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 overviews the relevant empirical literature on overreaction and the effect of extreme events, particularly earthquakes, on housing markets. Section 3 describes the data used in the analysis and the methodology. Section 4 presents and discusses the estimation results. Section 5 concludes.

2 Related Literature

Market overreaction has been widely examined in finance (Barberis, Shleifer and Vishny, 1998). In this literature, overreaction is associated to situations where the psychological biases of investors result in abnormal investing behavior in the face of risk and uncertainty (see also Kahneman and Riepe, 1998; Hirshleifer, 2001; Baker and Nofsinger, 2002). Investors tend to overweight new information and underweight past information, thereby causing the sudden rise and fall of stock prices; when agents finally understand the reality of the situation, prices revert and ultimately return back to their normal levels.

Empirical studies on this topic have especially focused on the reaction of investors to new, dramatic information and its corresponding effect on stock and equity prices. Several of these studies also link the overreaction phenomenon to market inefficiencies. In their seminal paper, De Bondt and Thaler (1985) pose and corroborate two empirical regularities consistent with the overreaction hypothesis. First, sharp variations in stock prices will be followed by subsequent variations in the opposite direction. Second, the larger the initial price movement, the greater will be the posterior adjustment. The vast majority of the research conducted afterwards has confirmed the apparent overreaction of financial markets to new information, including De Bondt and Thaler (1987), Chopra, Lakonishok and Ritter (1992), Ederington and Lee (1993, 1995), Brooks, Patel and Su (2003), among others.

Brooks, Patel and Su (2003) in one of the few studies who particularly focus on the reaction of equity markets to totally unanticipated, rare events in terms of both content and timing. The incidents analyzed include plane crashes, fire and plant explosions and death of CEOs and chairmen. They find that the stock prices of the affected companies exhibit a "normal-abnormal-normal" progression in the occurrence of an unanticipated news event. Prices first decrease after the negative event and then revert back to the levels prior to the incident; the reaction to the event is also not necessarily immediate. These findings are relevant to us as the occurrence of an earthquake is a fully unpredictable event. Moreover, earthquakes of considerable magnitude can create even greater awareness of potential damages and risks in the minds of people, and the degree of perceived risk may be further dictated by the floor level where the individual lives at (with people at lower floors feeling safer than in upper floors).

In the housing literature, of particular interest are the studies of Beron et al. (1997), Wong (2008) and Abadie and Dermisi (2008). These studies follow different approaches to examine the reaction of real estate markets to an extreme event and find mixed results. Beron et al. (1997) estimate hedonic price functions for (owner-occupied) single-family dwellings to analyze the response of consumers to the Loma Prieta earthquake of 1989. They include in their analysis a proxy variable for perceived earthquake risk, based on an expected lifetime cumulative loss of the house value, to examine changes in individuals' attitudes towards risk. They find that people tend to initially overestimate the probability of damage from earthquakes. Wong (2008) evaluates how the 2003 SARS epidemic affected the market for secondary residential properties in Hong Kong using a panel of housing estates. She does not find an excessive reaction in housing prices to the epidemic when compared to the predictions of a standard asset-pricing model. She links her results to the specific characteristics of the analyzed market, including high transaction costs, credit constraints and loss aversion. Finally, Abadie and Dermisi (2008) evaluate whether the higher perceived level of risk after the 9/11 attacks influenced the location decisions of office tenants in downtown Chicago. The authors use a quarterly panel of buildings and find that vacancy rates experienced a much more pronounced increase in the three most distinctive landmark buildings and their vicinities, as compared to other areas in the city.

In this sense, our paper is more closely related to the work of Abadie and Dermisi (2008). Our extensive transaction dataset permits us to focus on relative price differences before and after the earthquake of similar housing units located in lower versus upper floors. Concentrating on prices of different floor levels allow us to exploit potential changes in the level of perceived earthquake risk after the Wenchuan earthquake and account for other potential latent factors.

Other relevant studies analyzing the impact of natural events, particularly earthquakes, on real estate markets include Brookshire et al. (1985), Murdoch, Singh and Thayer (1993), Onder, Dokmeci and Keskin (2004), Bin and Polasky (2004), and Nakagawa, Saito and Yamaga (2007, 2009). Most of these studies find a negative impact of hazard risks on property values. In particular, Brookshire et al. (1985) show that individuals exhibit a "self-insuring" behavior and pay less for houses located in relatively hazardous areas (Special Studies Zones) in California. Murdoch, Singh and Thayer (1993) conclude that the 1989 Loma Prieta earthquake caused an area-wide reduction in property values and Onder, Dokmeci and Keskin (2004) find that distance to fault lines is an important factor in explaining house values in Istanbul's housing market. Bin and Polasky (2004) show that houses located within a floodplain in North Carolina have a lower market value than equivalent houses located outside the floodplain and that these differences became more accentuated after Hurricane Floyd in 1999.[6] Nakagawa, Saito and Yamaga (2007, 2009), in turn, find that housing rents and land prices in the Tokyo Metropolitan Area are substantially lower in risky areas than in safer areas. We also discuss average changes in housing prices after the Wenchuan earthquake.

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 Figure 1.[7] The data is obtained from the Housing Authority transaction system of Chengdu.[8] The sample period covers May 1, 2007 through May 31, 2009, basically one year before and one year after the Wenchuan earthquake. The dataset contains information on purchase date, transaction price, property location, name of building developer, area of unit, unit floor (for apartments), building type and building status. The building type includes residential apartments with and without elevator in the building, both commercial and residential apartments, and villas.[9] The building status refers to whether the property is an existing building such that the buyer can move in right after purchase or whether the buyer has to wait for a period of time before moving in because the building is under construction (i.e. forward contracts).[10] We supplement this data with the housing price index from the National Bureau of Statistics of China to control for varying conditions in the national real estate market.

We restrict our analysis to residential apartments with elevator in the building, which represent 88% of the total transactions observed in our full sample.[11] This permits us to examine

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[6] Wong (2008) also finds an average decrease in housing prices in Hong Kong estates directly affected by the SARS epidemic.
[7] The county districts for which we do not have information are mainly rural counties with a small number of housing transactions.
[8] All housing sales in Chengdu must be registered in the Housing Authority transaction system, similar to the regulation in all other cities in China.
[9] Villas are equivalent to single-family and/or townhomes.
[10] 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.
[11] Residential apartments without elevator constitute another 10% of the observed transactions and commercial and

the pricing behavior of comparable housing units located at different floor levels. The type of buyers looking for a new house may also differ by the type of building. We further restrict our sample to forward contract transactions provided that we base our study on examining pricing patterns before and after the earthquake and the tremor affected several of the already existing buildings across the city of Chengdu.[12] While the earthquake did not likely vary the relative supply of available (new) apartments across different floor levels, it is even less likely that it affected the relative supply of apartments under construction.[13] Working with new (under construction) apartment units also avoids the use of repeat sales data that can lead to spurious correlations (Cho, 1996). Our final working sample includes 313,805 observations.

It is worth pointing out that the city government implemented temporary housing subsidies after the earthquake to help displaced people. The subsidies 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.[14] This policy potentially resulted in a small reduction in the average size and price of new apartments sold, but it did not affect the size distribution and relative prices of units sold across different floor levels.[15] We base our analysis on prices per square meter and also control for the subsidy period and unit size in the regressions.

Table 1 reports summary statistics of the key variables. We present descriptive statistics 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 4,870 RMB (700 US dollars). We further observe that average prices significantly dropped by about 712 RMB (13.5%) after the earthquake. The average unit size of new apartments, however, only decreased in 3 square meters. We also do not find significant changes before and after the earthquake in the

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residential apartments and villas explain together the remaining 2%.

[12] Most of the new house purchases across all China are actually made through forward contracts (89% in our sample).

[13] We also do not observe changes after the earthquake in the share of new low- versus high-rise buildings, based on the units sold for which we have information on the total number of floors in their building (about half of our sample). Details are available upon request.

[14] Housing units less than or equal to 180 square meters represent 99% of the units in our sample.

[15] We regressed the log of the unit area on a dummy variable distinguishing the period before and after the subsidy, dummy variables for different floor levels and the corresponding interaction terms of the former and latter variables, and we do not find the interaction terms statistically significant at conventional levels. We find similar results when using the log of price per square meter as the dependent variable. Details are available upon request.

average floor level where the purchased units are located and in the percentage of units sold by floor level. Before the earthquake, 7% of the apartments sold were located in the 1-2 floor, 10% in the 3-4 floor, 11% in the 5-6 floor and 71% in the seventh floor or above; after the earthquake, 8% were located in the 1-2 floor, 12% in the 3-4 floor, 12% in the 5-6 floor and 69% in the fifth floor or above. There is also a decrease in the percentage of purchased units built by a major developer (6 percentage points) and in the national housing price index (one point).

Figure 2 plots, in turn, average prices by floor level both before and after the earthquake. We observe that prices generally increase with the floor level. This floor-level premium is in line 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 Yiu, 2004; Glaeser, Gyourko and Saks, 2005). In addition, the earthquake seems to have had a differentiated effect on average prices across different floor levels. While the average price of apartment units in lower floors (particularly units in the sixth floor or below) did not show much variation or slightly increased after the earthquake, the price of apartment units in upper floors (above the sixth floor) decreased. Further, the average decrease in prices among upper-level units increased with the floor level; that is, units in upper floors showed a higher absolute and percentage drop in prices than units in lower floors. For instance, the price per square meter of a unit located in the tenth floor decreased by 339 RMB (7%) versus 541 RMB (10%) of a unit in the twentieth floor and 2,551 RMB (30%) of a unit in the thirty-fifth floor.

Figure 3 provides additional insights about the potential impact of the Wenchuan earthquake on the prices of new apartments. The figure illustrates the price dynamics over the sample period of apartment units located at different floor levels. In particular, we compare the evolution of average monthly prices of units located in floor 1-2, floor 3-4, floor 5-6 and the 7 floor or above.[16] Prices seem to move in a similar fashion across floor levels. However, two interesting patterns occurred after the earthquake. First, units located in the first and second floor experienced a temporary and substantial increase in their prices after the earthquake (of around 10%). For about three months (July through September 2008), average prices of units in the first two floors were even similar to prices 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

[16]Certainly, there are numerous possible floor groupings. We group units in floor 7 and above together since we do not find statistical significant variations in relative prices across these floors. The grouping of the first six floors (1-2, 3-4 and 5-6) basically capture the major price differences among these floor levels.

differences between upper (7 floor or above) and all lower level units (1-2, 3-4 and 5-6 floors) during the entire second half of 2008. The average differences reduced from 450-500 RMB to 250-350 RMB per square meter; the price differences did not return to previous levels until February 2009.

These pricing trends are further corroborated in Figure A.1 in the Appendix, which present the evolution of daily (log) prices based on separate regression-discontinuity estimations for apartment units in floors 1-2, 3-4, 5-6 and 7 or above. We also find an important jump of about 15% in the prices of units located in the first and second floor after the earthquake versus a 2% and 4% change (although not statistically significant) for units in the third and fourth floor and the fifth and sixth floor. We further observe a significant decrease of 6% in the prices of units in the seventh floor or above.

Hence, a preliminary overview of the data suggests that the Wenchuan earthquake had a differentiated impact on the prices of new apartments located at different floor levels, especially on apartment units in the first two floors. Although our analysis focuses on prices, a look at the share of transactions by floor level also reveals that there was a temporary decrease after the earthquake in the number of purchases of units in floors 7 or above, relative to purchases of units in lower floors (see Figure A.2). Overall, these patterns provide some preliminary evidence supporting the apparent overreaction of homebuyers after the earthquake in terms of an increased perception of feeling safer by living at lower floors, considering also that the relative supply of new (under construction) apartments units across different floor levels did not likely change after the natural event.

3.2 Methodology

This section describes the empirical model used to examine the effect of the Wenchuan earthquake on prices of new apartment units located at different floor levels. We follow a hedonic price model 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 floor levels exhibited a different pricing behavior than units in upper floor levels after the earthquake, and assess whether these relative price differences are in line with a potential overreaction of the housing market after a natural event.

Our empirical strategy relies on the assumption that the floor level where a unit is located can serve as a basis to measure perceived earthquake risk. People may prefer to live in lower floors because they feel safer in the event of an earthquake as shocks are felt less strong than in upper floors and believe they have a higher probability of surviving as they could exit the building faster. Hence, the occurrence of an earthquake should trigger a temporary increase in the relative prices of units located in lower versus upper floors, after controlling for other potential factors driving housing prices. We focus on the relative price differences of units located in floors 1-2, 3-4 and 5-6 versus units in floors 7 or above.[17]

We first estimate the following log-linear price equation,

$$\begin{aligned} \ln p_{ijt} &= \alpha + \beta_1 Quake_t + \beta_2 Floor12_i + \beta_3 Floor34_i + \beta_4 Floor56_i + \beta_5 (Quake_t \text{ x } Floor12_i) \\ &+ \beta_6 (Quake_t \text{ x } Floor34_i) + \beta_7 (Quake_t \text{ x } Floor56_i) + X_i \gamma + \kappa_j + \eta_t + \varepsilon_{ijt} \end{aligned} \quad (1)$$

where p_{ijt} is the price per square meter of apartment unit *i* located in county district *j* and purchased at day *t*, $Quake_t$ is a dummy variable equal to one if the transaction occurred after the earthquake, $Floor12_i$, $Floor34_i$ and $Floor56_i$ are dummy variables indicating whether the apartment is located in floors 1-2, 3-4 and 5-6 respectively (floors 7 or above is the base category), and X_i is a vector of apartment unit controls. These controls include the apartment size (in square meters) and a dummy variable that indicates whether the building where the unit is located is constructed by a major developer, which we interpret as a proxy for the quality of the unit.[18] Finally, we specify the error term to have a location effect κ_j common to all units in a district, a time effect η_t representing common shocks to Chengdu's market, and a white noise error ε_{ijt}. In particular, we account for district fixed effects and include a time trend (and its squared) to capture any overall economic and housing trends in Chengdu during the period of our study. We also include the national housing price index to further control for the national real estate market trend and a dummy variable to identify the housing subsidy period.

[17] We also discuss below differentiated impacts for each of the first six floors.

[18] Recall that we restrict our analysis to units in buildings with an elevator. 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). We also controlled for the building height where the unit is located, but the inclusion of this regressor does not materially affect our estimation results. We exclude this control from the analysis because we only have this information for about half of the transactions in our sample.

The parameters of interest in equation (1) are β_2 through β_7. The magnitudes of coefficients β_2, β_3 and β_4 approximate the average price difference, prior to the earthquake, of units located in floors 1-2, 3-4 and 5-6 relative to units located in floors 7 or above. The signs and magnitudes of β_5, β_6 and β_7 indicate how these average price differences varied after the earthquake. This model permits us to determine whether there was an average change in the relative prices of new units located across different floor levels after the Wenchuan earthquake, particularly on units located in the first six floor levels relative to units in upper floor levels. We refer to this first model as the average-effect model.

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

$$
\begin{aligned}
\ln p_{ijt} &= \alpha + \sum_{S=0}^{12} \beta_{S1} QuakeM_{St} + \beta_2 Floor12_i + \beta_3 Floor34_i + \beta_4 Floor56_i \\
&\quad + \sum_{S=0}^{12} \beta_{S5} (QuakeM_{St} \text{ x } Floor12_i) + \sum_{S=0}^{12} \beta_{S6} (QuakeM_{St} \text{ x } Floor34_i) \qquad (2) \\
&\quad + \sum_{S=0}^{12} \beta_{S7} (QuakeM_{St} \text{ x } Floor56_i) + X_i \gamma + \kappa_j + \eta_t + \varepsilon_{ijt}
\end{aligned}
$$

where $QuakeM_{St}$, $s = 0,...,12$, are dummy variables corresponding to 30-days windows after the earthquake.[19] As in equation (1), parameters β_2, β_3 and β_4 in equation (2) capture average price differences, prior to the earthquake, of units located in floors 1-2, 3-4 and 5-6 relative to units located in floors 7 or above. The signs and magnitudes of β_{S5}, β_{S6} and β_{S7}, $s = 0,...,12$, approximate, in turn, the evolution of these price differences over the months following the earthquake. This model allows us to determine variations over time in the relative pricing behavior of purchased units in lower versus upper floors. We refer to this model as the dynamic-effect model. We also estimate below a more flexible model that permits us to recover the complete evolution of these relative price differences over the entire period of analysis. Ultimately, we want to assess if the estimated pricing patterns are supportive of an apparent overreaction of homebuyers after an extreme event.

[19] Since the earthquake occurred on May 12, *s*=0 corresponds to May 13 through June 11, *s*=1 to June 12 through July 11, and so forth.

4 Estimation Results

This section presents the estimation results and evaluates robustness. We first discuss the results of the average- and dynamic-effect models specified in equations (1) and (2). We then assess the validity of the results using alternative model specifications.

4.1 Base Results

Table 2 reports the estimation results of the average-effect model, which permits us to evaluate average changes in unit prices after the earthquake and whether these changes differed across units in lower versus upper floor levels. In column (1) we measure the unit floor through an ordered variable from one to 36 and in column (2) we further interact this variable with the post-earthquake dummy variable. In column (3) we use categorical variables to distinguish units in floors 1-2, 3-4 and 5-6 (floors 7 or above is the base category), and their corresponding interactions with the post-earthquake dummy, as described in equation (1). District 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 first two columns, where we account for the floor level using an ordered variable. First, we confirm the existence of a floor-level premium. As reported in column (1), the price per square meter of an apartment unit located one floor higher than another unit is, on average, 0.2% higher. Second, housing prices decreased after the earthquake by approximately 6.3% or 307 RMB (44 US dollars) per square meter. This finding is consistent with previous studies which find a decrease in property values in the face of extreme events and risks, including Brookshire et al. (1985), Murdoch, Singh and Thayer (1993), Bin and Polasky (2004) and Wong (2008). The occurrence of major hazard events tend to awaken or reinforce the perceived risks (and costs) associated with living in relatively hazardous areas. Finally, when interacting the post-earthquake dummy variable with the floor level in column (2), we observe a decrease in the floor-level premium after the earthquake. In particular, the floor premium decreased in 0.2 percentage points after the earthquake (from 0.3% to 0.1%). Hence, the earthquake seems to have had a higher (negative) impact on the prices of upper than lower floor units.

The results in column (3) permit to better assess potential differences in the relative variation of unit prices in lower versus upper floor levels after the earthquake. We compare average prices, before and after the earthquake, of apartment units in floors 1-2, 3-4 and 5-6 relative to units in floors 7 or above.[20] We find that the relative price difference between units in the first two floors and units above the sixth floor basically reversed after the earthquake. Prior to the Wenchuan earthquake, the price of apartments in floors 1-2 was 4.4% lower than units in floors 7 or above; after the earthquake, the price of the lower level units were 0.1% higher. We also observe a significant increase in the relative price of units in floors 3-4 to floors 7 or above (from -5.4% to -0.9%), combined with a smaller increase in the relative price of units in floors 5-6 to floors 7 or above (from -4.3% to -2.2%).[21] It follows, then, that there was an important variation in the relative prices of lower versus upper apartment units after the earthquake and the extent of the relative increase in the prices of lower- to upper-floor units decreased progressively from floors 1-2 through floors 5-6.

Regarding the coefficients of the control variables, they generally have the expected signs and are in most cases statistically significant across all specifications. The price per square meter decreases with the unit size. Apartments built by a major developer are around 6.5% more expensive than those built by other developers, likely reflecting a higher (or perceived) quality of the unit. Prices did not appear to decrease with the temporary housing subsidies implemented after the earthquake. Although not reported, apartment prices are also higher in the city center than in the suburbs.

While the results above reveal a significant average increase in the relative pricing of purchased units in lower versus upper floors after the earthquake, we are further interested in examining the evolution of these relative prices following the natural event. We are particularly interested in evaluating the progression of these relative price increases and whether they are in line with the increased perception, following the earthquake, of feeling safer by living at lower floor levels. We ultimately want to determine whether the observed behavior is consistent with an overreaction in the housing market after an unexpected extreme event.

Table 3 presents the results of the dynamic-effect model specified in equation (2), which permits to estimate the evolution of the relative prices of units in floors 1-2, 3-4 and 5-6 to units in floors 7 or above over the months following the Wenchuan earthquake. Instead of a single

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[20] As noted earlier, this floor grouping better describes the observed pricing behavior of units in the first six floors and of units in upper floors during our sample period.

[21] We also examined potential variations in relative unit prices across upper-floor levels, but we do not find significant changes.

post-earthquake dummy variable, we include dummy variables for each 30-days window after the earthquake and their corresponding interactions with the floor-level categorical variables. Column (1) corresponds to our base results and the remaining columns to additional estimations, discussed later. We note without further discussion that the estimated coefficients of the control variables here are generally similar to those in Table 2.

The results from column (1) indicate certain differences in the evolution of prices in floors 1-2, 3-4 and 5-6 relative to upper-floor units, which are better illustrated in Figure 4. The figure reports the estimated relative prices of lower- to upper-floor units both before the earthquake and for every 30-days window after the natural event. We observe two interesting patterns. First, the increase in the relative price of units in the first two floors to units in floors 7 or above basically started 60 days after the earthquake and lasted for about a year.[22] Further, the relative price difference of units in floors 1-2 to floors 7 or above was reversed during several months, reaching values over 3%, and only returned back to the levels observed prior to the earthquake (of -4%) after 360 days, i.e. around May 2009. Second, the relative prices of units in floors 3-4 and 5-6 to units in floors 7 or above also increased after the earthquake, but to a lower extent than in the first two floors. In particular, the relative price of units in floors 3-4 followed a similar path than the price in floors 1-2, increasing 60 days after the earthquake (with peaks of 2% in certain months) and returned back to negative values of around -4% towards the end of the period of analysis; the relative price of units in floors 5-6 only showed an important increase 120 days after the earthquake (with peaks of 1.5-2%) and also decreased back to negative values below -4% towards the end of the sample period.

These results are in line with a seeming overreaction of homebuyers after the Wenchuan earthquake. Under the premise that the floor level serves as a basis to measure perceived earthquake risk, this natural phenomenon should trigger an increase in the prices of units in lower floors relative to units in upper floors. After certain time, however, the potential fear that drives this pricing behavior should dissipate and housing prices should eventually return to normal price levels. The estimated relative prices of lower- to upper-floor units, particularly of units in the first two floors, precisely seem to have followed this progression after the

[22] It is worth noting that there was an important decline in the number of house purchases during the following 6-8 weeks after the earthquake. For example, 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.

earthquake. Hence, similar to an overreaction in the equity and stock market to dramatic news events (e.g., De Bondt and Thaler, 1985; Ederington and Lee, 1995; Brooks, Patel and Su, 2003), our results are supportive of an apparent overreaction in the real estate market after an unexpected, extreme event. Alike Brooks, Patel and Su (2003), we also find some delay in the price reaction to an unanticipated event, in our case of around 60 days when the total volume of house sales in Chengdu started to return back to normal levels.[23]

To put our results in perspective and better understand the economic magnitude of the seeming overreaction in the housing market after the Wenchuan earthquake, we can perform some back-of-the-envelope calculations. For instance, if the owner of a new apartment unit in the first or second floor decided to sell his apartment between July 2008 and April 2009 to buy a unit in the seventh floor or above and do the opposite around May 2009 (i.e. a year after the earthquake), she/he could have made gains in the order of 6-18% of his property value or 3-15% after discounting transaction costs. This calculation is based on the estimated percentage-points increase in the relative price of units in floors 1-2 to floors 7 or above over the months after the earthquake (reported in Figure 4), and considering that transactions costs in China are around 1.5% per transaction and are typically shared between buyers and sellers. These estimations further exclude potential gains from leverage.

Finally, we cannot rule out potential unobserved factors, other than consumers' overreaction, driving the relative pricing behavior of units in lower versus upper floors after the earthquake. However, since we focus on relative prices across different floor levels, potential (unobserved) changes on housing demand or supply factors would be accounted for as long as these changes occurred across all apartment units and not in units located in specific floor levels. For example, agents' overall expectations towards property values in disaster (hazardous) areas should be controlled for. Similarly, as noted above, the temporary housing subsidies do not seem to have affected the size distribution of new apartments across different floors. We also do not expect systematic variations after the earthquake in the amenities included in upper versus lower apartment units, although we cannot directly account for this. Changes in the relative supply of lower versus upper units under construction also seems unlikely; at least we do not observe variations after the earthquake in the share of low- versus high-rise buildings under construction,

[23] Brooks, Patel and Su (2003) associate the delay in the price reaction of the U.S. equity market after an unforeseen day event to an initial decrease in the total volume of trades, as compared to overnight events.

based on the units sold for which we have this type of information, as pointed above. Even if there were a decrease in the actual supply of new upper-level units, relative to lower-level units, because of a sudden increased concern regarding tall buildings in an active seismic area, the effect on relative prices should move in the opposite direction to what we observe.[24]

4.2 Additional Estimations

We now perform some robustness checks to further assess the validity of our results and reduce the plausibility of alternative explanations for the results obtained.

First, if the fear of living in upper floors, incited after the Wenchuan earthquake, is driving the relative pricing behavior of lower- versus upper-floor units, we would expect a higher variation in relative prices 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).[25] Hence, people living closer to this thrust fault, located West of Chengdu, should perceive a higher risk of living in upper floors in the event of future earthquakes, as there is a significant amplification of shacking near the fault rupture.[26]

We accordingly segment our sample into housing transactions in the West of the city, which are closer to the Longmen Shan Fault, and transactions in the East of the city, which are farther away from the fault, and performed separate estimations. As shown in Figure 1, the West side includes Dayi, Chongzhou, Dujiangyan, Pengzhou, Wenjiang and Pixian, while the East side includes all the other county districts plus the downtown area of Chengdu.

The estimation results for the two subsamples are reported in columns (2) and (3) of Table 3. Figure 5 summarizes the estimated relative prices of lower- to upper-floor units before the earthquake and for every 30-days window after the tremor for the West and East side of Chengdu. The figure shows that much of the variation in the relative prices, especially of units in the first two floors, occurred in the West side. We observe that the relative price of units in floors 1-2 to floors 7 or above was above 4% for several months after the earthquake (with peaks of 12-

[24] The awareness caused by the earthquake also likely led to building more resistant structures, but this should not affect relative prices across floor levels as all new units become safer.

[25] Another important factor 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 further from the fault source the larger the magnitude of the earthquake.

[26] The recent Lushan earthquake (7.0M) of April 2013 also occurred along the Longmen Shan Fault.

14%), and returned back to negative values similar to those observed before the earthquake (below -4%) after 360 days; we further note that the initial reversal in relative prices occurred in this case within 30 days after the earthquake.[27] The relative prices of units in floors 3-4 and 5-6 also show certain variation after the earthquake, although six months after the main tremor with peaks of 12% and 6% respectively. In the East side the relative prices of lower- to upper-floor units increased in a lower extent. The relative price difference of units in floors 1-2 to floors 7 or above reached values of 2-3% for a couple of months whereas the relative prices of units in floors 3-4 and 5-6 were only reversed during specific months, with corresponding peaks of 2.5% and 1.5%; the relative prices of all lower-floor units also seem to return to the levels prior to the earthquake after 300 days. Hence, the higher variation in relative prices in the West side, particularly of units in floors 1-2, is consistent with the higher perceived risk of living in upper floors in the proximity of a potential earthquake epicenter, which could have been prompted after the Wenchuan earthquake.

As an additional empirical check, we separately examined the progression followed by the relative price of units in each of the first six floors to units in floors 7 or above. The estimation results of this exercise are presented in Table A.1 in the Appendix and Figure 6 plots the evolution of relative prices for each floor level. We find that apartment units in the first floor experienced a much higher increase in their relative price, with values over 4% during several months after the earthquake and peaks of 10-11%, as compared to units in the other floors. The relative price of units in the second floor followed a similar path than the price of units in the first floor, also increasing 60 days after the earthquake, but the magnitude of the change was smaller and closer to the relative price changes observed in floors 3 through 6. This result suggests that consumers could have had a particular preference, triggered after the earthquake, for living in the first floor. This is in line with the notion of being able to exit the building in an easy and fast manner by, for example, not requiring using the stairs or even jumping from a window in the event of another tremor.[28]

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[27] Following the example above, selling in this case an apartment unit in the first or second floor in the months posterior the earthquake to buy a unit in an upper floor, and reversing to your original position a year after the earthquake, could have resulted in gains between 6% and up to 42% of the property value or 3% to 39% after accounting for transaction costs.

[28] It is interesting that the relative price of villas to upper-floor apartment units also exhibited a similar path than the first-floor units. As noted above, we do not include these buildings in our analysis in order to control for potential differences in the type of buyers looking for different types of houses (i.e. residential apartments versus single-family or townhomes). Yet, it is possible that the fear of living in upper floors could also have driven some

Finally, we estimate an alternative partially linear smooth coefficient model to further examine the robustness of our results. This semi-parametric estimation method allows us to directly model the relative price differences of units in lower to upper floors as a function of time without imposing any specific functional form on the evolution of these relative price differences. The estimation procedure also permits us to include a set of control variables.

We estimate the following log-linear price equation,

$$\begin{aligned} \ln p_{ijt} &= g_0(Time_t) + g_1(Time_t)\, Floor12_i + g_2(Time_t) Floor34_i \\ &\quad + g_3(Time_t)\, Floor56_i + X_i\gamma + \kappa_j + \varepsilon_{ijt} \end{aligned} \tag{3}$$

where $Time_t$ is a time variable accounting for 30-days windows before and after the Wenchuan earthquake and $g_f(\cdot)$, $f = 0,..,3$, are unspecified smooth functions of $Time_t$.

The estimation is performed over a five percent random sample of the dataset, approximately 15,691 observations, due to the computational burden of the methodology. The random sample maintains the proportion of transactions by floor level and districts. The bandwidth of $Time_t$ is first estimated via least-squares cross-validation procedure using a second-order Gaussian kernel function. This bandwidth estimation also accounts for a daily time trend and the national housing price index, which are then smoothed out to derive the unspecified functions $g_f(\cdot)$, $f = 0,..,3$.[29]

Figure 7 shows how the relative price differences of units in floors 1-2, 3-4 and 5-6 to floors 7 or above vary over the entire sample period, i.e. May 2007 through May 2009. We observe that prior to the earthquake, the relative price of units in the first two floors fluctuated between -3% and -5%; after the earthquake, the relative price experienced an important increase, with positive values of 1% to 4% between July and December 2008, and then returned back to the values exhibited prior to the earthquake. The relative prices of units in floors 3-4 and 5-6 followed a similar pattern with somewhat more stable negative values close to -7% and -6% prior to the tremor, and temporary increases up to -1% and -0.5% after the tremor; these prices also started to decrease towards the beginning of 2009. Overall, the progression of relative prices

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homebuyers away from apartment units and purchase instead a villa.

[29] We do not include these two controls in equation (3) due to potential multicollinearity issues in the estimation process. For further details on the estimation method refer to Li and Racine (2007).

of lower- to upper-level units observed during the 12-months following the earthquake was not parallel to the one observed 12-months prior to the natural event. The results using this alternative, less restrictive model provide additional supportive evidence regarding the apparent overreaction in the housing market after the earthquake, likely driven by the fear of living in upper floors.[30]

In sum, the additional estimations performed help to support our central findings and reduce the possibility of alternative explanations, other than a seeming overreaction of homebuyers, driving the observed relative pricing behavior of lower- to upper-floor units after the earthquake.

5 Concluding Remarks

The Wenchuan earthquake of May 12, 2008 was an unforeseen, dramatic event, which not only caused severe property damage and casualties but also had an important psychological impact on the residents of Chengdu and raised their awareness towards earthquake risks. This paper uses the Wenchuan earthquake as a natural experiment to investigate the reaction of the housing market to this event. We particularly focus on the relative pricing behavior of comparable housing units in lower versus upper floors before and after the earthquake, as the level of perceived earthquake risk may be further dictated by the floor level where the unit is located. We base our analysis on an extensive transaction dataset of new (under construction) apartment units purchased across nine county districts and the downtown area of Chengdu between May 2007 and May 2009.

The estimation results show that average housing prices decreased after the earthquake consistent with the well documented negative impact of hazard events (risks) on property values. However, the relative price of apartment units in lower to upper floors, especially units in the first two floors, significantly increased for several months after the earthquake. We find these results supportive of an increased risk perception and fear, triggered after the earthquake, of locating in upper floor levels in the event of future earthquakes. Additional robustness tests and extensions further reduce the possibility of other interpretations to the observed relative pricing

[30] We further fitted a model with dummy variables for 30-days windows both before and after the earthquake and their corresponding interactions with the categorical variables for floors 1-2, 3-4 and 5-6. The full estimation results are reported in Table A.2 and Figure A.3 plots the evolution of the estimated relative prices. The results also confirm that the increase and temporary reversal in the relative prices of lower to upper-floor units, especially of units in floors 1-2, was not observed at any point prior to the tremor.

behavior. Overall, the results support the apparent overreaction of homebuyers to the earthquake, similar to the overreaction of investors in stock markets to new, unexpected events.

The results of this paper should stimulate additional studies regarding behavior anomalies in real estate markets, driven by the nature of agents' risk perceptions, and the consequent effects on market efficiency. In particular, the reversal in the relative price of units in the first floors to upper floors after the earthquake indicates a seeming abnormal (or maybe irrational) behavior resulting from an overestimation of perceived risks relative to actual risks. Yet, the fact that this price anomaly carry on for several months cast doubts on the efficiency of the housing market and the extent of market arbitrage. Similarly, the decrease in average housing prices after the earthquake seems in line with a "self-insuring" behavior of rational individuals living in relatively hazardous areas. However, the degree to which the observed changes in prices correspond to agents responding to actual risks versus exaggerated perceived risks is worth exploring in future works.

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Table 1. Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	Diff.
Full sample (313,805 observations)					
Price (RMB per meter square)	4,869	1,612	304	28,000	
Unit size (square meters)	97.1	30.7	20.1	735.4	
Floor level	11.9	7.8	1.0	36.0	
1-2 floor unit	0.08	0.27	0.00	1.00	
3-4 floor unit	0.11	0.31	0.00	1.00	
5-6 floor unit	0.12	0.32	0.00	1.00	
7-above floor unit	0.70	0.46	0.00	1.00	
If top developer	0.36	0.48	0.00	1.00	
Housing price index (base year=2010)	100.51	0.71	99.30	101.90	
Before the earthquake (139,901 observations)					
Price (RMB per meter square)	5,263	1,553	590	21,830	
Unit size (square meters)	98.8	32.2	20.1	735.4	
Floor level	12.0	7.6	1.0	36.0	
1-2 floor unit	0.07	0.25	0.00	1.00	
3-4 floor unit	0.10	0.31	0.00	1.00	
5-6 floor unit	0.11	0.32	0.00	1.00	
7-above floor unit	0.71	0.45	0.00	1.00	
If top developer	0.40	0.49	0.00	1.00	
Housing price index (base year=2010)	101.06	0.60	100.20	101.90	
After the earthquake (173,904 observations)					
Price (RMB per meter square)	4,551	1,588	304	28,000	-712*
Unit size (square meters)	95.7	29.4	20.1	613.1	-3.1
Floor level	11.9	7.9	1.0	36.0	-0.1
1-2 floor unit	0.08	0.27	0.00	1.00	0.01
3-4 floor unit	0.12	0.32	0.00	1.00	0.01
5-6 floor unit	0.12	0.32	0.00	1.00	0.00
7-above floor unit	0.69	0.46	0.00	1.00	-0.03
If top developer	0.33	0.47	0.00	1.00	-0.06**
Housing price index (base year=2010)	100.07	0.43	99.30	100.70	-0.99**

Note: The reported differences between the two subsamples 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. (**) and (*) denotes significance at 1% and 5% level.

Table 2. Log of price per square meter regressions, average-effect model

Variable	Using floor level		Using floor dummies
	(1)	(2)	(3)
Floor level	0.002	0.003	
	(0.000)	(0.000)	
1-2 floor unit			-0.045
			(0.006)
3-4 floor unit			-0.055
			(0.002)
5-6 floor unit			-0.044
			(0.004)
Post-earthquake	-0.065	-0.040	-0.076
	(0.019)	(0.018)	(0.016)
Floor level x post-earthquake		-0.002	
		(0.001)	
1-2 floor unit x post-earthquake			0.046
			(0.020)
3-4 floor unit x post-earthquake			0.046
			(0.010)
5-6 floor unit x post-earthquake			0.022
			(0.009)
Log unit size (square meters)	-0.061	-0.061	-0.063
	(0.030)	(0.029)	(0.029)
If top developer	0.062	0.062	0.064
	(0.025)	(0.025)	(0.025)
Log housing price index	7.688	7.650	7.738
	(1.048)	(1.063)	(1.034)
Subsidy period	-0.026	-0.027	-0.026
	(0.052)	(0.053)	(0.053)
Constant	-26.797	-26.632	-26.975
	(4.926)	(4.993)	(4.859)
# observations	313,805	313,805	313,805
R-squared	0.392	0.392	0.391

Note: All specifications include district fixed effects and a trend and trend squared term. White robust standard errors reported in parentheses, clustered at the district level.

Table 3. Log of price per square meter regressions, dynamic-effect model

Variable	(1) Full sample	(2) West side	(3) East side
1-2 floor unit	-0.045	-0.050	-0.049
	(0.006)	(0.022)	(0.004)
3-4 floor unit	-0.055	-0.074	-0.057
	(0.003)	(0.026)	(0.002)
5-6 floor unit	-0.044	-0.100	-0.040
	(0.004)	(0.029)	(0.002)
Post-30 days	-0.029	-0.013	-0.029
	(0.010)	(0.047)	(0.010)
Post-60 days	-0.092	0.018	-0.100
	(0.019)	(0.057)	(0.014)
Post-90 days	-0.041	-0.049	-0.024
	(0.023)	(0.031)	(0.018)
Post-120 days	-0.026	-0.074	-0.002
	(0.039)	(0.046)	(0.032)
Post-150 days	-0.064	-0.052	-0.051
	(0.071)	(0.059)	(0.091)
Post-180 days	-0.056	-0.031	-0.049
	(0.022)	(0.079)	(0.024)
Post-210 days	-0.063	0.017	-0.066
	(0.119)	(0.125)	(0.154)
Post-240 days	-0.004	-0.021	0.007
	(0.046)	(0.111)	(0.049)
Post-270 days	-0.008	0.079	-0.016
	(0.034)	(0.141)	(0.033)
Post-300 days	0.091	0.176	0.083
	(0.040)	(0.184)	(0.035)
Post-330 days	0.138	0.243	0.125
	(0.046)	(0.202)	(0.040)
Post-360 days	0.219	0.306	0.207
	(0.051)	(0.227)	(0.044)
Post-390 days	0.283	0.377	0.269
	(0.054)	(0.270)	(0.035)
1-2 floor unit x post-30 days	-0.016	0.083	-0.037
	(0.037)	(0.029)	(0.034)
1-2 floor unit x post-60 days	-0.004	0.065	-0.007
	(0.015)	(0.036)	(0.014)
1-2 floor unit x post-90 days	0.080	0.158	0.065
	(0.030)	(0.012)	(0.031)
1-2 floor unit x post-120 days	0.068	0.120	0.062
	(0.011)	(0.032)	(0.013)
1-2 floor unit x post-150 days	0.029	0.028	0.036
	(0.021)	(0.054)	(0.012)
1-2 floor unit x post-180 days	0.030	0.119	0.002
	(0.029)	(0.044)	(0.025)

(*Cont.*)

Variable	(1) Full sample	(2) West side	(3) East side
1-2 floor unit x post-210 days	0.090	0.162	0.067
	(0.100)	(0.040)	(0.124)
1-2 floor unit x post-240 days	0.057	0.198	0.033
	(0.026)	(0.025)	(0.025)
1-2 floor unit x post-270 days	0.077	0.085	0.076
	(0.025)	(0.045)	(0.033)
1-2 floor unit x post-300 days	0.076	0.099	0.072
	(0.027)	(0.029)	(0.037)
1-2 floor unit x post-330 days	0.053	0.134	0.021
	(0.039)	(0.027)	(0.046)
1-2 floor unit x post-360 days	0.055	0.092	0.043
	(0.026)	(0.038)	(0.035)
1-2 floor unit x post-390 days	-0.002	-0.039	0.021
	(0.026)	(0.069)	(0.002)
3-4 floor unit x post-30 days	0.021	0.032	0.019
	(0.012)	(0.019)	(0.015)
3-4 floor unit x post-60 days	0.003	-0.131	0.027
	(0.034)	(0.040)	(0.020)
3-4 floor unit x post-90 days	0.045	0.029	0.066
	(0.022)	(0.021)	(0.021)
3-4 floor unit x post-120 days	0.023	0.026	0.034
	(0.016)	(0.031)	(0.012)
3-4 floor unit x post-150 days	0.025	-0.000	0.051
	(0.029)	(0.046)	(0.012)
3-4 floor unit x post-180 days	0.024	0.036	0.037
	(0.021)	(0.045)	(0.014)
3-4 floor unit x post-210 days	0.080	0.094	0.082
	(0.094)	(0.036)	(0.120)
3-4 floor unit x post-240 days	0.048	0.202	0.025
	(0.021)	(0.045)	(0.028)
3-4 floor unit x post-270 days	0.078	0.149	0.055
	(0.018)	(0.062)	(0.011)
3-4 floor unit x post-300 days	0.064	0.082	0.063
	(0.012)	(0.042)	(0.012)
3-4 floor unit x post-330 days	0.059	0.107	0.045
	(0.017)	(0.046)	(0.014)
3-4 floor unit x post-360 days	0.059	0.106	0.050
	(0.015)	(0.055)	(0.011)
3-4 floor unit x post-390 days	0.019	-0.025	0.049
	(0.030)	(0.069)	(0.011)
5-6 floor unit x post-30 days	0.006	0.048	0.002
	(0.011)	(0.035)	(0.009)
5-6 floor unit x post-60 days	0.012	-0.049	0.026
	(0.022)	(0.039)	(0.012)
5-6 floor unit x post-90 days	0.014	0.067	0.026
	(0.016)	(0.028)	(0.007)

(*Cont.*)

Variable	(1) Full sample	(2) West side	(3) East side
5-6 floor unit x post-120 days	0.002	0.050	0.013
	(0.023)	(0.038)	(0.026)
5-6 floor unit x post-150 days	0.013	0.019	0.034
	(0.029)	(0.048)	(0.013)
5-6 floor unit x post-180 days	0.042	0.075	0.050
	(0.018)	(0.052)	(0.012)
5-6 floor unit x post-210 days	0.049	0.086	0.053
	(0.045)	(0.029)	(0.046)
5-6 floor unit x post-240 days	0.027	0.152	0.016
	(0.016)	(0.038)	(0.020)
5-6 floor unit x post-270 days	0.067	0.163	0.049
	(0.018)	(0.055)	(0.024)
5-6 floor unit x post-300 days	0.024	0.084	0.018
	(0.012)	(0.026)	(0.013)
5-6 floor unit x post-330 days	0.026	0.078	0.020
	(0.012)	(0.035)	(0.014)
5-6 floor unit x post-360 days	0.028	0.089	0.022
	(0.011)	(0.036)	(0.014)
5-6 floor unit x post-390 days	-0.006	-0.035	0.028
	(0.034)	(0.072)	(0.016)
Log unit size (square meters)	-0.063	0.017	-0.075
	(0.029)	(0.063)	(0.022)
If top developer	0.064	0.069	0.065
	(0.025)	(0.009)	(0.030)
Log housing price index	3.924	6.168	3.812
	(0.441)	(2.269)	(0.674)
Subsidy period	0.051	-0.073	0.055
	(0.023)	(0.059)	(0.022)
Constant	-9.386	-20.863	-8.811
	(1.948)	(10.387)	(3.009)
# observations	313,805	42,957	270,848
R-squared	0.397	0.283	0.286

Note: All specifications include district fixed effects and a trend and trend squared term. White robust standard errors reported in parentheses, clustered at the district level.

Figure 1. Map of areas included in the study

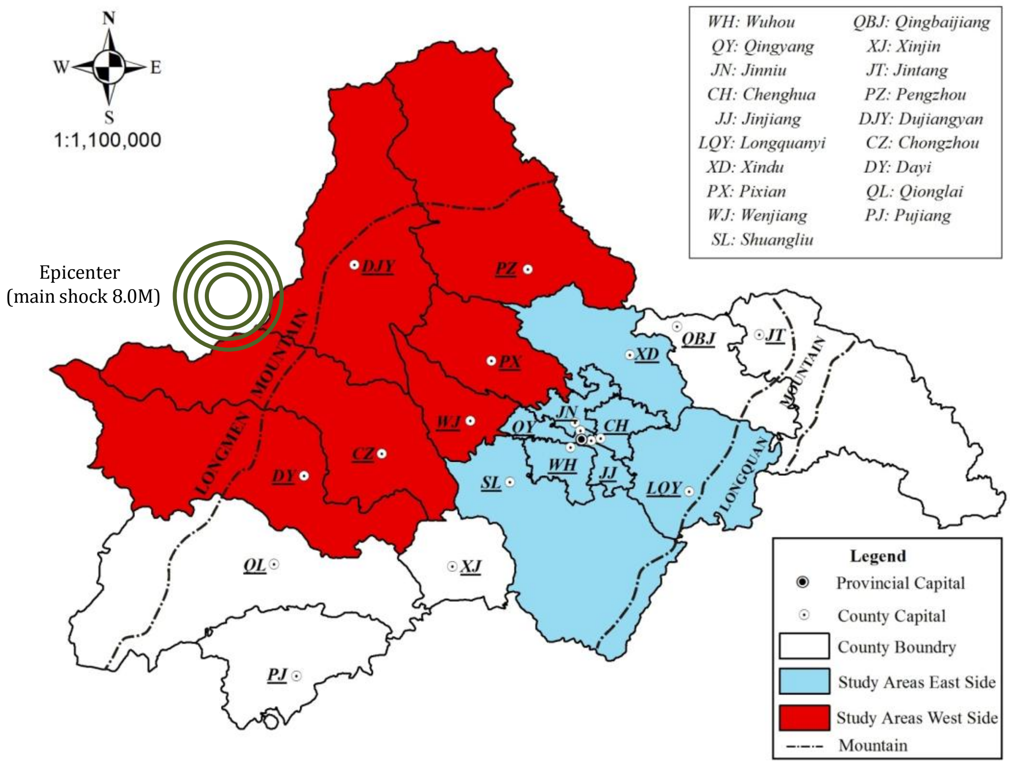


Figure 2. Average prices by floor level, before and after the earthquake

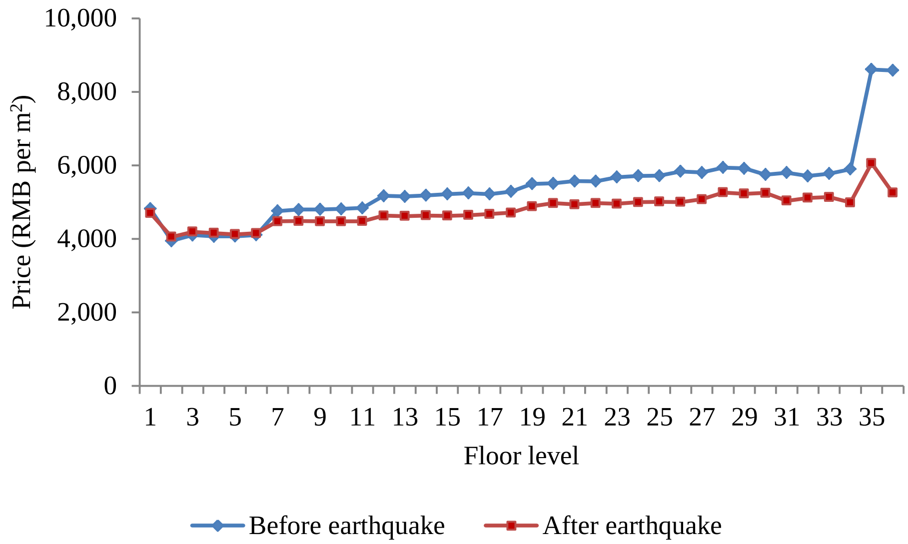


Figure 3. Evolution of monthly average prices for different floor levels

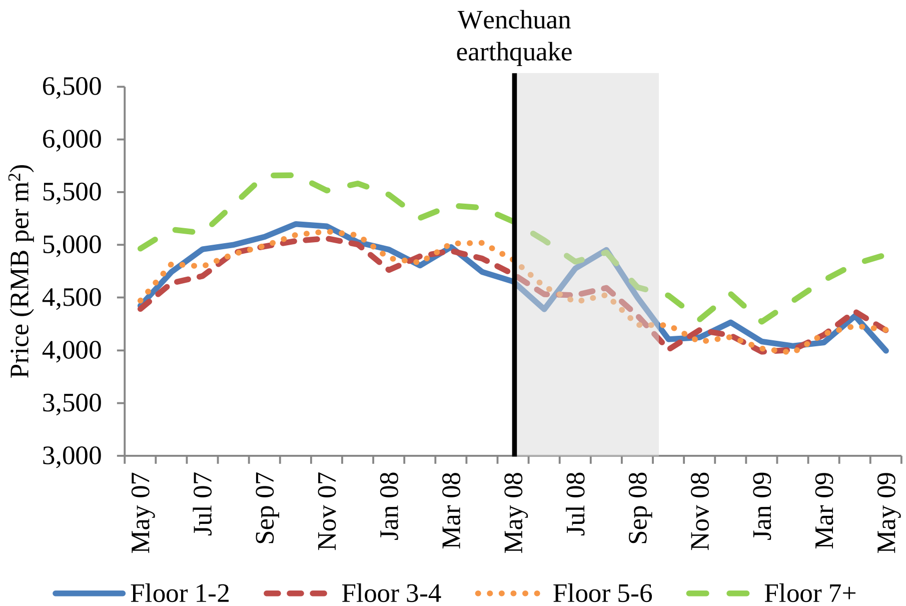
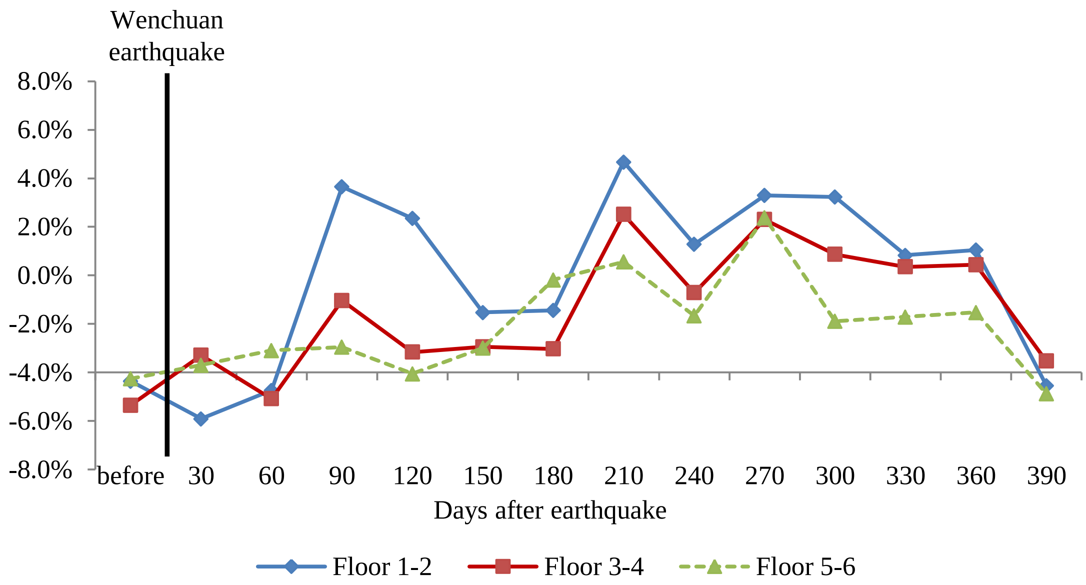
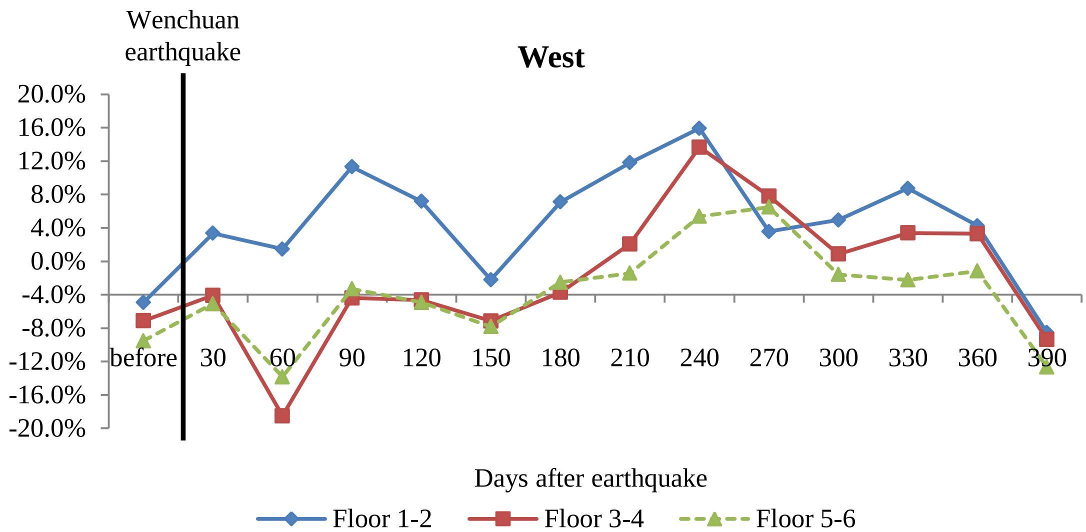


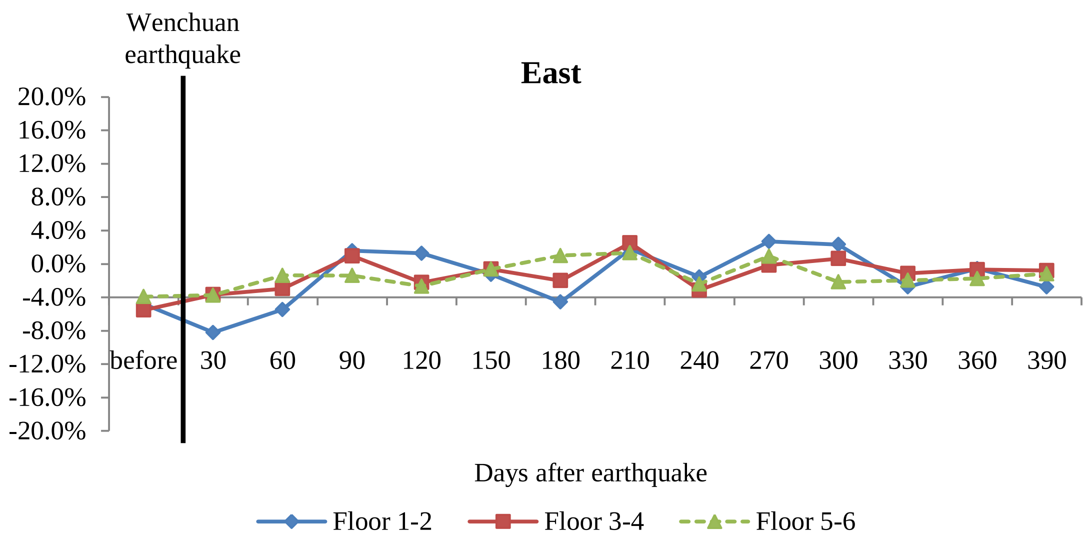
Figure 4. Estimated relative prices of lower- to upper-floor units, dynamic-effect model



Note: Relative prices based on dynamic-effect model specified in equation (2). Upper-floor units are units in floors 7 or above. See Table 3 for full estimation results.

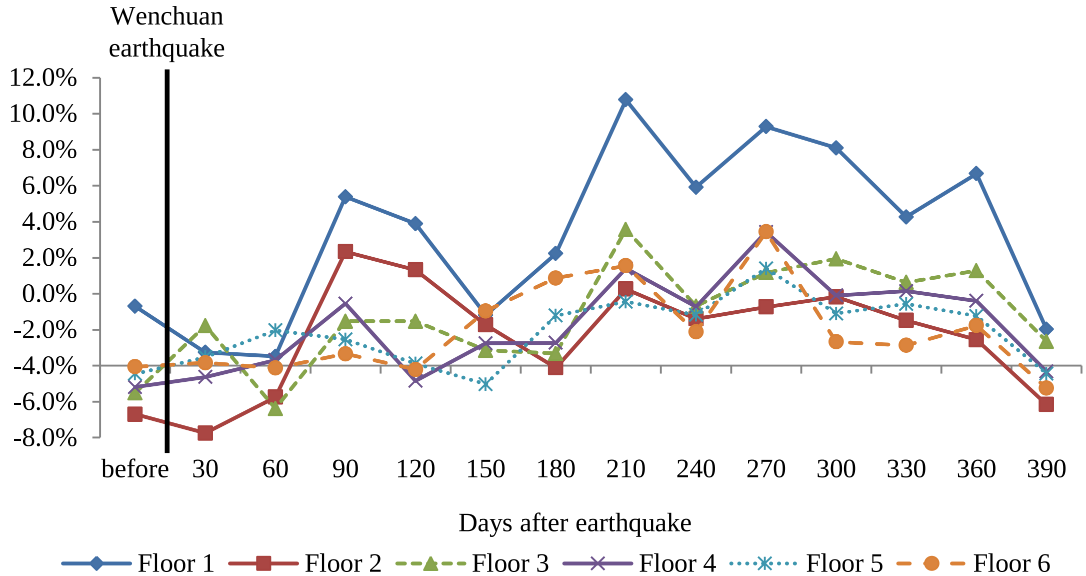
Figure 5. Estimated relative prices of lower- to upper-floor units, West and East side





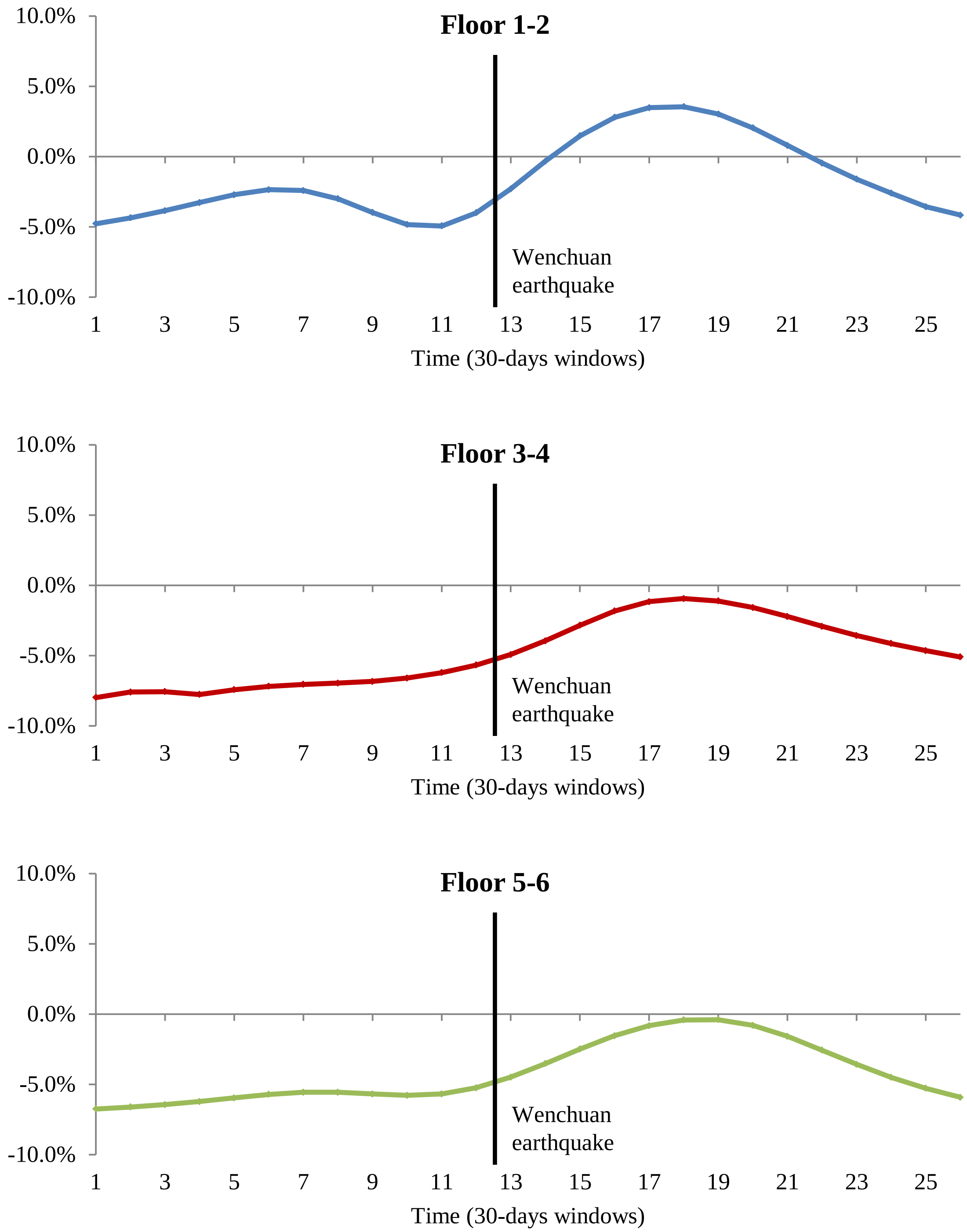
Note: Relative prices based on dynamic-effect model for the West and East side of the city of Chengdu. Upper-floor units are units in floors 7 or above. See Table 3 for full estimation results.

Figure 6. Estimated relative prices of lower- to upper-floor units by floor level



Note: Relative prices based on dynamic-effect model distinguishing between units in the first six floors. Upper-floor units are units in floors 7 or above. See Table A.1 for full estimation results.

Figure 7. Estimated relative prices of lower- to upper-floor units, smooth-coefficient model



Note: Bandwidth of *Time* estimated via least squares cross-validation, accounting also for a daily time trend and the national housing price index. The kernel type used is second-order Gaussian. The unspecified smooth functions, $g_f(\cdot),\ f = 0,..,3,$ are then derived by smoothing out the time trend and housing index. Upper-floor units are units in floors 7 or above.

Appendix

Table A.1. Log of price per square meter regression, dynamic-effect model distinguishing by floor level

Variable	(1)
Floor 1 unit	-0.007
	(0.006)
Floor 2 unit	-0.069
	(0.007)
Floor 3 unit	-0.057
	(0.004)
Floor 4 unit	-0.053
	(0.002)
Floor 5 unit	-0.046
	(0.002)
Floor 6 unit	-0.041
	(0.007)
Post-30 days	-0.029
	(0.010)
Post-60 days	-0.092
	(0.020)
Post-90 days	-0.041
	(0.023)
Post-120 days	-0.026
	(0.039)
Post-150 days	-0.063
	(0.071)
Post-180 days	-0.055
	(0.022)
Post-210 days	-0.062
	(0.120)
Post-240 days	-0.003
	(0.046)
Post-270 days	-0.008
	(0.034)
Post-300 days	0.092
	(0.040)
Post-330 days	0.139
	(0.046)
Post-360 days	0.220
	(0.051)
Post-390 days	0.284
	(0.054)
Floor 1 unit x post-30 days	-0.026
	(0.066)
Floor 1 unit x post-60 days	-0.028
	(0.015)
Floor 1 unit x post-90 days	0.059
	(0.051)

(*Cont.*)

Variable	(1)
Floor 1 unit x post-120 days	0.045
	(0.031)
Floor 1 unit x post-150 days	-0.005
	(0.047)
Floor 1 unit x post-180 days	0.029
	(0.033)
Floor 1 unit x post-210 days	0.109
	(0.106)
Floor 1 unit x post-240 days	0.065
	(0.041)
Floor 1 unit x post-270 days	0.096
	(0.043)
Floor 1 unit x post-300 days	0.085
	(0.043)
Floor 1 unit x post-330 days	0.049
	(0.054)
Floor 1 unit x post-360 days	0.072
	(0.034)
Floor 1 unit x post-390 days	-0.013
	(0.032)
Floor 2 unit x post-30 days	-0.011
	(0.016)
Floor 2 unit x post-60 days	0.010
	(0.020)
Floor 2 unit x post-90 days	0.092
	(0.021)
Floor 2 unit x post-120 days	0.082
	(0.023)
Floor 2 unit x post-150 days	0.052
	(0.014)
Floor 2 unit x post-180 days	0.027
	(0.024)
Floor 2 unit x post-210 days	0.072
	(0.097)
Floor 2 unit x post-240 days	0.055
	(0.020)
Floor 2 unit x post-270 days	0.062
	(0.019)
Floor 2 unit x post-300 days	0.068
	(0.023)
Floor 2 unit x post-330 days	0.054
	(0.029)
Floor 2 unit x post-360 days	0.043
	(0.021)
Floor 2 unit x post-390 days	0.006
	(0.025)

(*Cont.*)

Variable	(1)
Floor 3 unit x post-30 days	0.039
	(0.018)
Floor 3 unit x post-60 days	-0.009
	(0.044)
Floor 3 unit x post-90 days	0.041
	(0.032)
Floor 3 unit x post-120 days	0.041
	(0.011)
Floor 3 unit x post-150 days	0.025
	(0.027)
Floor 3 unit x post-180 days	0.023
	(0.017)
Floor 3 unit x post-210 days	0.092
	(0.096)
Floor 3 unit x post-240 days	0.050
	(0.027)
Floor 3 unit x post-270 days	0.068
	(0.020)
Floor 3 unit x post-300 days	0.076
	(0.014)
Floor 3 unit x post-330 days	0.063
	(0.018)
Floor 3 unit x post-360 days	0.069
	(0.016)
Floor 3 unit x post-390 days	0.030
	(0.029)
Floor 4 unit x post-30 days	0.006
	(0.011)
Floor 4 unit x post-60 days	0.016
	(0.025)
Floor 4 unit x post-90 days	0.048
	(0.021)
Floor 4 unit x post-120 days	0.004
	(0.027)
Floor 4 unit x post-150 days	0.025
	(0.033)
Floor 4 unit x post-180 days	0.026
	(0.027)
Floor 4 unit x post-210 days	0.067
	(0.092)
Floor 4 unit x post-240 days	0.046
	(0.016)
Floor 4 unit x post-270 days	0.087
	(0.018)
Floor 4 unit x post-300 days	0.052
	(0.010)

(*Cont.*)

Variable	(1)
Floor 4 unit x post-330 days	0.055
	(0.017)
Floor 4 unit x post-360 days	0.049
	(0.015)
Floor 4 unit x post-390 days	0.009
	(0.030)
Floor 5 unit x post-30 days	0.010
	(0.018)
Floor 5 unit x post-60 days	0.025
	(0.029)
Floor 5 unit x post-90 days	0.020
	(0.016)
Floor 5 unit x post-120 days	0.006
	(0.027)
Floor 5 unit x post-150 days	-0.006
	(0.023)
Floor 5 unit x post-180 days	0.033
	(0.017)
Floor 5 unit x post-210 days	0.041
	(0.048)
Floor 5 unit x post-240 days	0.034
	(0.017)
Floor 5 unit x post-270 days	0.059
	(0.021)
Floor 5 unit x post-300 days	0.034
	(0.015)
Floor 5 unit x post-330 days	0.040
	(0.012)
Floor 5 unit x post-360 days	0.033
	(0.014)
Floor 5 unit x post-390 days	0.000
	(0.032)
Floor 6 unit x post-30 days	0.002
	(0.007)
Floor 6 unit x post-60 days	-0.001
	(0.017)
Floor 6 unit x post-90 days	0.007
	(0.019)
Floor 6 unit x post-120 days	-0.002
	(0.020)
Floor 6 unit x post-150 days	0.032
	(0.037)
Floor 6 unit x post-180 days	0.050
	(0.021)
Floor 6 unit x post-210 days	0.057
	(0.044)

(*Cont.*)

Variable	(1)
Floor 6 unit x post-240 days	0.020
	(0.017)
Floor 6 unit x post-270 days	0.075
	(0.017)
Floor 6 unit x post-300 days	0.014
	(0.014)
Floor 6 unit x post-330 days	0.012
	(0.014)
Floor 6 unit x post-360 days	0.024
	(0.010)
Floor 6 unit x post-390 days	-0.013
	(0.036)
Log unit size (square meters)	-0.064
	(0.028)
If top developer	0.064
	(0.025)
Log housing price index	3.921
	(0.439)
Subsidy period	0.051
	(0.023)
Constant	-9.367
	(1.942)
# observations	313,805
R-squared	0.398

Note: All specifications include district fixed effects and a trend and trend squared term. White robust standard errors reported in parentheses, clustered at the district level.

Table A.2. Log of price per square meter regression, alternative dynamic-effect model

Variable	(1)
1-2 floor unit	-0.089
	(0.011)
3-4 floor unit	-0.065
	(0.005)
5-6 floor unit	-0.062
	(0.006)
Prior-360 days	-0.000
	(0.005)
Prior-330 days	-0.017
	(0.009)
Prior-300 days	-0.022
	(0.015)
Prior-270 days	0.036
	(0.018)
Prior-240 days	0.068
	(0.022)
Prior-210 days	-0.009
	(0.029)
Prior-180 days	-0.051
	(0.030)
Prior-150 days	-0.039
	(0.035)
Prior-120 days	-0.072
	(0.035)
Prior-90 days	-0.148
	(0.041)
Prior-60 days	-0.178
	(0.043)
Prior-30 days	-0.217
	(0.049)
Post-30 days	-0.253
	(0.057)
Post-60 days	-0.339
	(0.071)
Post-90 days	-0.326
	(0.053)
Post-120 days	-0.364
	(0.056)
Post-150 days	-0.454
	(0.088)
Post-180 days	-0.497
	(0.090)
Post-210 days	-0.570
	(0.142)

(*Cont.*)

Variable	(1)
Post-240 days	-0.567
	(0.097)
Post-270 days	-0.608
	(0.126)
Post-300 days	-0.571
	(0.141)
Post-330 days	-0.572
	(0.151)
Post-360 days	-0.550
	(0.164)
Post-390 days	-0.541
	(0.183)
1-2 floor unit x prior-360 days	-0.020
	(0.004)
1-2 floor unit x prior-330 days	0.052
	(0.012)
1-2 floor unit x prior-300 days	0.076
	(0.007)
1-2 floor unit x prior-270 days	0.020
	(0.020)
1-2 floor unit x prior-240 days	0.061
	(0.021)
1-2 floor unit x prior-210 days	0.077
	(0.008)
1-2 floor unit x prior-180 days	0.070
	(0.020)
1-2 floor unit x prior-150 days	0.018
	(0.029)
1-2 floor unit x prior-120 days	0.050
	(0.013)
1-2 floor unit x prior-90 days	0.020
	(0.021)
1-2 floor unit x prior-60 days	0.043
	(0.026)
1-2 floor unit x prior-30 days	0.048
	(0.048)
1-2 floor unit x post-30 days	0.027
	(0.052)
1-2 floor unit x post-60 days	0.041
	(0.017)
1-2 floor unit x post-90 days	0.124
	(0.046)
1-2 floor unit x post-120 days	0.111
	(0.023)
1-2 floor unit x post-150 days	0.075
	(0.021)
1-2 floor unit x post-180 days	0.076
	(0.044)

(*Cont.*)

Variable	(1)
1-2 floor unit x post-210 days	0.134
	(0.114)
1-2 floor unit x post-240 days	0.101
	(0.035)
1-2 floor unit x post-270 days	0.123
	(0.035)
1-2 floor unit x post-300 days	0.121
	(0.040)
1-2 floor unit x post-330 days	0.097
	(0.054)
1-2 floor unit x post-360 days	0.100
	(0.040)
1-2 floor unit x post-390 days	0.042
	(0.025)
3-4 floor unit x prior-360 days	-0.066
	(0.007)
3-4 floor unit x prior-330 days	0.001
	(0.009)
3-4 floor unit x prior-300 days	0.017
	(0.007)
3-4 floor unit x prior-270 days	-0.010
	(0.011)
3-4 floor unit x prior-240 days	0.024
	(0.012)
3-4 floor unit x prior-210 days	0.017
	(0.008)
3-4 floor unit x prior-180 days	0.051
	(0.006)
3-4 floor unit x prior-150 days	-0.012
	(0.018)
3-4 floor unit x prior-120 days	-0.009
	(0.010)
3-4 floor unit x prior-90 days	0.013
	(0.011)
3-4 floor unit x prior-60 days	0.037
	(0.011)
3-4 floor unit x prior-30 days	0.037
	(0.017)
3-4 floor unit x post-30 days	0.031
	(0.017)
3-4 floor unit x post-60 days	0.013
	(0.034)
3-4 floor unit x post-90 days	0.053
	(0.024)
3-4 floor unit x post-120 days	0.033
	(0.016)
3-4 floor unit x post-150 days	0.036
	(0.029)

(*Cont.*)

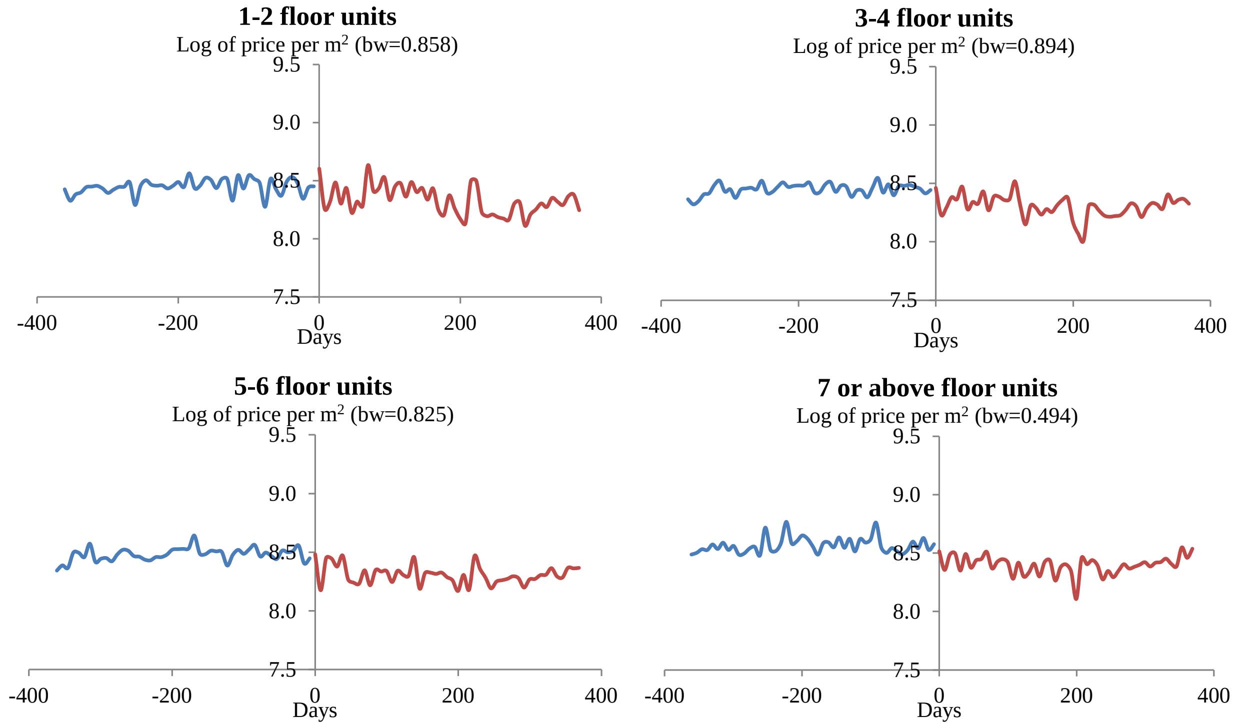
Variable	(1)
3-4 floor unit x post-180 days	0.035
	(0.021)
3-4 floor unit x post-210 days	0.089
	(0.098)
3-4 floor unit x post-240 days	0.058
	(0.023)
3-4 floor unit x post-270 days	0.088
	(0.022)
3-4 floor unit x post-300 days	0.074
	(0.015)
3-4 floor unit x post-330 days	0.068
	(0.022)
3-4 floor unit x post-360 days	0.071
	(0.020)
3-4 floor unit x post-390 days	0.029
	(0.030)
5-6 floor unit x prior-360 days	-0.025
	(0.005)
5-6 floor unit x prior-330 days	0.006
	(0.009)
5-6 floor unit x prior-300 days	0.025
	(0.005)
5-6 floor unit x prior-270 days	-0.007
	(0.006)
5-6 floor unit x prior-240 days	0.008
	(0.011)
5-6 floor unit x prior-210 days	0.029
	(0.005)
5-6 floor unit x prior-180 days	0.055
	(0.011)
5-6 floor unit x prior-150 days	-0.006
	(0.019)
5-6 floor unit x prior-120 days	0.004
	(0.007)
5-6 floor unit x prior-90 days	0.028
	(0.007)
5-6 floor unit x prior-60 days	0.047
	(0.009)
5-6 floor unit x prior-30 days	0.062
	(0.012)
5-6 floor unit x post-30 days	0.025
	(0.013)
5-6 floor unit x post-60 days	0.031
	(0.023)
5-6 floor unit x post-90 days	0.031
	(0.018)
5-6 floor unit x post-120 days	0.021
	(0.022)

(*Cont.*)

Variable	(1)
5-6 floor unit x post-150 days	0.031
	(0.031)
5-6 floor unit x post-180 days	0.062
	(0.017)
5-6 floor unit x post-210 days	0.067
	(0.050)
5-6 floor unit x post-240 days	0.045
	(0.015)
5-6 floor unit x post-270 days	0.086
	(0.016)
5-6 floor unit x post-300 days	0.043
	(0.012)
5-6 floor unit x post-330 days	0.045
	(0.013)
5-6 floor unit x post-360 days	0.047
	(0.012)
5-6 floor unit x post-390 days	0.012
	(0.034)
Log unit size (square meters)	-0.063
	(0.029)
If top developer	0.065
	(0.025)
Log housing price index	-0.941
	(0.819)
Subsidy period	0.033
	(0.019)
Constant	13.085
	(3.709)
# observations	313,805
R-squared	0.402

Note: All specifications include district fixed effects and a trend and trend squared term. White robust standard errors reported in parentheses, clustered at the district level.

Figure A.1. Regression-discontinuity estimations of log prices for different floor levels



Note: Estimations based on a sharp design where the assignment variable is set to zero on May 12, 2008. Bandwidths determined by local linear regressions based on Imbens and Kalyanaraman (2009).

Figure A.2. Shares of monthly transactions by floor level

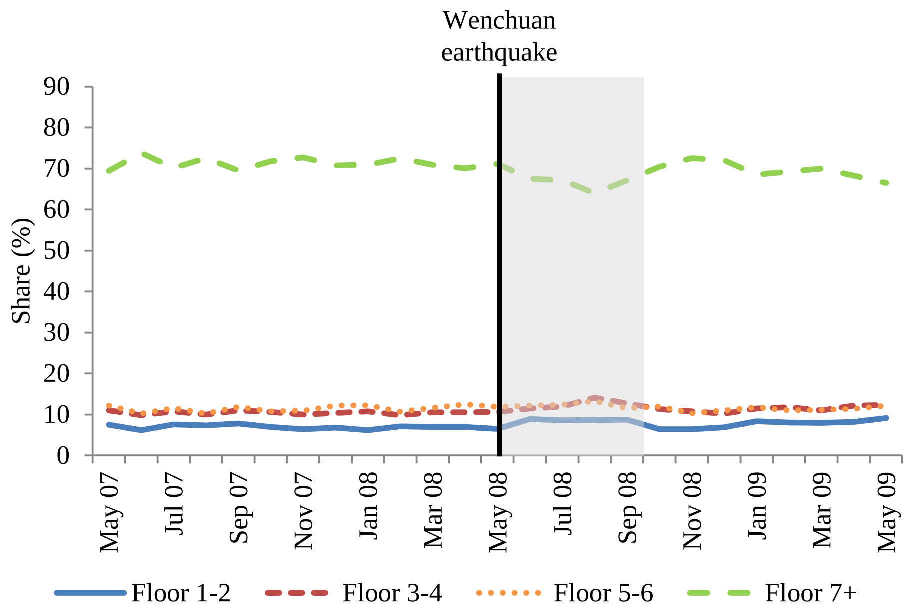
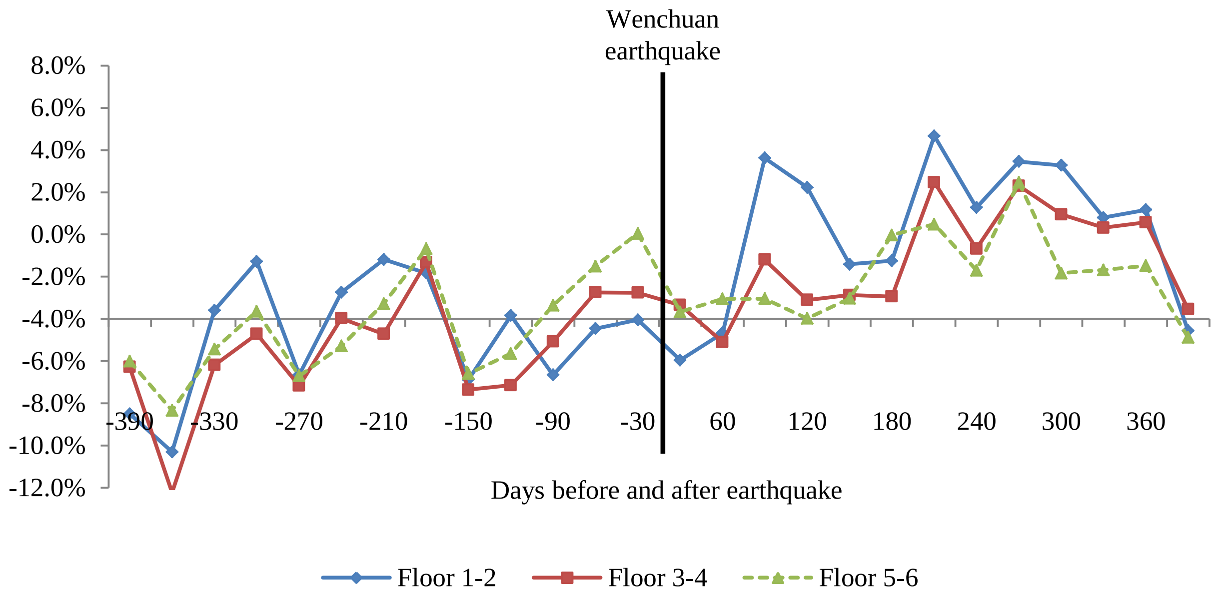


Figure A.3. Estimated relative prices of lower- to upper-floor units, alternative dynamic-effect model



Note: Relative premiums based on alternative dynamic-effect model with dummy variables for 30-days windows prior and post to the earthquake. Upper-floor units are units in floors 7 or above. See Table A.2 for full estimation results.