Ecological Economics 230 (2025) 108485

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Multiple hazards and residential rents in Switzerland: Who pays the price of extreme natural events?

F.J. Blok *, F. Fuerst

Department of Land Economy, University of Cambridge, 19 Silver Street, Cambridge CB3 9EP, UK

ARTICLE INFO

Keywords:
Natural hazard risk
Hedonic regression
Rental market
Real estate investment
Flooding

ABSTRACT

Natural hazard risk is captured in property prices through two principal channels: the risk to the building and the risk to its occupiers. These two effects are typically bundled up in transaction prices, thereby becoming individually unobservable. This study analyses residential rents as those should solely represent the risk to occupiers, who pay for their own losses in the case of a natural hazard event, but not for the owner's potential damage to the asset. Applying a hedonic framework to a sample of 18,339 dwellings across Switzerland, we examine the relationship between residential rents and exposure to five different climate-related natural hazards, some of which have been hitherto understudied. Strong evidence of a small rental discount of 1.4 % is found for dwellings that are subject to moderate flood hazard. Similar, albeit weaker, estimates are found for surface runoff hazard. Gravitational hazards including landslide, debris flow, and hillslope debris flow are not associated with significantly lower rents, possibly due to the small sample size. Our findings imply that not all natural hazard risk is reflected in the cost-side of the profit-equation in commercial residential real estate, but partly manifests itself in the form of reduced income, which is often less apparent.

1. Introduction

Climate- and weather-related extreme events are estimated to have caused 450–520 billion euros (2020 prices) in economic losses between 1980 and 2020 in the 32-country European Economic Area (European Environmental Agency, 2022). Given that damage to buildings is the largest part of these losses, the question arises of who ends up bearing the cost between owners, tenants, insurers, taxpayers, or another party. This is of particular relevance at a time when investors are trying to get a better understanding of their exposure to climate change and central banks are conducting climate change stress tests to assess the impact on the financial system (Acharya et al., 2023). This study investigates whether natural hazard exposure is reflected in lower rents for residential properties and thereby helps shed some light on this question.

At first glance, natural hazard risks seem to be of limited concern to property investors in Switzerland, the country of this study, as building insurance is socialized: it is mandatory to be insured and premiums are uniform regardless of risk exposure. Natural hazards, however, do not only threaten the structure of the building but also affect the occupant. The costs of a natural disaster in the context of residential property can be split into four components: the physical damage to the structure, death or injury of the occupants, any disruption suffered by residents in the wake of the disaster, and damage to the contents of the home.

While the property-related structural costs are borne by the owner and ultimately the insurer, the latter three costs fall on the occupant. This paper asks if those tenants are paying less rent for properties exposed to natural hazard risk in Switzerland, and by extension whether the cashflows of landlords are affected. This question is especially relevant in a European context where the owner-occupier segment is relatively small, and tenants often live in rented apartments long-term; in Switzerland the rate of homeownership is only 36.3 % (BFS, 2021).

This research includes most climate-related natural hazards that affect residential properties in Switzerland: flooding, surface runoff, and gravitational hazards including debris flow and hillslope debris flow. While the former hazard has been the subject of many previous studies, this study is one of the few so far to investigate the latter hazards and to examine them at the same time. The richness of the dataset allows us to control for virtually all relevant confounders.

1.1. State of research

A sizeable and growing body of literature is devoted to the question

* Corresponding author.
E-mail address: fjb49@cam.ac.uk (F.J. Blok).

https://doi.org/10.1016/j.ecolecon.2024.108485
Received 26 April 2024; Received in revised form 8 November 2024; Accepted 29 November 2024
Available online 18 December 2024
0921-8009/

of how exposure to natural hazards affects the value of (residential) property. This includes forest fires (Donovan et al., 2007; Mueller et al., 2007; Mueller and Loomis, 2014), earthquakes (Murdoch et al., 1993; Naoi et al., 2009; Singh, 2019) and flooding. The latter hazard has been a popular research topic, Table 1 lists the most relevant studies.

Meta-analyses by Beltrán et al. (2018) and Contat et al. (2024) found discounts of 4.6 % and 3.9 %, respectively, for properties located in 100-year flood zones. Most relevant in the context of our paper are Hirsch and Hahn (2018) examining residential rents in a neighbouring European state, and Reich et al. (2020) studying flood events and house prices in Zürich. In particular, the latter working paper finds a small 1.3 % baseline discount for flooding hazard (small or moderate) using the same hazard levels and maps as this study.

Gravitational hazards such as landslides and debris flow have not been the subject of much academic research. The only previous paper we found was by Kim et al. (2017), who found a discount for landslide hazard of up to 11.3 % for the most affected properties in South Korea. Assessing different hazards together has rarely been done prior, despite many hazards being interlinked.[1] Low lying properties, for example, are vulnerable both to riverine flooding and surface runoff (pluvial flooding). They are unlikely, however, to be affected by gravitational hazards like landslides that affects buildings located on or at the foot of hillslopes. It is therefore possible that price effects previously ascribed to certain hazards are actually (in part) a result of a different hazard or lack thereof.

1.2. Study area and hazards

Natural hazards in Switzerland can be divided into four broad categories: hydrological hazards, gravitational hazards, geological hazards (earthquakes), and meteorological hazards (storm & hail). The first two types are the subject of this study. As Switzerland is landlocked, flooding can only result from rivers and lakes overflowing, which we simply call ‘flooding’ in the remainder. Inundation can also result from (extreme) precipitation, which is called ‘surface runoff’ here. Flooding is usually also ultimately the result of precipitation, but surface runoff is caused directly by rain or melting snow when the soil (and/or sewage system) cannot absorb the water quickly enough.

Included gravitational hazards are debris flow, hillslope debris flow and landslides.[2] These three hazards can appear to be quite similar, but they are distinct phenomena nonetheless: Hillslope debris flow contains much more water than a landslide and usually starts higher up on steeper slopes. Debris flow emerges in streambeds, while hillslope debris flow does not.

In terms of structural damage, the two hydrological hazards are the costliest hazards featured in this study, while landslides cause most deaths in and around buildings (see Table 2).[3] Following a series of severe natural disasters in 1999, the Swiss government set out to map the intensity of various natural hazards across Switzerland in a systemic way (Bründl et al., 2009). Terrain analysis, topographic and geological maps, aerial photographs and satellite images, as well as event inventories and historical chronicles inform the hazard analysis. The physical impacts of the hazard are derived from process analysis, enhanced by physical modelling. Intensity is expressed in terms of expected physical impact (pressure, velocity, inundation depth, etc.) during a reference period and is a combination of expected impact and, for all hazards except surface runoff, probability of occurrence. Areas not affected by a hazard are assigned hazard level 1 (level 0 does not exist). Appendix A details how probability and intensity combine into the five hazard levels shown in Table 3.

Although an effort has been made to make the hazard levels comparable across natural hazards - the same levels corresponding to a similar expected loss to structures and persons - they are not strictly comparable as different hazards are modelled in different ways. A general description of the modelling of all hazards can be found in reports by the Federal Office for Spatial Development (2005) and the *Bundesamt für Umwelt* (BAFU, 1999). Gravitational hazard levels are defined in more detail in BUWAL/BWW/BRP (1997), flood hazard levels in BWW/BRP/BUWAL (1997), and surface runoff, which is defined slightly differently, in BAFU (2018). Hazard maps are published online by the individual cantons.

As Table 3 shows, only the two highest hazard levels are associated with risks to occupants. We therefore expect to only see a significant discount for moderate and substantial hazard relative to the three lower levels, with a bigger discount for substantial hazard. No significant differences in rent between the three lowest levels are expected to be observed, but any such differences would be best ascribable to the disruption suffered by residents and/or damaged contents.

Flooding events occur very frequently in Switzerland but are usually small in scale and localized (WSL, 2023). The most recent catastrophic floods, destroying multiple villages in Aargau, Solothurn, Basel-Landschaft, Bern, and Vaud, happened in 2007 (Hilker et al., 2008). No catastrophic events related to other hazards included in this study have been recorded recently either, meaning our results are unlikely to be influenced by recent events or events happening during the study period.

1.3. Swiss rental market

There are no restrictions on rents in Switzerland at the time the contract is first agreed. Once the contract is signed, however, tenants enjoy protection against evictions and rent increases. Rents are not allowed to be increased unless there is a rise in the nationally derived reference rate for loans, which last happened in the first quarter of 2021. Additionally, 40 % of inflation and a yearly general cost increase add-on of 0.25 %–1 % depending on the region can be passed on to the tenants. Exceptions apply for renovations. This means that rents for older contracts are generally lower than for more recently signed contracts. The exceptions are the cantons of Geneva, where rent controls are in place, and Vaud, which limits rent increases after renovation. Both cantons are excluded from the sample for these reasons.

1.4. Hazard management and insurance

In Switzerland, basic building insurance covering natural hazards (except earthquakes) is mandatory for all homeowners,[4] with risk-independent premiums.[5] This eliminates natural hazard costs from ownership decisions and ensures equal coverage for owner-occupiers and landlords. Contents insurance is optional but often combined with building insurance. Insurers can price contents coverage based on risk, meaning tenants largely bear the risk natural hazards pose to their possessions themselves. However, annual premiums vary by only a few hundred Francs at most.

Although buyers are supposed to be made aware of the relevant hazard maps during the purchasing process, no such procedure is

[1] Athukorala et al. (2016), considering flooding and wildfires together, is the only one we could find.

[2] Our dataset also includes rockfall and avalanche, but the prevalence of these hazards is too low for reliable estimation.

[3] For comparison, the value of statistical life used by authorities in the context of natural hazards in Switzerland is currently 6.6 million CHF (EconoMe, 2022).

[4] Walls, floors, ceilings, and internal fixtures. Emergency alternative accommodation costs coverage and damage to windows for example is not compulsory.

[5] Only in the Cantons of Ticino, most municipalities in Appenzell Innerrhoden, Vaud, and Geneva is building-insurance not mandatory (the latter two cantons are not included in this study).

Table 1
Selected flooding studies.

Study	Location	Flood Type	Variable	Time period	Baseline Discount	Post-flooding discount	Decay time
MacDonald et al. *(1987)*	Monroe, Louisiana (USA)	River	100-year floodplain	1988	7 %	n/a	n/a
Bin and Polasky *(2004)*	Pitt County, North Carolina (USA)	Coastal	100-year floodplain	1992–2002	3.8 %	4.5 %	n/a
Daniel et al. (2007)	Meuse River (NL)	River	flooded in 1993	1990–2004	7 %	7 %	n/a
Bin et al. *(2008)*	Carteret County, North Carolina (USA)	Coastal	100-year floodplain	2000–2004	7.8 %	n/a	n/a
Kousky (2010)	St. Louis County, Missouri (USA)	River	100-year floodplain	1979–2006	3.2–4.5 %	insignificant	–
Atreya et al. (2013)	Dougherty County, Georgia (USA)	River	100-year floodplain	1985–2004	9 %	29–35 %	4–9 years
Bin and Landry (2013)	Pitt County, North Carolina (USA)	Coastal	100-year floodplain	2002–2008	Insignificant	5.7–8.8 %	5–6 years
Atreya and Czajkowski (2016)	Galveston County, Texas (USA)	Coastal	4 categories	2001–2010	positive	n/a	n/a
Zhang and Leonard (2018)	Fargo-Moorhead Metropolitan Area, North Dakota (USA)	River	100-year floodplain	2007–2013	3.6–12.2 %	15 %	3 years
Hirsch and Hahn (2018)	Regensburg, Bavaria (DE)	River	100-year floodplain	2012–2015	1.8 % (rents)	n/a	n/a
Hino and Burke (2020)	United States	All	100-year floodplain	1996–2017	insignificant	n/a	n/a
Reich et al. (2020)	Canton of Zurich (CH)	River	3 categories	2007–2019	1.3 %	3.5 %	1 month
Mutlu et al. (2023)	Limburg Province (NL)	River	flooded in 1993 and 1995	1990–2020	5.6 %	5.3 %	9–12 years*

Notes: The baseline discount is the sale or asking price discount associated with exposure to flooding hazards, additional reductions in price directly after a flooding event are shown in the second to last column, and the decay time indicates how long it takes for this additional discount to disappear again. *with concurrent improvement of flood defences.

Table 2
Annual impact of natural hazards in Switzerland.

Natural Hazard	Mean annual damage to buildings (Million CHF)*	Mean annual deaths…	…of which in buildings
Inundation	96.2	1.6	0.2
Landslides	2.4	0.7	0.6
Rockfall		1.3	0.1
Debris Flow	n/a	0.3	
Period	2002–2021	1946–2021	1946–2015
Source	VKG (2022)	WSL (2022)	Andres et al. (2017)

Notes: Inundation includes Flooding and Surface Runoff, Landslides includes Hillslope Debris Flow. *19 cantons only.

Table 3
Hazard level definitions.

Level	Definition	Description
1	No hazard	*No risk to persons or structures.*
2	Residual hazard	*No risk to persons. Minor damage to buildings cannot be excluded completely.*
3	Small hazard	*No risk to persons. Minor damage to buildings is possible.*
4	Moderate hazard	*Significant damage to buildings is possible but sudden destruction is very unlikely. Persons are at risk outside buildings.*
5	Substantial hazard	*Sudden destruction of buildings is possible. Persons are at risk inside and outside buildings.*

Note: Descriptions translated into English from BAFU (2015).

currently in place for prospective tenants. Hazard maps are easily accessible online, however, and relatively straightforward in terms of interpretation.

2. Theoretical framework

It is useful to express the value of natural disaster risk as the annual expected loss (*AEL*), this is given by the following equation (Kaplan and Garrick, 1981):

$$\mathrm{AEL(j)} = \int_{\mathrm{h_{min}}}^{\infty} f(\mathrm{h})\mathrm{S(h)Vdx} = \int_{0}^{1} \mathrm{S}(\psi)Vd\psi$$

Where:
f = probability density function of the hazard (hazard function)
S = loss function
V = value at risk
h = intensity/form of the hazard (e.g., inundation depth or pressure)
h_{min} = lower integration limit, above which damage is to be expected
ψ = probability of reoccurrence
$AEL(j)$ = annual expected loss (due to a specific natural hazard, j)

In the situation where the owner and occupier are not the same, there are two separate functions: $AEL(j)_L$ representing the loss function of the landlord and $AEL(j)_O$ for the occupant. For the former, V is the value of the building, for the tenant it includes themselves and their possessions.

2.1. Hazards and rent

A simple hedonic framework (Rosen, 1974) is used, where the annual rental price of housing R is equal to a vector of site-specific, structural, and locational characteristics $\boldsymbol{x}$:

$$\mathrm{R} = \mathrm{R}(\mathbf{x})$$

The marginal cost of an additional amount of attribute x_z is $R_x = \partial R/\partial x_z$. Consumers can choose between spending their annual income y on rent or on composite good b (with a price of 1). α_i is a parameter representing household i's preferences.

$$\mathrm{y} = \mathrm{b} + \mathrm{R}(\mathbf{x})$$

$$\mathrm{U_i} = \alpha_i \mathbf{x}_i + \mathrm{b_i}$$

$$\mathrm{s.t.R}(\mathbf{x})_i = \mathrm{y_i} - \mathrm{b_i}$$

The willingness to pay (*WTP*) for various amounts of attributes while holding utility constant is given by:

$$\overline{\mathrm{V}} = f(\mathrm{y} - \mathrm{WTP}(\alpha), \mathbf{x}, \alpha)$$

The marginal willingness to pay for attribute x_z therefore is $WTP_x(\alpha)$, which is equal to R_x at the optimal choice of attribute x_z.

From the perspective of a tenant, the effects of a natural hazard in our model are an (annualized) fixed cost and are deducted from income. Expected utility becomes:

$$U(y - R(\mathbf{x}) - AEL_O, \mathbf{x}, \alpha)$$

The option price (*OP*) is the maximum willingness to pay for a reduction in AEL_O, holding expected utility constant. *OP* is analogous to *WTP* and a change in *OP* due to a change in hazard level measures the marginal willingness to pay for hazard reduction. Let σ be the reduction in AEL_O, available by location choice:

$$\overline{V} = f(y - R(\mathbf{x}) - (AEL_O - \sigma) - OP, \mathbf{x}, \alpha)$$

Thus, OP is the maximum amount that an agent is willing to pay for a reduction in AEL_O and remain indifferent in terms of (expected) utility. The marginal willingness to pay for a reduction in hazard is given by $\partial OP/\partial\sigma = OP_\sigma$. In a perfect market, locations with lower natural hazard will be bid up (holding $\boldsymbol{x}$ constant). Therefore R is also a function of AEL_O. The difference in annual rent for a reduction in hazard is given by R_{AEL}. $OP_{AEL} = R_{AEL}$, just like $R_x = WTP_x(\alpha)$ in the general model. In the case of perfect information on natural hazards this gives:

$$WTP_{AEL} = OP_\sigma = R_{AEL} = -AEL_O$$

Total annual rent R_t in period t for a property exposed to natural hazard j is given by:

$$R_t(j) = R(\mathbf{x}) - AEL_O$$

2.2. Hazards, income and property value

In real estate valuation models for income-generating assets, the asset's value is the discounted total of all future net income. When growth is assumed to be constant, the value (P) of a property exposed to natural hazard j is given by:

$$P(j) = \sum_{t=0}^{T} \frac{(NOI_t)(1+g)^t}{(1+i)^t}$$

Where *NOI* is the owner's net operating income. This can be represented as a perpetuity approximating to:

$$P(j) = \frac{NOI}{i-g}$$

Where $i - g$ is the capitalization rate. *NOI* is the rental income minus the periodic costs of owning the asset C_t (management, refurbishment, etc.) and $AEL(j)_L$:

$$NOI = R_t(j) - C_t - AEL(j)_L$$

In the particular case of Switzerland, the owner must take out insurance for natural hazards at fixed annual cost I_t, removing $AEL(j)_L$ from the equation:

$$NOI = R_t(j) - C_t - I_t$$

This means that in the present case the impact of natural hazards on investors net operating income is contained in $R_t(j)$ only and cost of ownership should not be meaningfully higher in hazardous areas. Although only rents and *NOI* are the subject of this study, the property's value can be derived as:

$$P(j) = \frac{R_t(j) - C_t - I_t}{i-g}$$

3. Data

We use a sample of 23,757 currently active (as of 2022) arms-length residential rental contracts across Switzerland signed since January 1st 2021 obtained from *Wüest Partner* (WP), a provider of real estate consulting in Switzerland, Germany and France. The data are sampled at the building-level: landlords, often larger professional real estate investors, sharing information on their properties and current tenancies with WP. Structural characteristics are determined through standardized on-site inspections, where different valuers assess material composition and component conditions using consistent criteria to enable reliable comparison across buildings. Locational attributes (including the natural hazard levels) are assigned by WP using the coordinates of the properties. The dependent variable, rent, is observed at the level of the dwelling but all explanatory variables except size, number of rooms and floor level are observed at the level of the buildings contained. See Appendix B for a description of all included variables and the observation-level.

After removing all observations with missing values and excluding the rent-controlled cantons of Vaud and Geneva we are left with 18,425 contracts across 3337 different buildings.[6] The sample period starts after the last change in the reference rate in the first quarter of 2021, as it is impossible to accurately infer the rent as agreed upon at the contract start-date from the currently paid rent (see Section 1.3.). This is because not all landlords will have raised rents by the maximum percentage that is allowed by national legislation.

3.1. Cleaning and transformations

In total, 86 observations with unrealistic characteristics were removed: 49 observations with average room size of >100 m^2 (unless they were classified as loft-style apartments) and 2 units with less than 2 rooms and an average room size of <8 m^2. Furthermore, 33 contracts with an annual rent of over 900 CHF/m^2, one with annual rent <50 CHF/m^2 and one with a total annual rent below 1200 CHF were excluded. Rents are log-transformed for the estimations.

The dataset contains distances to various points of interest. In the case of distance to water (nearest lake and nearest river), these values are converted into categorical variables to allow for detailed examination in relation to flood hazard. Other distances (city centre, public transport, etc.) are inverted using the power parameter 2. Direct access to an amenity (distance = 0) is assigned the value 1. Floor-level is also converted into a categorical variable with all floor levels over 7 assigned the value 8.

3.2. Sample characteristics

Our sample consists of homes that are more expensive, younger and smaller than average for Switzerland. Sample means of rent/m^2 and total annual rent in CHF are 253 and 18,234 respectively, while the corresponding figures for the 23 included Swiss cantons are 196 and 16,568 in 2021 according to the Swiss Federal Statistical Office (BFS, 2023c, 2023d). This difference is expected as the latter averages contain longer-running and non-market rate contracts as well. Differences are not (only) a result of the distribution of the sample in terms of location or built period; average rents by canton and age category are also found to be higher in the sample (BFS, 2023d). Given that 73 % of rented homes in Switzerland were constructed before 1991 (BFS, 2023a), we can infer that the sample consists of more modern buildings than average as the mean building age in the sample is 34 years. The average size of a home in Switzerland is 99 m^2 versus 76.6 m^2 in the sample, but this figure is for all houses, including owner-occupancy (BFS, 2023b). Please see Appendix C for further descriptive statistics.

3.3. Hazards

When examining the data, it becomes apparent that, apart from flood and runoff, exposure to high hazard levels is quite uncommon in the sample (see Table 4). Five-level hazard ratings are converted into a three-level hazard rating by combining the small, residual, and no

[6] Notably, no surface runoff hazard levels are included for observations located in the canton of Lucerne, effectively forcing us to exclude this canton from the sample as well.

Table 4
observations by hazard level and type at the building-level.

Hazard Level	Flooding	Surface Runoff	Debris Flow	Hillslope Debris Flow	Landslide	*Gravitational (all)*
None	1895	2105	3262	3247	3286	*3147*
Residual	241	0	3	0	9	*8*
Small	491	964	0	0	19	*13*
Moderate	485	196	72	90	22	*168*
Substantial	225	72	0	0	1	*1*
Total	3337	3337	3337	3337	3337	*3337*

hazard categories into a single category called 'small or less'. This is because, except for flooding, there are very few observations for residual hazard in the sample and, apart from runoff, also few for small. Furthermore, residual and small hazards represent no risk to inhabitants and are therefore not expected to be reflected in rents (see Section 1.2).

The number of buildings exposed to gravitational hazards, especially landslides, is small in this sample. Landslide hazards is included in the estimations (with the single observation for substantial landslide hazard included in the moderate category) but estimates are not shown in the results section or interpreted due to their insufficient number. Because the three gravitational hazards are quite similar in appearance and the hazard levels are meant to be comparable, the decision was made to combine them into a single hazard ('gravitational hazard') that takes the value of the greatest gravitational hazard the building is exposed to as shown in the last column of Table 4. This allows us to analyse gravitational collectively in addition to including them individually with reduced statistical power.

Before proceeding with the hedonic analysis, the relationship between the variables of interest and some crucial controls is examined. For this purpose, hazards are converted to binary variables taking the value 1 if the hazard level is moderate or substantial. Pearson correlation coefficients and relevant (joint) frequency tables are shown in Appendix C, Table 1, noteworthy relationships are discussed here.

First, we observe that flooding hazard and debris flow hazard often occur jointly, as do hillslope debris flow and landslides. Both are to be expected as they have similar causes (debris flow starting in streams and hillslope debris flow and landslides starting on hillsides). More surprisingly is the relatively strong correlation between distance to river and hillslope debris flow hazard and between distance to lake and debris flow.

Flooding is negatively correlated with population density and building size (# Apartments), suggesting that this hazard is more prevalent outside densely populated cities in our sample. Crucially, there is no strong correlation between hazards and measures of building quality (age, size) and socio-economic variables (mean income) in this sample. Properties in hazardous places are not found to be constructed to a lower standard (see Appendix C, Table 2). This is not the case for other hazards either, or for the state of maintenance (not shown). Thirdly, we look at the relationship between flood hazards level and distance to river (Appendix C, Table 3) to confirm sufficient variability and ensure that the two variables are not collinear.

4. Method of analysis

Hedonic regression analysis is the established method for estimating the rental price effect of a building's exposure to natural hazards. The weighted least squares (WLS) hedonic regression equation used to estimate marginal WTP for different hazards is as follows:

$$ln(Rent)_{ij} = \Big(\beta_0 + \beta_1\boldsymbol{Hydrological\_Hazards}_j + \beta_2\boldsymbol{Gravitational\_Hazards}_j + \beta_3 S_{ij} + \beta_4 S_{ij}^2 + \beta_5 Floor_{ij} + \beta_6 Rooms_{ij} + \beta_7\boldsymbol{Z}_j + \beta_8\boldsymbol{Canton}_j + \psi\Big)w_i + \varepsilon_{ij}$$

Where $ln(Rent)_{ij}$ is the natural logarithm of total annual rent paid for dwelling i in building j. $\boldsymbol{Hydrologial\_Hazards}_j$ is a vector of hazard level-dummies for flood and surface runoff and $\boldsymbol{Gravitational\_Hazards}_j$ is a vector of gravitational hazard level-dummies, with the three gravitational hazards either included separately or combined into a single categorical variable. S_{ij} is the size of the dwelling i in square meters of floor area, $Floor_{ij}$ the floor level at which the dwelling is located and $Rooms_{ij}$ the number of rooms in the dwelling. $\boldsymbol{Z}_j$ denotes a vector of controls at the level of the building including building standard and locational variables. Fixed effects are included in the form of canton-dummies and a vector of month*year dummies ψ indicating when the rental contract went into force. ε_i is an error term (heteroskedasticity-robust standard errors are used).

The choice to weight observations by factor w_i, the inverse of the number of active contracts i in building j is informed by the nature of the sample (Solon et al., 2015). The rental contracts and corresponding dwellings in this sample are not drawn randomly from the population but are building-clusters; each owned (or at least managed) by a single agent. Instead of clustering errors at the building level where the treatment happens (Abadie et al., 2023), we have decided to assign an equal weight to each building in the sample to avoid our results being driven by a small number of building or landlords. Aggregating rents to the building-level, a third option, would lead to a loss of information from the side of individual tenants. A weighted regression approach balances these two considerations.

Accurate estimation of hydrological hazards requires controlling for the positive amenities associated with living close to water. Controls for the distance to the nearest lake, distance to river, and lakeview are therefore included. Gravitational hazards mostly affect buildings on sloped terrain. To control for any amenities associated with living on a hillslope, we control for the incline of the slope, the orientation of the plot, elevation relative to the community and view of mountains and lakes.[7] To control for the quality of location within a municipality, we employ inverse distances to public transport, city centre and nature.

Data protection regulations do not allow us to pinpoint the exact locations of the properties included in our sample, which rules out spatial weight matrices for spatial autoregression or other spatial econometric techniques. By including variables such as income and population density at a high resolution, we control for socio-economic factors that might be correlated with natural hazards.

5. Results

Table 5 shows estimation results for the baseline model with all controlling variables included (1), the model with FE at the cantonal level (2), and the same model with the three gravitational hazards grouped together as described in Section 3 (3). Please see Appendix D for full results for all models, including those with fewer controlling variables, as well as residual plots for all three models shown in Table 5. The log-linear specification allows us to interpret the coefficients as fractional and percentage changes.

The complete model estimates (2) & (3) find a significant discount for flooding: 1.4 % lower rents for dwellings facing moderate flood

[7] This latter variable is modelled for the building-level, not accounting for position (floor level, side) of the dwelling within it.

Table 5
Baseline Model.

	Variable	(1)		(2)		(3)	
Flooding	*Small or less*	reference level		reference level		reference level	
	Moderate	−0.0201***	(0.00655)	−0.0135**	(0.00619)	−0.0135**	(0.00618)
	Substantial	−0.0383***	(0.00957)	−0.0186*	(0.00949)	−0.0190**	(0.00957)
	Small or less	reference level		reference level		reference level	
	Moderate	−0.0148	(0.00906)	−0.0163*	(0.00896)	−0.0160*	(0.00896)
Surface Runoff	*Substantial*	−0.0214	(0.0158)	−0.0251*	(0.0150)	−0.0250*	(0.0150)
	Small or less	reference level		reference level			
Hillslope Debris Flow	*Moderate*	0.0164	(0.0148)	0.0185	(0.0146)		
	Small or less	reference level		reference level			
Debris Flow	*Moderate*	−0.00182	(0.0151)	0.00244	(0.0137)		
	Small or less					reference level	
Gravitational Hazards (all)	*Moderate*					0.00801	(0.0100)
	Canton Fixed Effects	*No*		*Yes*		*Yes*	
	R^2	0.787		0.810		0.810	
	Degrees of Freedom	18,276		18,256		18,258	
	BIC	−11,435.7		−13,354.0		−13,370.4	
	AIC	−11,928.2		−14,002.8		−14,003.5	
	N	18,339		18,339		18,339	
	Sum of Weights	3337		3337		3337	

Notes: Dependent variable is the log of total annual rent. Estimates are relative to the reference level (small or less hazard). Standard errors in parentheses. *p 0.1; **p 0.05; ***p 0.01. Standard errors and p values are based on the robust, consistent heteroskedasticity corrected covariance matrix. Estimates for included controlling variables are not shown.

hazard and 1.9 % for substantial flood hazard. The difference between these two flood hazard estimates is not significant. Estimates for surface runoff hazard are comparable at 1.6 % and 2.5 % respectively, significant at the 10 % level. Estimates for gravitational hazards are consistently zero, both when including them separately and when including them as a single variable in model (3). Estimates using the original five hazard levels give similar results, see Appendix D, Table 2.

5.1. Robustness checks

We check if the decisions to weight observations by the inverse of the number of dwellings in the same building, and the restrictions imposed on the sample affect our results. Table 6 shows estimation results for an unweighted regression (using errors clustered at the building-level), a regression including contracts signed prior to 2021,[8] and for a sample including the cantons of Vaud and Geneva. All estimations include canton-FE and are otherwise identical to Model (3) in Table 5, full results are shown in Appendix D, Table 3. Results for moderate flooding hazard and gravitational hazards are found to be very robust while results for substantial flood hazard and surface runoff are more sensitive to model choice and lose their significance in many alternative specifications.

6. Conclusions

This study uses a hedonic regression to estimate the effect on residential rents of exposure to four prevalent climate-related natural hazards in Switzerland: flooding, surface runoff, debris flow, and hillslope debris flow. The a priori assumption was that relatively small discounts should apply, as tenants do not pay for repairs to the structure of the building in the event of damage resulting from a natural disaster. Instead, they face disruption, risk to life and limb, and damage to the contents of the home.

This research is limited mostly by the lack of locational data which would allow for a more precise border discontinuity design and/or spatial autoregression technique. This may reduce the accuracy of our estimates, but this is compensated for by the inclusion of virtually all relevant controlling variables in the context of hydrological and gravitational hazards. By considering different hazards simultaneously, these variables also act as controls for each other, reducing the possibility of erroneously ascribing a rental discount to a particular hazard.

Strong evidence is found that flood hazard is priced into residential rents in Switzerland. The discount for ‘moderate’ flood hazard is significant across model specifications and is estimated to be around 1.4 %, corresponding to 232 CHF annually at the mean rent level. The higher ‘substantial’ flood hazard level is associated with slightly higher discount of 1.9 % but the difference with moderate hazard is insignificant and estimates are more sensitive to model-choice. This finding is in line with the 1.8 % rent-discount found by Hirsch and Hahn (2018) and the 1.3 % discount found by Reich et al. (2020) for house prices: in the Swiss situation with socialized insurance discounts for prices and rents should be similar. The evidence of a discount for surface runoff hazard is weaker; similar in magnitude to the flooding discounts but significant only in some model specifications.

The magnitude of the discount is substantially smaller than the 3.9 % to4.6 % that has been found in studies examining house prices in other countries, predominantly the US. These results support the hypothesis that the costs (both monetary and non-monetary) of a natural disaster are normally shared between occupants and owners. This implies that real estate investors are exposed to climate change on the income in addition to the cost side. Risks are always borne by tenants who, according to our findings, obtain a reduction in rent on the income side. Conversely, renters are able to pass on at least part of their expected costs, at least as long as rents are not (fully) regulated. On the cost side, most risk can (or must) be passed on to willing insurers in exchange for a premium. Only these insurance premiums can be easily appreciated by investors and others, while tenants’ lower willingness to pay is less apparent.

No evidence is found that less prevalent gravitational hazards (hillslope debris flow, debris flow, landslides) are priced into residential rents in Switzerland. Possible explanations include that tenants are less affected relative to property owners compared to hydrological hazards, that gravitational hazards are less on people’s minds due to their comparative rarity, or that the number of at-risk properties contained in the sample is too small or unrepresentative.

It appears advisable for developers, investors, financial institutions, and (financial) supervisors to take the non-structural component of climate-related natural hazard risk and the associated lower rental income into account when considering exposure of real estate to climate change. Further research is recommended on the question of why only

[8] Please note that the increase in number of dwellings (N) is much larger than the increase in number of unique buildings (sum of weights).

Table 6
Alternative model specifications.

	Variable	Unweighted		Full Sample (2017–2022)		All Cantons	
Flooding	*Small or Less*	reference level		reference level		reference level	
	Moderate	−0.0230***	(0.00841)	−0.0198***	(0.00402)	−0.0192***	(0.00594)
	Substantial	−0.0109	(0.0129)	−0.00849	(0.00593)	−0.0125	(0.00855)
	Small or less	reference level		reference level		reference level	
	Moderate	−0.00468	(0.0154)	−0.00291	(0.00731)	−0.00803	(0.00889)
Surface Runoff	*Substantial*	−0.00612	(0.0199)	−0.0175	(0.0109)	−0.00753	(0.0148)
	Small or less	reference level		reference level		reference level	
Gravitational Hazards (all)	*Moderate*	−0.00596	(0.0126)	0.00540	(0.00567)	0.00338	(0.00942)
	Canton Fixed Effects	Yes		Yes		Yes	
	R^2	0.831		0.788		0.783	
	Degrees of Freedom	3336		72,172		22,253	
	BIC	−15,902.3		−40,486.3		−12,012.1	
	AIC	−16,551.1		−41,386.8		−12,693.3	
	N	18,339		72,270		22,338	
	Sum of Weights			4800		4087	

Notes: Dependent variable is the log of total annual rent. Estimates are relative to the reference level (small or less hazard). Standard errors in parentheses. *p 0.1; **p 0.05; ***p 0.01. Standard errors and p values are clustered at the building-level in the unweighted estimation and use the robust, consistent heteroskedasticity corrected covariance matrix in the other estimations. Estimates for included controlling variables are not shown.

flooding appears to be reflected in rent levels, and not any other natural hazards. An important question that arises from this research, is how any permanent reductions in net operating income through a rental discount interact with differences in the capitalization rates/yields of these investment properties.

CRediT authorship contribution statement

F.J. Blok: Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **F. Fuerst:** Writing – review & editing, Supervision, Methodology.

Declaration of competing interest

Floris Blok reports financial support was provided by Swiss Life Asset Managers. Franz Fuerst declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank Swiss Life Investment Managers for providing funding towards this research, and we are grateful to Wüest Partner AG in Zurich for giving access to their data. We thank Ante Busic for his help in enabling this research project, Angelika Brändle at WP for expert advice and support with running the regressions in Zurich, and Marius Zumwald and Robert Weinert for valuable comments on earlier versions of this study. Franz Fuerst thanks the Cambridge University Land Society (CULS) for their continued support of his research.

Appendix A. Hazard level definitions

Hazard levels are a combination of probability and intensity (see Fig. A1). Probability is expressed in terms of expected years between events and intensity. Intensity is expressed in terms of expected physical impact during a reference period, which differs depending on the type of hazard. In the case of flooding for example, strong intensity is defined as more than $2m$ inundation depth (d) or a d^*v of $> 2m^2/second$, where v is flow velocity. The corresponding values for medium intensity are $2m > d > 0.5m$ and $2m^2/second > d^*v > 0.5m^2/second$ repectively. Table A1 shows which hazard level corresponds to which colour in Fig. A1 and the maps published by the cantons online on their respective geoportals.[9]

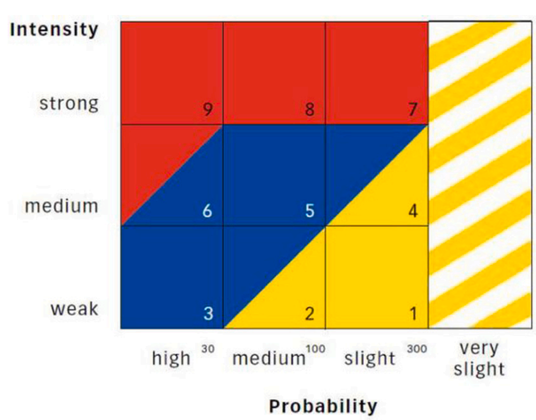

Fig. A1. hazard levels as a function of probability and intensity. Source: Federal Office for Spatial Development (2005).

[9] See https://www.bafu.admin.ch/bafu/de/home/themen/naturgefahren/fachinformationen/naturgefahrensituation-und-raumnutzung/gefahrengrundlagen/gefahrenkarten–intensitaetskarten-und-gefahrenhinweiskarten.html for a list of links to each canton's hazard maps.

Only surface runoff hazard (*Oberflächenabfluss*) is defined in a slightly different way. Instead of a combination of return periods and intensity, the expected inundation depth for a rainfall event with a return period of 100-years is given in three categories: $< 0.1m$ (light pink), $0.1m$–$0.25m$ (lilac), and $\geq 0.25m$ (purple). This one-dimensional hazard definition is converted into the five hazard levels shown in Table A1 for comparability whereby purple is substantial hazard, lilac is moderate hazard, and light pink is small hazard. No colour again means no hazard, and residual hazard does not exist for surface runoff hazard.

Table A1
Hazard level definitions.

Level	Definition	Hazard-map Colour	Surface Runoff-map Colour
1	No hazard	None (no hazard)	None (no hazard)
2	Residual hazard	White-yellow striped	
3	Small hazard	Yellow	Light pink
4	Moderate hazard	Blue	Lilac
5	Substantial hazard	Red	Purple

Appendix B. Included variables

Table B1
names, measurement levels and descriptions of untransformed included variables.

Variable Name	Measurement level	Description
Rent	dwelling	Total rent per year in CHF
Standard	building	Grade for the standard (building quality) of the building in general 1 = worst, 5 is best
State	building	Structural state of the building (maintenance level). 1 = worst, 5 is best
Parking	building	Dummy variable that takes the value 1 if the building has indoor parking (a garage)
Hillslope Debris Flow	building	Hillslope debris hazard rating
Debris Flow	building	Debris flow hazard rating
Landslide	building	Landslide hazard rating
Flooding	building	Flooding hazard rating
Surface Runoff	building	Surface Runoff hazard rating
Floor Area	dwelling	Size in square meters of the dwelling
Floor	dwelling	Floor level. Takes value 8 for all floor levels >7. 0 is ground floor.
Rooms	dwelling	Number of rooms in the dwelling
Age	building	Age of the building in years
Dist. Centre	building	Distance in meters to nearest town centre
Dist. Transport	building	Distance in meters to transport
Dist. Lake	building	Distance in meters to a lake
Dist. River	building	Distance in meters to a river
Dist. Nature	building	Distance in meters to nature
Lakeview	building	Lake view is an index of lake view quality based on a digital model of the terrain. For each point, we calculated the amount of water surface visible from a vantage height of 2 m. This is a theoretical visibility of the mountains without considering visibility obstructions by buildings, vegetation, etc.
Mountainview	building	The most dominant and renowned peaks of the Swiss mountain landscape were selected, and for each location we calculated how many of these peaks are visible. This was converted into an index. This is a theoretical visibility of the mountains without considering visibility obstructions by buildings, vegetation, etc.
Pop. Density	building	Population density in a radius of 1000 m
Tax Rate	building	Marginal income tax rate for a two-person household (married, renters, no children) earning 120,000 CHF per year
Canton	canton	Canton ID
Elevation	building	Building's elevation in meters above sea level
Rel. Elevation	building	Elevation of the building minus the elevation of the municipality
Incline	building	Incline of the plot upon which the building stands
Orientation	building	Exposition of the plot upon which the building stands (if inclined, otherwise 0)
Mean Income	building	Mean household income in a radius of 1000 m
# Apartments	building	Number of dwellings in the building
Alpine Area	municipality	Takes the value 1 if the building is located in the mountains according to BFS. 0 otherwise.
Mean Summer Temp.	building	Mean temperature in summer. 10 by 10 km grid (e-obs)

Appendix C. Descriptive statistics

Table C1
Pearson correlation between included variables.

	ln(Rent)	Flooding (binary)	Surface Runoff (binary)	Debris Flow (binary)	Hillslope Debris (binary)	Landslide (binary)	Inv. Dist. River	Inv. Dist. Lake	Lakeview	Mountain-view	Rel. Elevation	Incline	Altitude	Orientation
ln(Rent)	1	−0,0634	0,0147	−0,0011	0,0061	0,0226	0,055	0,0561	−0,035	0,0413	−0,0448	−0,034	−0,1546	0,0511
Flooding (binary)	−0,0634	1	0,0156	0,1768	0,0589	0,053	0,0981	0,1168	0,0759	−0,1343	−0,0969	0,0319	0,0816	−0,0665
Surface Runoff (binary)	0,0147	0,0156	1	−0,01	−0,0256	−0,0109	−0,0137	0,038	0,0162	0,0051	−0,0568	−0,0873	−0,0153	0,0586
Debris Flow (binary)	−0,0011	0,1768	−0,01	1	0,016	0,0618	−0,0006	0,019	−0,0176	−0,0516	−0,0039	0,0403	0,0746	−0,083
Hillslope Debris (binary)	0,0061	0,0589	−0,0256	0,016	1	0,1738	0,1956	0,0808	0,0452	0,003	0,0984	0,3456	0,1464	−0,1635
Landslide (binary)	0,0226	0,053	−0,0109	0,0618	0,1738	1	−0,0015	0,1987	0,0017	−0,0413	0,0249	0,2287	0,0747	−0,1073
Inv. Dist. River	0,055	0,0981	−0,0137	−0,0006	0,1956	−0,0015	1	−0,005	−0,0128	0,0048	−0,0477	0,0311	−0,0298	−0,0688
Inv. Dist. Lake	0,0561	0,1168	0,038	0,019	0,0808	0,1987	−0,005	1	0,3137	0,0648	−0,0558	0,1003	−0,0195	−0,0547
Lakeview	−0,035	0,0759	0,0162	−0,0176	0,0452	0,0017	−0,0128	0,3137	1	0,1805	0,0654	0,1118	−0,046	−0,1091
Mountainview	0,0413	−0,1343	0,0051	−0,0516	0,003	−0,0413	0,0048	0,0648	0,1805	1	0,2403	0,0885	0,143	−0,0617
Rel. Elevation	−0,0448	−0,0969	−0,0568	−0,0039	0,0984	0,0249	−0,0477	−0,0558	0,0654	0,2403	1	0,2494	0,2184	−0,2148
Incline	−0,034	0,0319	−0,0873	0,0403	0,3456	0,2287	0,0311	0,1003	0,1118	0,0885	0,2494	1	0,3063	−0,6478
Altitude	−0,1546	0,0816	−0,0153	0,0746	0,1464	0,0747	−0,0298	−0,0195	−0,046	0,143	0,2184	0,3063	1	−0,2374
Orientation	0,0511	−0,0665	0,0586	−0,083	−0,1635	−0,1073	−0,0688	−0,0547	−0,1091	−0,0617	−0,2148	−0,6478	−0,2374	1
Alpine Area	−0,1506	0,0843	0,0269	0,0575	0,0497	−0,0017	−0,018	0,0464	0,0527	−0,1316	−0,072	0,0804	0,1506	−0,0125
Mean Summer Temp.	0,1429	−0,1185	−0,0188	−0,108	−0,1238	−0,0326	0,0142	0,0142	0,0348	0,0008	−0,0032	−0,15	−0,6935	0,1284
Floor Level	0,0995	0,0051	0,0249	−0,0393	0,0506	−0,0112	−0,0009	0,0066	−0,0279	−0,0581	−0,0277	−0,0841	−0,0414	0,0691
# Rooms	0,5856	0,0296	−0,0048	0,0241	0,0507	0,0209	0,0273	−0,0064	0,0144	−0,004	−0,0667	0,0468	0,0315	−0,0423
Age	−0,2255	0,0023	0,0359	−0,0388	−0,0237	0,0015	−0,0291	0,0618	0,0341	0,0486	0,0658	0,0858	0,071	−0,0638
Parking	0,1435	−0,018	−0,0336	0,0228	0,0134	0,0128	0,0043	−0,0432	−0,0277	−0,0198	−0,1281	0,0091	−0,0149	−0,0257
Size	0,7061	0,0291	0,0184	0,0379	0,0589	0,02	0,0369	0,0111	−0,0052	0,0116	−0,08	0,033	0,0034	−0,0195
Inv. Dist. Nature	0,0329	0,0218	0,0948	−0,0165	−0,0112	−0,0075	−0,0117	−0,0225	−0,0335	0,0159	−0,0315	−0,0215	0,0402	0,046
Inv. Dist. Transport	−0,02	0,0368	0,0505	−0,0055	0,0176	0,0123	−0,0133	0,0321	−0,0056	−0,0104	−0,0186	−0,024	0,0246	−0,0024
Inv. Dist. Centre	0,0195	0,0195	0,0737	−0,0166	−0,0463	−0,003	−0,0083	0,0723	0,0283	0,0193	−0,0637	−0,0966	−0,0046	0,0706
ln(Mean Income)	0,3096	−0,0772	−0,0351	0,0497	−0,0401	0,0313	0,0547	0,0205	−0,0818	0,1203	−0,0228	−0,0015	0,0188	−0,0045
Tax Rate	−0,3178	0,0352	0,0236	−0,0042	0,0285	0,0051	−0,1128	−0,035	0,0272	0,1616	0,0469	0,057	0,2343	−0,0569
Pop. Density	0,1159	−0,1269	0,0648	−0,1015	−0,0524	−0,0263	−0,002	−0,0555	−0,0804	−0,0563	0,0358	−0,1433	−0,2086	0,1181
# Apartments	−0,0583	−0,0997	−0,0499	−0,0488	0,034	−0,0245	0,0224	−0,0622	−0,0842	−0,0261	0,189	−0,0914	0,0333	0,0815

	Alpine Area	Mean Summer Temp.	Floor Level	# Rooms	Age	Parking	Size	Inv. Dist. Nature	Inv. Dist. Transport	Inv. Dist. Centre	ln(Mean Income)	Tax Rate	Pop. Density	# Apartments
ln(Rent)	−0,1506	0,1429	0,0995	0,5856	−0,2255	0,1435	0,7061	0,0329	−0,02	0,0195	0,3096	−0,3178	0,1159	−0,0583
Flooding (binary)	0,0843	−0,1185	0,0051	0,0296	0,0023	−0,018	0,0291	0,0218	0,0368	0,0195	−0,0772	0,0352	−0,1269	−0,0997
Surface Runoff (binary)	0,0269	−0,0188	0,0249	−0,0048	0,0359	−0,0336	0,0184	0,0948	0,0505	0,0737	−0,0351	0,0236	0,0648	−0,0499
Debris Flow (binary)	0,0575	−0,108	−0,0393	0,0241	−0,0388	0,0228	0,0379	−0,0165	−0,0055	−0,0166	0,0497	−0,0042	−0,1015	−0,0488
Hillslope Debris (binary)	0,0497	−0,1238	0,0506	0,0507	−0,0237	0,0134	0,0589	−0,0112	0,0176	−0,0463	−0,0401	0,0285	−0,0524	0,034
Landslide (binary)	−0,0017	−0,0326	−0,0112	0,0209	0,0015	0,0128	0,02	−0,0075	0,0123	−0,003	0,0313	0,0051	−0,0263	−0,0245
Inv. Dist. River	−0,018	0,0142	−0,0009	0,0273	−0,0291	0,0043	0,0369	−0,0117	−0,0133	−0,0083	0,0547	−0,1128	−0,002	0,0224
Inv. Dist. Lake	0,0464	0,0142	0,0066	−0,0064	0,0618	−0,0432	0,0111	−0,0225	0,0321	0,0723	0,0205	−0,035	−0,0555	−0,0622
Lakeview	0,0527	0,0348	−0,0279	0,0144	0,0341	−0,0277	−0,0052	−0,0335	−0,0056	0,0283	−0,0818	0,0272	−0,0804	−0,0842
Mountainview	−0,1316	0,0008	−0,0581	−0,004	0,0486	−0,0198	0,0116	0,0159	−0,0104	0,0193	0,1203	0,1616	−0,0563	−0,0261
Rel. Elevation	−0,072	−0,0032	−0,0277	−0,0667	0,0658	−0,1281	−0,08	−0,0315	−0,0186	−0,0637	−0,0228	0,0469	0,0358	0,189
Incline	0,0804	−0,15	−0,0841	0,0468	0,0858	0,0091	0,033	−0,0215	−0,024	−0,0966	−0,0015	0,057	−0,1433	−0,0914
Altitude	0,1506	−0,6935	−0,0414	0,0315	0,071	−0,0149	0,0034	0,0402	0,0246	−0,0046	0,0188	0,2343	−0,2086	0,0333
Orientation	−0,0125	0,1284	0,0691	−0,0423	−0,0638	−0,0257	−0,0195	0,046	−0,0024	0,0706	−0,0045	−0,0569	0,1181	0,0815
Alpine Area	1	−0,3341	0,0039	0,0123	−0,0703	0,0209	−0,0186	0,0714	−0,0126	−0,0406	−0,318	−0,0673	−0,1027	−0,0371
Mean Summer Temp.	−0,3341	1	0,0155	−0,0452	0,013	−0,0144	−0,0232	−0,049	−0,0058	0,0106	−0,0434	−0,1293	0,2627	0,035
Floor Level	0,0039	0,0155	1	−0,0361	−0,0536	−0,0035	−0,0038	−0,033	0,0353	0,0884	−0,1175	−0,0126	0,1501	0,2193
# Rooms	0,0123	−0,0452	−0,0361	1	−0,109	0,1971	0,8539	0,0326	−0,0341	−0,1184	0,1149	−0,0214	−0,2253	−0,0848
Age	−0,0703	0,013	−0,0536	−0,109	1	−0,4332	−0,1882	−0,1421	0,067	0,1682	−0,0856	0,1018	0,2981	−0,2326

(*continued on next page*)

Table C1 (*continued*)

	Alpine Area	Mean Summer Temp.	Floor Level	# Rooms	Age	Parking	Size	Inv. Dist. Nature	Inv. Dist. Transport	Inv. Dist. Centre	ln(Mean Income)	Tax Rate	Pop. Density	# Apartments
Parking	0,0209	−0,0144	−0,0035	0,1971	−0,4332	1	0,2094	0,0476	−0,0445	−0,195	0,1343	−0,0764	−0,2665	0,0462
Size	−0,0186	−0,0232	−0,0038	0,8539	−0,1882	0,2094	1	0,0534	−0,0144	−0,0715	0,1444	−0,0711	−0,188	−0,108
Inv. Dist. Nature	0,0714	−0,049	−0,033	0,0326	−0,1421	0,0476	0,0534	1	−0,0407	−0,0496	0,0306	−0,0334	−0,1243	0,0569
Inv. Dist. Transport	−0,0126	−0,0058	0,0353	−0,0341	0,067	−0,0445	−0,0144	−0,0407	1	0,1282	−0,0569	0,0126	0,0535	−0,0592
Inv. Dist. Centre	−0,0406	0,0106	0,0884	−0,1184	0,1682	−0,195	−0,0715	−0,0496	0,1282	1	−0,0641	−0,0048	0,215	−0,1072
ln(Mean Income)	−0,318	−0,0434	−0,1175	0,1149	−0,0856	0,1343	0,1444	0,0306	−0,0569	−0,0641	1	−0,4516	−0,2732	0,0131
Tax Rate	−0,0673	−0,1293	−0,0126	−0,0214	0,1018	−0,0764	−0,0711	−0,0334	0,0126	−0,0048	−0,4516	1	0,0188	−0,0867
Pop. Density	−0,1027	0,2627	0,1501	−0,2253	0,2981	−0,2665	−0,188	−0,1243	0,0535	0,215	−0,2732	0,0188	1	0,0094
# Apartments	−0,0371	0,035	0,2193	−0,0848	−0,2326	0,0462	−0,108	0,0569	−0,0592	−0,1072	0,0131	−0,0867	0,0094	1

Table C2
joint frequencies of flooding hazard and built standard at the building-level.

Standard	Small	Moderate	Substantial	Total
1	0	0	0	0
2	54	7	5	66
3	1523	295	125	1943
4	1014	180	91	1285
5	36	3	4	43
Total	2627	485	225	3337

Table C3
joint frequencies of flooding hazard and distance to river at the building-level.

Dist. River	Small	Moderate	Substantial	Total
<250	376	57	96	529
250–500	483	77	13	573
500–1000	680	94	37	811
1000–1500	391	95	17	503
>1500	706	162	62	930
Total	2636	485	225	3337

Table C4
weighted and unweighted descriptive statistics of the sample.

Variable Name		Mean (weighted)	Std. dev. (weighted)	Mean (unweighted)	Std. dev. (unweighted)	Min.	Max.
	ln(Rent)	9728	0,377	9741	0,373	7352	11,919
Flooding	*Small or less*			reference level			
	Moderate	0,145	0,353	0,119	0,323	0	1
	Substantial	0,067	0,251	0,066	0,248	0	1
Surface Runoff	*Small or less*			reference level			
	Moderate	0,059	0,235	0,057	0,232	0	1
	Substantial	0,022	0,145	0,017	0,130	0	1
Hillslope Debris Flow	*Small or less*			reference level			
	Moderate	0,027	0,162	0,028	0,164	0	1
Debris Flow	*Small or less*			reference level			
	Moderate	0,022	0,145	0,019	0,136	0	1
Landslide	*Small or less*			reference level			
	Moderate	0,007	0,083	0,005	0,073	0	1
Gravitational Hazards (all)	*Small or less*						
	Moderate	0,051	0,219	0,048	0,214	0	1
Dist. River	*<250*			reference level			
	250–500	0,156	0,363	0,149	0,356	0	1
	500–1000	0,172	0,377	0,175	0,380	0	1
	1000–1500	0,243	0,429	0,269	0,443	0	1

(*continued on next page*)

Table C4 (*continued*)

Variable Name		Mean (weighted)	Std. dev. (weighted)	Mean (unweighted)	Std. dev. (unweighted)	Min.	Max.
	>1500	0,151	0,358	0,146	0,353	0	1
Dist. Lake	*<250*			reference level			
	250–500	0,034	0,180	0,029	0,167	0	1
	500–1000	0,055	0,227	0,036	0,187	0	1
	1000–1500	0,076	0,265	0,063	0,243	0	1
	>1500	0,063	0,242	0,068	0,252	0	1
	Lakeview	145,882	434,245	121,607	403,565	0	3948
	Mountainview	9329	10,314	9326	10,391	0	57
	Rel. Elevation	9017	27,728	8390	26,971	−144,177	224,103
	Incline	2960	3429	2617	3095	0,012	30,025
	Elevation	452,571	142,527	446,785	130,790	195,706	1859,500
Orientation	*1*			reference level			
	2	0,042	0,200	0,033	0,177	0	1
	3	0,035	0,184	0,035	0,183	0	1
	4	0,045	0,207	0,039	0,193	0	1
	5	0,041	0,198	0,032	0,175	0	1
	6	0,047	0,212	0,041	0,199	0	1
	7	0,036	0,186	0,035	0,185	0	1
	8	0,036	0,186	0,033	0,178	0	1
	9	0,676	0,468	0,718	0,450	0	1
	Alpine Area	0,133	0,339	0,120	0,324	0	1
	Mean Summer Temp.	17,265	1138	17,303	1082	7593	20,495
Floor Level	*Ground Floor*			reference level			
	1	0,241	0,428	0,221	0,415	0	1
	2	0,243	0,429	0,223	0,416	0	1
	3	0,169	0,375	0,169	0,374	0	1
	4	0,080	0,272	0,093	0,291	0	1
	5	0,041	0,199	0,051	0,220	0	1
	6	0,019	0,138	0,029	0,167	0	1
	7	0,007	0,085	0,016	0,125	0	1
	8	0,017	0,130	0,032	0,176	0	1
	Rooms	3266	1086	3180	1087	1	7
	Age	46,759	30,068	34,112	29,972	0	122
	Age^2	3090,190	3563,641	2061,925	2953,722	0	14,884
Standard	*2*			reference level			
	3	0,582	0,493	0,460	0,498	0	1
	4	0,385	0,487	0,510	0,500	0	1
	5	0,013	0,113	0,016	0,127	0	1
State	*2*			reference level			
	3	0,427	0,495	0,291	0,454	0	1
	4	0,327	0,469	0,266	0,442	0	1
	5	0,201	0,401	0,416	0,493	0	1
	Parking	0,808	0,394	0,878	0,327	0	1
	Floor Area	78,919	28,630	76,5528	28,172	9	430
	Floor Area^2	7047,649	5581,688	6653,9410	5151,651	81	184,900
	ln(# Apartments)	3275	0,825	3883	0,895	0	6273
	Inv. Dist. Nature	0,0001	0,0006	0,0002	0,0011	0,0000	0,01
	Inv. Dist. Transport	0,0001	0,0003	0,0001	0,0002	0,0000	0,0025
	Inv. Dist. Centre	0,0011	0,003	0,0008	0,003	0,0000	0,01
	ln(Mean Income)	11,614	0,108	11,612	0,108	11,184	11,898
	Tax Rate	0,1074	0,021	0,1075	0,020	0,035	0,155
	Pop. Density	4974,974	2975,366	4833,223	2785,949	20,456	16,360,090
	Weight	0,182	0,2198	–	–	0,0062	1

Appendix D. Full regression results

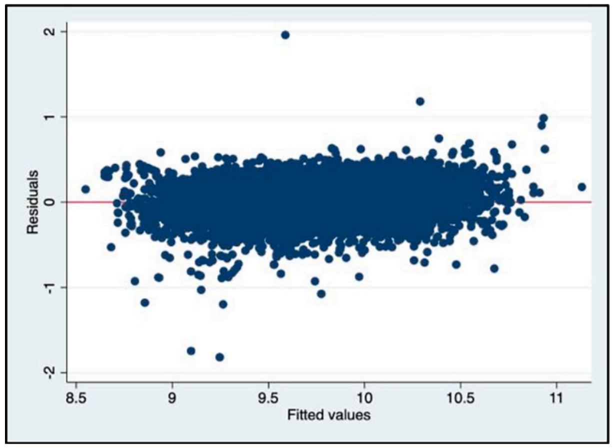

Fig. D1. Residuals Model 1.

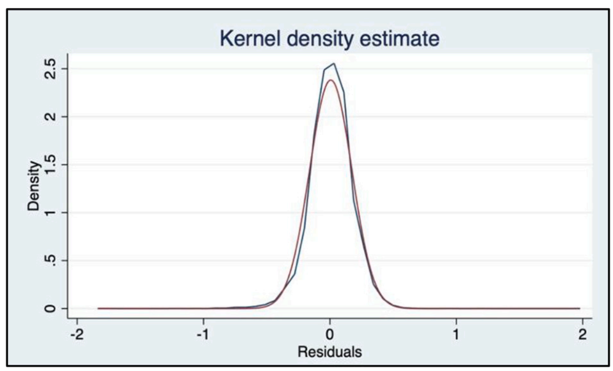

Fig. D2. Residual distribution Model 1.

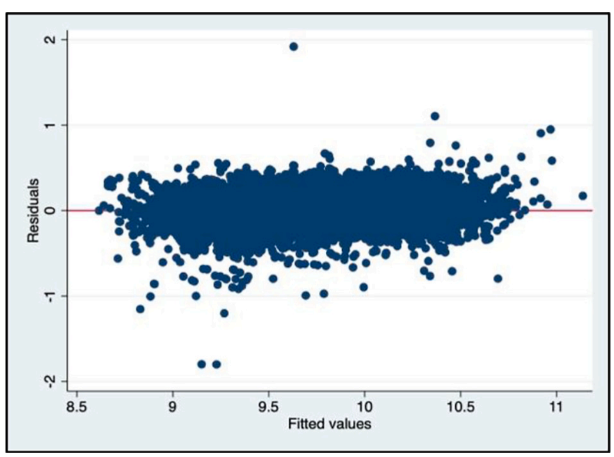

Fig. D3. Residuals Model 2.

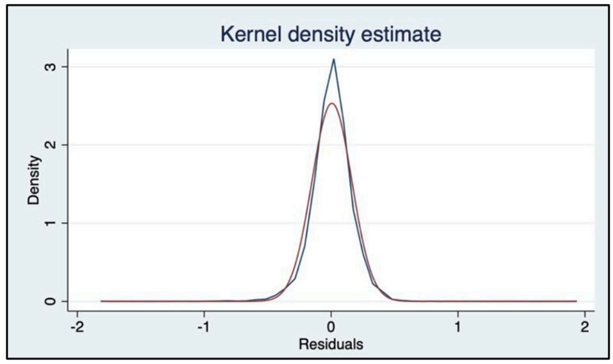

Fig. D4. Residual distribution Model 2.

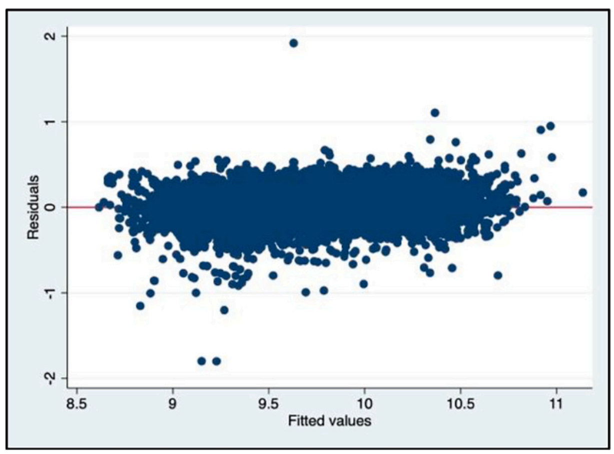

Fig. D5. Residuals Model 3.

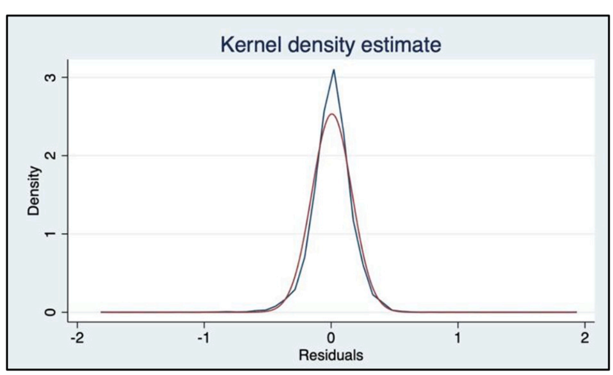

Fig. D6. Residual distribution Model 3.

Table D1
Full regression outputs of baseline models.

	Variable	(i)	(ii)	(iii)	(iv)	(v)	(1)	(2)	(3)
Flooding	*Small or less*	reference level	reference level	reference level	reference level	reference level	reference level	reference level	reference level
	Moderate	-0.0546*** (0.0136)	-0.0573*** (0.0130)	-0.0437*** (0.0129)	-0.0367*** (0.0125)	-0.0462*** (0.00798)	-0.0201*** (0.00655)	-0.0135** (0.00619)	-0.0135** (0.00618)
	Substantial	-0.0848*** (0.0193)	-0.0990*** (0.0196)	-0.0851*** (0.0196)	-0.0697*** (0.0185)	-0.0839*** (0.0111)	-0.0383*** (0.00957)	-0.0186* (0.00949)	-0.0190** (0.00957)
Surface Runoff	*Small or less*	reference level	reference level	reference level	reference level	reference level	reference level	reference level	reference level
	Moderate	-0.0000778 (0.0218)	-0.000465 (0.0209)	-0.00386 (0.0208)	-0.00575 (0.0194)	-0.0233** (0.0110)	-0.0148 (0.00906)	-0.0163* (0.00896)	-0.0160* (0.00896)
	Substantial	0.0435 (0.0338)	0.0344 (0.0318)	0.0336 (0.0314)	0.0392 (0.0297)	-0.0332 (0.0215)	-0.0214 (0.0158)	-0.0251* (0.0150)	-0.0250* (0.0150)
Hillslope Debris	*Small or less*	reference level	reference level	reference level	reference level	reference level	reference level	reference level	
Flow	*Moderate*	0.0422 (0.0278)	0.0126 (0.0260)	0.0191 (0.0259)	0.0825*** (0.0302)	0.0176 (0.0193)	0.0164 (0.0148)	0.0185 (0.0146)	
Debris Flow	*Small or less*	reference level	reference level	reference level	reference level	reference level	reference level	reference level	
	Moderate	0.00876 (0.0277)	0.0112 (0.0274)	0.00935 (0.0269)	0.0640** (0.0265)	0.0177 (0.0180)	-0.00182 (0.0151)	0.00244 (0.0137)	
Landslide	*Small or less*	reference level	reference level	reference level	reference level	reference level	reference level	reference level	
	Moderate	0.124* (0.0684)	0.0730 (0.0636)	0.0679 (0.0580)	0.122** (0.0615)	0.0932** (0.0408)	0.0253 (0.0320)	0.00541 (0.0330)	
Gravitational	*Small or less*								reference level
Hazards (all)	*Moderate*								0.00801 (0.0100)
Dist. River	*<250*		0.0418*** (0.0140)	0.0406*** (0.0138)	0.0188 (0.0141)	0.0132 (0.00892)	0.0383*** (0.00732)	0.0366*** (0.00701)	0.0367*** (0.00698)
	250-500		-0.0351** (0.0145)	-0.0381*** (0.0143)	-0.0550*** (0.0148)	-0.0155* (0.00925)	0.0139* (0.00782)	0.0164** (0.00766)	0.0163** (0.00762)
	500-1000		0.0194 (0.0123)	0.0172 (0.0120)	0.00428 (0.0121)	0.0181** (0.00735)	0.0148** (0.00604)	0.0222*** (0.00576)	0.0222*** (0.00577)
	1000-1500		-0.0211 (0.0136)	-0.0178 (0.0134)	-0.0275** (0.0131)	-0.00771 (0.00816)	-0.0159** (0.00674)	0.000212 (0.00627)	0.000149 (0.00626)
	>1500		reference level	reference level	reference level	reference level	reference level	reference level	reference level
Dist. Lake	*<250*		0.234*** (0.0365)	0.360*** (0.0413)	0.377*** (0.0415)	0.337*** (0.0231)	0.288*** (0.0204)	0.250*** (0.0196)	0.251*** (0.0196)
	250-500		0.256*** (0.0271)	0.348*** (0.0287)	0.361*** (0.0277)	0.322*** (0.0162)	0.256*** (0.0147)	0.221*** (0.0135)	0.221*** (0.0135)
	500-1000		0.0912*** (0.0189)	0.164*** (0.0207)	0.199*** (0.0208)	0.179*** (0.0138)	0.103*** (0.0103)	0.0972*** (0.0103)	0.0973*** (0.0103)
	1000-1500		0.0543*** (0.0178)	0.0900*** (0.0179)	0.114*** (0.0170)	0.0797*** (0.0108)	0.0205** (0.00900)	0.0159* (0.00897)	0.0162* (0.00899)
	>1500		reference level	reference level	reference level	reference level	reference level	reference level	reference level
	Lakeview			-0.000145*** (0.0000129)	-0.000150*** (0.0000130)	-0.000147*** (0.00000708)	-0.0000824*** (0.00000608)	-0.0000483*** (0.00000639)	-0.0000485*** (0.00000639)
	Mountainview			0.00275*** (0.000411)	0.00200*** (0.000414)	0.00163*** (0.000261)	0.00189*** (0.000205)	0.00114*** (0.000239)	0.00114*** (0.000239)
	Inv. Dist. Nature				24.22*** (2.696)	-1.997 (2.840)	0.387 (1.813)	-0.156 (2.057)	-0.113 (2.054)
	Inv. Dist. Transport				-6.993 (16.71)	-7.373 (9.328)	-8.429 (7.034)	2.153 (6.526)	2.521 (6.535)
	Inv. Dist. Centre				11.95*** (1.718)	4.774*** (1.194)	1.357 (0.995)	2.347** (0.958)	2.334** (0.962)
	Rel. Elevation				0.000607*** (0.000178)	0.00131*** (0.000119)	0.00110*** (0.0000958)	0.000913*** (0.0000911)	0.000913*** (0.0000912)
	Incline				-0.00367 (0.00264)	-0.00448*** (0.00157)	-0.000628 (0.00118)	-0.000474 (0.00117)	-0.000127 (0.00111)
	Elevation				-0.000293*** (0.0000462)	-0.000254*** (0.0000318)	0.00000758 (0.0000250)	-0.0000636* (0.0000340)	-0.0000646* (0.0000350)
	Alpine Area				-0.210*** (0.0133)	-0.146*** (0.00812)	-0.0795*** (0.00771)		
	Mean Summer Temp.				-0.0194*** (0.00524)	-0.00633* (0.00336)	-0.000944 (0.00262)	0.00727*** (0.00274)	0.00717*** (0.00274)
	# Rooms					0.00432 (0.00607)	0.0275*** (0.00551)	0.0257*** (0.00539)	0.0257*** (0.00538)
	Age					-0.00251*** (0.000349)	-0.00366*** (0.000314)	-0.00370*** (0.000295)	-0.00371*** (0.000295)
	Age^2					0.0000296*** (0.00000316)	0.0000314*** (0.00000281)	0.0000308*** (0.00000265)	0.0000309*** (0.00000265)
	Parking					-0.0216** (0.00990)	-0.0105 (0.00861)	-0.0150* (0.00825)	-0.0151* (0.00827)
	Floor Area					0.0138*** (0.000732)	0.0126*** (0.000705)	0.0129*** (0.000700)	0.0129*** (0.000699)
	Floor Area^2					-0.0000292*** (0.00000339)	-0.0000265*** (0.00000328)	-0.0000275*** (0.00000325)	-0.0000275*** (0.00000325)
	ln(# Apartments)					-0.0117*** (0.00409)	-0.0184*** (0.00350)	-0.0189*** (0.00344)	-0.0189*** (0.00343)
	ln(Mean Income)						0.652*** (0.0266)	0.332*** (0.0312)	0.331*** (0.0310)
	Tax Rate						-2.831*** (0.127)		
	Pop. Density						0.0000375*** (0.00000111)	0.0000279*** (0.00000121)	0.0000279*** (0.00000121)
	Orientation						included	included	included
	Floor Level						included	included	included
	State						included	included	included
	Standard						included	included	included
	Contract start Quarter	included	included	included	included	included	included	included	included
	Constant	9.733*** (0.00881)	9.701*** (0.0116)	9.678*** (0.0123)	10.10*** (0.109)	8.952*** (0.0780)	1.295*** (0.326)	4.752*** (0.369)	4.775*** (0.366)
	Canton Fixed Effects	No	No	No	No	No	No	Yes	Yes
	R^2	0.007	0.046	0.066	0.128	0.677	0.787	0.810	0.810
	Degrees of Freedom	18326	18318	18316	18300	18279	18276	18256	18258
	BIC	16289.9	15621.3	15264.9	14147.6	-3872.5	-11435.7	-13354.0	-13370.4
	AIC	16188.3	15457.2	15085.1	13842.8	-4341.5	-11928.2	-14002.8	-14003.5
	N	18339	18339	18339	18339	18339	18339	18339	18339
	Sum of Weights	3356	3356	3356	3356	3356	3356	3356	3356

Note: Dependent variable is the log of total annual rent. Estimates are relative to the reference level (small or less hazard). Standard errors in parentheses. *p 0.1; **p 0.05; ***p 0.01. Standard errors and p values are based on the robust, consistent heteroskedasticity corrected covariance matrix.

Table D2
Regression estimates using five-level hazard levels.

Variable		(1)		(2)		(3)	
Flooding	*None*	reference level		reference level		reference level	
	Residual	0.0118	(0.00728)	0.00425	(0.00717)	0.00454	(0.00719)
	Small	−0.00320	(0.00613)	−0.00462	(0.00614)	−0.00461	(0.00612)
	Moderate	−0.0197***	(0.00680)	−0.0143**	(0.00644)	−0.0144**	(0.00642)
	Substantial	−0.0371***	(0.00978)	−0.0185*	(0.00980)	−0.0188*	(0.00987)
	None	reference level		reference level		reference level	
	Residual	no observations		no observations		no observations	
Surface Runoff	*Small*	0.0113**	(0.00500)	0.0121**	(0.00473)	0.0123***	(0.00472)
	Moderate	−0.0109	(0.00916)	−0.0118	(0.00906)	−0.0115	(0.00905)
	Substantial	−0.0178	(0.0158)	−0.0207	(0.0150)	−0.0208	(0.0150)
	None	reference level		reference level			
	Residual	no observations		no observations			
Hillslope DebrisFlow	*Small*	no observations		no observations			
	Moderate	0.0104	(0.0148)	0.0136	(0.0147)		
	Substantial	no observations		no observations			
	None	reference level		reference level			
	Residual	0.0296	(0.0308)	0.0507	(0.0330)		
Debris Flow	*Small*	no observations		no observations			
	Moderate	−0.00172	(0.0151)	0.00223	(0.0137)		
	Substantial	no observations		no observations			
	None					reference level	
	Residual					0.0849***	(0.0196)
	Small					0.0282	(0.0208)
	Moderate					0.00799	(0.0100)
Gravitational Hazards (all)	*Substantial*					0.0810***	(0.0254)
	Canton Fixed Effects	*No*		*Yes*		*Yes*	
	R^2	0.787		0.810		0.810	
	Degrees of Freedom	18,269		18,249		18,252	
	BIC	−11,406.6		−13,318.9		−13,347.2	
	AIC	−11,953.8		−14,022.4		−14,027.2	
	N	18,339		18,339		18,339	
	Sum of Weights	3337		3337		3337	

Note: Dependent variable is the log of total annual rent. Estimates are relative to the reference level (small or less hazard). Standard errors in parentheses. *p 0.1; **p 0.05; ***p 0.01. Standard errors and p values are based on the robust, consistent heteroskedasticity corrected covariance matrix. Estimates for included controlling variables are not shown.

Table D3
regression outputs of alternative models.

	Variable	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Flooding	*Small or less*	reference level	reference level	reference level	reference level	reference level	reference level	reference level	reference level	reference level
	Moderate	-0.0302*** (0.00900)	-0.0233*** (0.00838)	-0.0230*** (0.00841)	-0.0260*** (0.00404)	-0.0201*** (0.00403)	-0.0198*** (0.00402)	-0.0322*** (0.00658)	-0.0191*** (0.00595)	-0.0192*** (0.00594)
	Substantial	-0.0167 (0.0141)	-0.0117 (0.0129)	-0.0109 (0.0129)	-0.0245*** (0.00580)	-0.00991* (0.00587)	-0.00849 (0.00593)	-0.0265*** (0.00932)	-0.0119 (0.00851)	-0.0125 (0.00855)
Surface Runoff	*Small or less*	reference level	reference level	reference level	reference level	reference level	reference level	reference level	reference level	reference level
	Moderate	-0.00278 (0.0176)	-0.00449 (0.0154)	-0.00468 (0.0154)	-0.00228 (0.00727)	-0.00270 (0.00731)	-0.00291 (0.00731)	-0.0109 (0.00922)	-0.00827 (0.00890)	-0.00803 (0.00889)
	Substantial	0.000763 (0.0185)	-0.00687 (0.0200)	-0.00612 (0.0199)	-0.0119 (0.0112)	-0.0172 (0.0109)	-0.0175 (0.0109)	-0.000373 (0.0162)	-0.00785 (0.0148)	-0.00753 (0.0148)
Hillslope Debris	*Small or less*	reference level	reference level		reference level	reference level		reference level	reference level	
Flow	*Moderate*	-0.0483** (0.0225)	-0.0102 (0.0178)		0.0000387 (0.00930)	0.00150 (0.00892)		0.0280** (0.0134)	0.0129 (0.0129)	
Debris Flow	*Small or less*	reference level	reference level		reference level	reference level		reference level	reference level	
	Moderate	-0.0151 (0.0219)	-0.00629 (0.0166)		0.0144* (0.00806)	0.0191** (0.00812)		-0.0102 (0.0157)	-0.00683 (0.0139)	
Landslide	*Small or less*	reference level	reference level		reference level	reference level		reference level	reference level	
	Moderate	0.0714* (0.0378)	0.0566 (0.0362)		0.00428 (0.0169)	-0.00644 (0.0174)		0.0306 (0.0376)	0.0211 (0.0311)	
Gravitational	*Small or less*			reference level			reference level			reference level
Hazards (all)	*Moderate*			-0.00596 (0.0126)			0.00540 (0.00567)			0.00338 (0.00942)
	Controls	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
	Canton Fixed Effects	*No*	*Yes*	*Yes*	*No*	*Yes*	*Yes*	*No*	*Yes*	*Yes*
	Standard Errors	*Clustered (Building)*	*Clustered (Building)*	*Clustered (Building)*	*Heteroskedasticity Robust*	*Heteroskedasticity Robust*	*Heteroskedasticity Robust*	*Heteroskedasticity Robust*	*Heteroskedasticity Robust*	*Heteroskedasticity Robust*
	R^2	0.808	0.831	0.830	0.769	0.788	0.788	0.743	0.783	0.783
	Degrees of Freedom	3336	3336	3336	72192	72172	72174	22275	22253	22255
	BIC	-13849.9	-15902.3	-15910.4	-34412.7	-40486.3	-40497.1	-8465.4	-12012.1	-12027.7
	AIC	-14342.3	-16551.1	-16543.5	-35129.3	-41386.8	-41379.2	-8970.3	-12693.3	-12692.8
	N	18339	18339	18339	72270	72270	72270	22338	22338	22338
	Sum of Weights				4800	4800	4800	4087	4087	4087

Note: Dependent variable is the log of total annual rent. Estimates are relative to the reference level (small or less hazard). Standard errors in parentheses. *p 0.1; **p 0.05; ***p 0.01. Estimates for included controlling variables are not shown.

Data availability

The authors do not have permission to share data.

References

Abadie, A., Athey, S., Imbens, G.W., Wooldridge, J.M., 2023. When should you adjust standard errors for clustering? Q. J. Econ. 138 (1), 1–35.

Acharya, V.V., Berner, R., Engle, R., Jung, H., Stroebel, J., Zeng, X., Zhao, Y., 2023. Climate stress testing. Annu. Rev. Financ. Econ. 15, 291–326.

Andres, N., Badoux, A., Techel, F., Hegg, C., 2017. Todesfälle durch Naturgefahrenprozesse in der Schweiz von 1946 bis 2015. Wasser Energie Luft 109, 105–110.

Athukorala, W., Martin, W., Neelawala, P., Rajapaksa, D., Wilson, C., 2016. Impact of wildfires and floods on property values: a before and after analysis. Singapore Econ. Rev. 61 (01). https://doi.org/10.1142/S0217590816400026.

Atreya, A., Czajkowski, J., 2016. Graduated flood risks and property prices in Galveston County. Real Estate Econ. 47 (3), 807–844. https://doi.org/10.1111/1540-6229.12163.

Atreya, A., Ferreira, S., Kriesel, W., 2013. Forgetting the flood? An analysis of the flood risk discount over time. Land Econ. 89 (4), 577–596. https://doi.org/10.3368/le.89.4.577.

BAFU, 1999. Risikoanalyse bei gravitativen Naturgefahren - Methode. Retrieved from Bern: https://www.bafu.admin.ch/bafu/de/home/themen/naturgefahren/publikationen-studien/publikationen/risikoanalyse-gravitativen-naturgefahren.html.

BAFU, 2018. Gefährdungskarte Oberflächenabfluss Schweiz - Technischer Bericht. Retrieved from Bern: https://www.bafu.admin.ch/dam/bafu/de/dokumente/naturgefahren/externe-studien-berichte/gefaehrdungskarte-oberflaechenabfluss-schweiz-technischer-bericht.pdf.download.pdf/gefaehrdungskarte_oberflaechenabfluss_schweiz_technischer_bericht.pdf.

Beltrán, A., Maddison, D., Elliott, R.J.R., 2018. Is flood risk capitalised into property values? Ecol. Econ. 146, 668–685. https://doi.org/10.1016/j.ecolecon.2017.12.015.

BFS, 2021. Home ownership rate by canton. Retrieved from: https://www.bfs.admin.ch/asset/en/ts-x-09.03.02.01.03b.

BFS, 2023a. Bewohnte Wohnungen nach Bauperiode und Bewohnertyp. Retrieved from: https://www.bfs.admin.ch/bfs/de/home.assetdetail.24129048.html.

BFS, 2023b. Durchschnittliche Wohnfläche nach Zimmerzahl und Kanton. Retrieved from: https://www.bfs.admin.ch/bfs/de/home/statistiken/bau-wohnungswesen/wohnungen/groesse.assetdetail.27585240.html.

BFS, 2023c. Durchschnittlicher Mietpreis in Franken nach Bauperiode und Kanton. Retrieved from: https://www.bfs.admin.ch/bfs/de/home/statistiken/bau-wohnungswesen/wohnungen/mietwohnungen.assetdetail.24129084.html.

BFS, 2023d. Durchschnittlicher Mietpreis pro m2 in Franken nach Bauperiode und Kanton. Retrieved from: https://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/tabellen.assetdetail.24129103.html.

Bin, O., Landry, C.E., 2013. Changes in implicit flood risk premiums: empirical evidence from the housing market. J. Environ. Econ. Manag. 65 (3), 361–376. https://doi.org/10.1016/j.jeem.2012.12.002.

Bin, O., Polasky, S., 2004. Effects of flood hazards on property values - evidence before and after Hurricane Floyd. Land Econ. 80 (4), 490–500.

Bin, O., Crawford, T.W., Kruse, J.B., Landry, C., 2008. Viewscapes and flood hazard: coastal housing market response to amenities and risk. Land Econ. 4 (3), 434–448. https://doi.org/10.3368/le.84.3.434.

Bründl, M., Romang, H.E., Bischof, N., Rheinberger, C.M., 2009. The risk concept and its application in natural hazard risk management in Switzerland. Nat. Hazards Earth Syst. Sci. 9 (3), 801–813.

BUWAL/BWW/BRP, 1997. Berücksichtigung der Massenbewegungsgefahren bei raumwirksamen Tätigkeiten - Empfehlungen 1997. Retrieved from Bern: https://www.geo.uzh.ch/~chuggel/riskcourse/massenbew_beruecks.pdf.

BWW/BRP/BUWAL, 1997. Berücksichtigung der Hochwassergefahren bei raumwirksamen Tätigkeiten - Empfehlungen 1997. Retrieved from Bern: https://www.bafu.admin.ch/bafu/de/home/themen/naturgefahren/publikationen-studien/publikationen/beruecksichtigung-hochwassergefahren-raumwirksamen-taetigkeiten.html.

Contat, J., Hopkins, C., Mejia, L., Suandi, M., 2024. When climate meets real estate: a survey of the literature. Real Estate Econ. 52 (3), 618–659. https://doi.org/10.1111/1540-6229.12489.

Daniel, V.E., Florax, R.J.G.M., Rietveld, P., 2007. Long term divergence between ex-ante and ex-post hedonic prices of the Meuse River flooding in The Netherlands. In: Paper Presented at the 47th Congress of the European Regional Science Association.

Donovan, G.H., Champ, P.A., Butry, D.T., 2007. Wildfire risk and housing prices: a case study from Colorado Springs. Land Econ. 83 (2), 217–233. https://doi.org/10.3368/le.83.2.217.

EconoMe, 2022. P10 Value of Statistical Life VOSL. 5.1. Retrieved from. https://econome.ch/eco_work/eco_wiki_main.php?wiki_link=80.

European Environmental Agency, 2022. Economic losses and fatalities from weather- and climate-related events in Europe. Retrieved from. https://www.eea.europa.eu/publications/economic-losses-and-fatalities-from.

Federal Office for Spatial Development, 2005. Recommendation Spatial Planning and Natural Hazards. Retrieved from Bern: www.are.ch.

Hilker, N., Badoux, A., Hegg, C., 2008. Unwetterschäden in der Schweiz im Jahre 2007. Wasser Energie Luft 100 (2), 115–123.

Hino, M., Burke, M., 2020. Does information about climate risk affect property values?. In: NBER Working Paper Series (26807 ed.).

Hirsch, J., Hahn, J., 2018. How flood risk impacts residential rents and property prices: empirical analysis of a German property market. J. Prop. Invest. Financ. 36 (1), 50–67. https://doi.org/10.1108/JPIF-11-2016-0088.

Kaplan, S., Garrick, B.J., 1981. On the quantitative definition of risk. Risk Anal. 1 (1), 11–27.

Kim, J., Park, J., Yoon, D.K., Cho, G.-H., 2017. Amenity or hazard? The effects of landslide hazard on property value in Woomyeon Nature Park area, Korea. Landsc. Urban Plan. 157, 523–531. https://doi.org/10.1016/j.landurbplan.2016.07.012.

Kousky, C., 2010. Learning from extreme events: risk perceptions after the flood. Land Econ. 86 (3), 395–422. https://doi.org/10.3368/le.86.3.395.

MacDonald, D.N., Murdoch, J.C., White, H.L., 1987. Uncertain hazards, insurance, and consumer choice- evidence from housing markets. Land Econ. 63 (4), 361–371.

Mueller, J., Loomis, J.B., 2014. Does the estimated impact of wildfires vary with the housing price distribution? A quantile regression approach. Land Use Policy 41, 121–127. https://doi.org/10.1016/j.landusepol.2014.05.008.

Mueller, J., Loomis, J., González-Cabán, A., 2007. Do repeated wildfires change Homebuyers' demand for homes in high-risk areas? A hedonic analysis of the short and long-term effects of repeated wildfires on house prices in Southern California. J. Real Estate Financ. Econ. 38 (2), 155–172. https://doi.org/10.1007/s11146-007-9083-1.

Murdoch, J.C., Singh, H., Thayer, M., 1993. The impact of natural hazards on housing values: the Loma Prieta earthquake. Real Estate Econ. 21 (2), 167–184. https://doi.org/10.1111/1540-6229.00606.

Mutlu, A., Roy, D., Filatova, T., 2023. Capitalized value of evolving flood risks discount and nature-based solution premiums on property prices. Ecol. Econ. 205, 107682. https://doi.org/10.1016/j.ecolecon.2022.107682.

Naoi, M., Seko, M., Sumita, K., 2009. Earthquake risk and housing prices in Japan - evidence before and after massive earthquakes. Reg. Sci. Urban Econ. 39 (6), 658–669.

Reich, S.K., Hintermann, B., Zischg, A., 2020. Informed by wet feet: How do floods affect property prices?. In: WWZ Working Paper (No. 2020/18) https://doi.org/10.5451/unibas-ep79633.

Rosen, S., 1974. Hedonic prices and implicit markets: product differentiation in pure competition. J. Polit. Econ. 82 (1), 34–55. https://doi.org/10.1086/260169.

Singh, R., 2019. Seismic risk and house prices: evidence from earthquake fault zoning. Reg. Sci. Urban Econ. 75, 187–209. https://doi.org/10.1016/j.regsciurbeco.2019.02.001.

Solon, G., Haider, S.J., Wooldridge, J.M., 2015. What are we weighting for? J. Hum. Resour. 50 (2), 301–316.

VKG, 2022. Elementar: Übersicht 2002–2021 – Elementarschäden an Gebäuden. Vereinigung Kantonaler Gebäudeversicherungen VKG, Bern.

WSL, 2022. Todesfälle durch Hochwasser, Murgänge, Rutschungen und Sturzprozesse. Retrieved from: https://www.bafu.admin.ch/bafu/de/home/themen/naturgefahren/fachinformationen/schaeden-und-lehren-aus-naturereignissen.html.

WSL, 2023. Unwetterschadens-Datenbank. Retrieved from: https://www.wsl.ch/de/naturgefahren/hochwasser-und-ueberschwemmung/unwetterschadens-datenbank/.

Zhang, L., Leonard, T., 2018. Flood hazards impact on neighborhood house prices. J. Real Estate Financ. Econ. 58 (4), 656–674. https://doi.org/10.1007/s11146-018-9664-1.