

Natural catastrophes and insurance
in a developing economy:
new theoretical and empirical evidence

Christian Hott*and Thi Xuyen Tran[†]

Online Appendix

*Corresponding author, Helmut-Schmidt-University Hamburg, Hamburg, Germany. hottc@hsu-hh.de.

[†]Helmut-Schmidt-University Hamburg, Hamburg, Germany.

1 Data

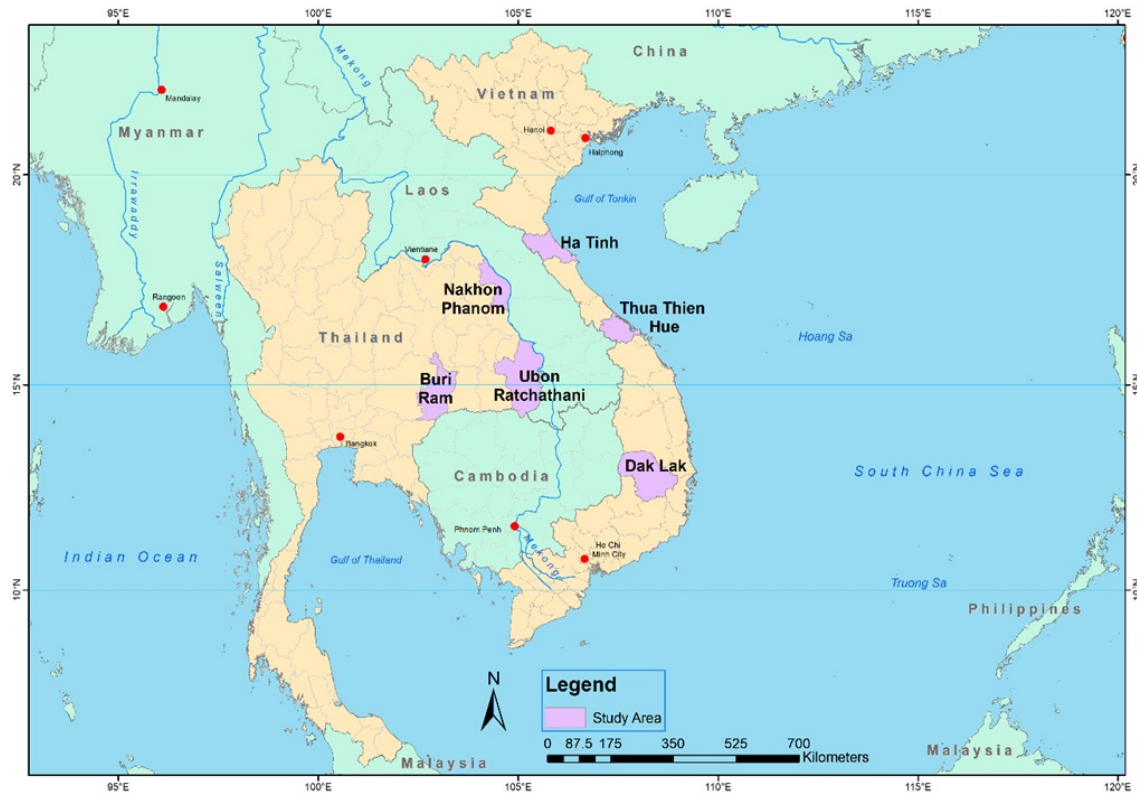


Figure A1. A study area in Vietnam and Thailand.

Source: TVSEP.

Table A1. Descriptive statistics table for variables in 5 waves for Vietnam

| | 2008 | | 2010 | | 2013 | | 2016 | | 2017 | |
|--|---------|---------|---------|---------|---------|---------|---------|----------|---------|----------|
| | 2148 HH | | 2099 HH | | 2009 HH | | 1884 HH | | 1898 HH | |
| | mean | sd | mean | sd | mean | sd | mean | sd | mean | sd |
| <i>Dependent variable</i> | | | | | | | | | | |
| Has property insurance | 0.2 | 0.4 | 0.13 | 0.34 | 0.44 | 0.5 | 0.62 | 0.49 | 0.44 | 0.5 |
| <i>Control variables</i> | | | | | | | | | | |
| Frequency | 0.26 | 0.60 | 0.33 | 0.47 | 0.24 | 0.43 | 0.04 | 0.19 | 0.45 | 0.71 |
| Severity | 11.38 | 25.48 | 14.13 | 20.07 | 7.08 | 12.60 | 1.28 | 6.44 | 15.29 | 23.91 |
| Total losses | 498.27 | 1517.34 | 485.76 | 1569.78 | 248.17 | 716.45 | 703.56 | 3389.05 | 235.08 | 1084.74 |
| Total income | 6714.53 | 9128.91 | 5934.14 | 7739.15 | 6863.09 | 8683.34 | 9552.55 | 10962.15 | 9725.66 | 11147.95 |
| Had property insurance in previous wave | 0.003 | 0.06 | 0.20 | 0.40 | 0.14 | 0.35 | 0.43 | 0.50 | 0.60 | 0.49 |
| Regulation | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| Household size | 5.00 | 1.87 | 5.27 | 1.96 | 5.62 | 2.12 | 5.86 | 2.11 | 4.48 | 1.80 |
| <i>Household head</i> | | | | | | | | | | |
| Age | 48.97 | 13.92 | 50.74 | 13.57 | 53.49 | 13.39 | 55.27 | 12.57 | 56.28 | 12.71 |
| Gender | 0.84 | 0.37 | 0.83 | 0.38 | 0.81 | 0.39 | 0.80 | 0.40 | 0.78 | 0.41 |
| Education | 0.19 | 0.39 | 0.19 | 0.40 | 0.20 | 0.40 | 0.19 | 0.39 | 0.19 | 0.40 |
| Farmer | 0.66 | 0.47 | 0.64 | 0.48 | 0.63 | 0.48 | 0.63 | 0.48 | 0.65 | 0.48 |

Source: Calculated by authors based on TVSEP data.

Table A2. Descriptive statistics using balanced panel (2008, 2010, 2013, 2016, and 2017)

| | Vietnam | | | | | | | | | |
|---|----------|----------|---------|----------|---------|----------|----------|----------|----------|----------|
| | 2008 | | 2010 | | 2013 | | 2016 | | 2017 | |
| | 1786 HH | | 1786 HH | | 1786 HH | | 1786 HH | | 1786 HH | |
| | mean | sd | mean | sd | mean | sd | mean | sd | mean | sd |
| <i>Dependent variable</i> | | | | | | | | | | |
| Has property insurance | 0.21 | 0.40 | 0.14 | 0.35 | 0.44 | 0.50 | 0.62 | 0.48 | 0.45 | 0.50 |
| <i>Control variables</i> | | | | | | | | | | |
| Total losses | 507.55 | 1553.11 | 523.12 | 1658.08 | 251.38 | 708.38 | 705.97 | 3445.29 | 239.61 | 1099.93 |
| Total income | 6714.92 | 8888.22 | 6005.47 | 7595.97 | 6914.04 | 8367.93 | 9558.02 | 11033.73 | 9772.74 | 11316.91 |
| Having property insurance in previous wave | 0.003 | 0.05 | 0.21 | 0.40 | 0.14 | 0.35 | 0.44 | 0.50 | 0.62 | 0.48 |
| Household size | 5.11 | 1.80 | 5.37 | 1.89 | 5.70 | 2.06 | 5.86 | 2.09 | 4.49 | 1.77 |
| <i>Household head</i> | | | | | | | | | | |
| Age | 48.55 | 13.24 | 50.28 | 12.93 | 53.26 | 12.85 | 55.32 | 12.51 | 56.27 | 12.65 |
| Gender | 0.86 | 0.35 | 0.85 | 0.36 | 0.82 | 0.38 | 0.80 | 0.40 | 0.79 | 0.41 |
| Education | 0.20 | 0.40 | 0.20 | 0.40 | 0.21 | 0.41 | 0.19 | 0.39 | 0.20 | 0.40 |
| Farmer | 0.68 | 0.47 | 0.66 | 0.47 | 0.64 | 0.48 | 0.63 | 0.48 | 0.65 | 0.48 |
| | | | | | | | | | | |
| | Thailand | | | | | | | | | |
| | 2008 | | 2010 | | 2013 | | 2016 | | 2017 | |
| | 1801 HH | | 1801 HH | | 1801 HH | | 1801 HH | | 1801 HH | |
| | mean | sd | mean | sd | mean | sd | mean | sd | mean | sd |
| <i>Dependent variable</i> | | | | | | | | | | |
| Has property insurance | 0.006 | 0.078 | 0.004 | 0.067 | 0.011 | 0.102 | 0.005 | 0.071 | 0.016 | 0.126 |
| <i>Control variables</i> | | | | | | | | | | |
| Total losses | 413.33 | 1484.06 | 319.25 | 894.69 | 358.24 | 844.80 | 702.45 | 8116.04 | 122.12 | 727.83 |
| Total income | 7505.99 | 14105.90 | 9057.27 | 16672.38 | 9967.63 | 24873.77 | 13534.96 | 41254.96 | 10892.64 | 18749.99 |
| Had property insurance in previous wave | 0.01 | 0.10 | 0.006 | 0.078 | 0.004 | 0.067 | 0.011 | 0.102 | 0.005 | 0.071 |
| Household size | 5.29 | 2.08 | 5.60 | 2.18 | 5.07 | 1.99 | 6.11 | 2.35 | 4.86 | 2.02 |
| <i>Household head</i> | | | | | | | | | | |
| Age | 55.61 | 12.73 | 57.36 | 12.38 | 59.45 | 12.19 | 61.19 | 11.69 | 62.10 | 11.74 |
| Gender | 0.74 | 0.44 | 0.73 | 0.44 | 0.70 | 0.46 | 0.66 | 0.47 | 0.66 | 0.48 |
| Education | 0.10 | 0.30 | 0.10 | 0.30 | 0.11 | 0.32 | 0.13 | 0.34 | 0.12 | 0.32 |
| Farmer | 0.63 | 0.48 | 0.62 | 0.49 | 0.63 | 0.48 | 0.57 | 0.49 | 0.53 | 0.50 |

Source: Calculated by authors based on TVSEP data.

2 Estimation results using the five-year panel dataset

Table A3. Factors impact on property insurance demand in Vietnam (data from 2008-2017)

| | <i>Dependent variable:</i> | | |
|-------------------------------------|----------------------------------|---------------------------|---------------------------|
| | Household has property insurance | | |
| | (1) | (2) | (3) |
| Total income | 0.000003*** (0.000001) | 0.000003*** (0.000001) | 0.000003*** (0.000001) |
| Had property insurance in last wave | -0.1037*** (0.0123) | -0.1042*** (0.0123) | -0.1067*** (0.0124) |
| Regulation | 0.3122*** (0.0111) | 0.3127*** (0.0111) | 0.3325*** (0.0102) |
| Frequency | -0.0870*** (0.0110) | | |
| Frequency*Regulation | 0.0992*** (0.0162) | | |
| Severity | | -0.0020*** (0.0003) | |
| Severity*Regulation | | 0.0024*** (0.0004) | |
| Total losses | | | -0.00001*** (0.00001) |
| Total losses * Regulation | | | 0.00002*** (0.00001) |
| Household characteristics | Yes | Yes | Yes |
| Household-fixed effects | Yes | Yes | Yes |
| Adjusted R ² | 0.3177 | 0.3174 | 0.3150 |
| Observations | 10038 | 10038 | 10038 |

Notes: *p<0.1; **p<0.05; ***p<0.01.

Robust standard errors in parentheses.

According to column (1), in the absence of regulation change, for each additional storm or tropical depression experienced by a household, the probability of having property insurance decreases by approximately 8.7 percentage points. However, among households who have never experienced a tropical cyclone, the amendment to the Insurance Business Law increases the probability of purchasing property insurance by 31.22 percentage points. Furthermore, the effect of the regulatory change on property insurance ownership rises by nearly 10 percentage points for each additional tropical cyclone event a household has experienced. Similarly, estimation results from column (2) suggest that the effect of the change in insurance regulation on the likelihood of being insured increases by nearly 2.4 percentage points for each additional episode of wind speed of 10 knots that a house-

hold experienced. Regarding total losses from natural disasters in column (3), the effect of the change in insurance law on the probability of having property insurance increases by 2 percentage points for each additional US\$1,000 in PPP-adjusted losses caused by these events.

3 Difference-in-difference-in-differences approach

This study examines the impact of the change in insurance regulation in Vietnam in 2011 on the relationship between natural disasters and the probability of having property insurance. The ideal approach for this analysis is a difference-in-difference-in-differences (DDD) model, with households in Vietnam serving as the treatment group. Since the TVSEP surveys also provide data from Thailand, households in Thailand are used as the control group.

Thailand serves as a suitable control group for Vietnam in this study. It is an upper middle-income country and also located in Southeast Asia. Thailand spans approximately 513,115 km^2 and had a population of over 71.8 million in 2023. The country is also highly prone to natural hazards, including floods, storms, droughts and landslides (World Bank, 2023). Descriptive statistics presented in table A2 suggest that Vietnam and Thailand share comparable economic and demographic contexts. Furthermore, both countries shared parallel trends in having property insurance prior to 2011. Therefore, any divergence in having property insurance between the two countries after 2011 is likely attributable to the intervention in Vietnam. However, as illustrated in table A4, the proportion of households with property insurance in Thailand is notably smaller than that in Vietnam.

The application of the DDD method relies on the parallel trends assumption holding

true. This assumption requires that in the absence of the change in Vietnam’s Insurance Business Law in 2011, households in the treatment group and households in the control group experienced the same trend in obtaining property insurance.

To assess whether this assumption holds, we employ two complementary approaches. First, we examine the share of households having property insurance in Vietnam and Thailand over time, as presented in table A4. This table clearly shows that both groups exhibit the same decreasing trend in having property insurance.

Table A4. Share of households having property insurance in Vietnam and Thailand

| | | 2008 | 2010 | 2013 | 2016 | 2017 |
|--------------------|--|------|------|------|------|------|
| Total observations | | 1786 | 1786 | 1786 | 1786 | 1786 |
| Vietnam | Household has property insurance | 367 | 254 | 788 | 1112 | 796 |
| | Share of household having property insurance (%) | 20.5 | 14.2 | 44.1 | 62.3 | 44.6 |
| Total observations | | 1801 | 1801 | 1801 | 1801 | 1801 |
| Thailand | Household has property insurance | 11 | 8 | 19 | 9 | 29 |
| | Share of household having property insurance (%) | 0.61 | 0.44 | 1.05 | 0.5 | 1.6 |

Source: Calculated by authors based on TVSEP data.

Second, we provide quantitative evidence for the parallel trends assumption by conducting a placebo test. To perform the placebo test, we restrict our sample to the pre-treatment years 2008 and 2010, and replicate our benchmark strategy as if Vietnam’s Insurance Business Law had been changed in 2009 – two years prior to its actual adoption. We estimate equation (A1) using this restricted sample. That means we compare the probability of buying property insurance between the treatment group and the control group before and after the placebo event and the effect of natural disasters in this relationship. Table A5 presents the placebo test result.

The coefficient of triple interaction Treatment * Year 2010 * Total losses is positive and statistically insignificant. It indicates that, on average, before the placebo change in law

Table A5. Placebo test

| | <i>Dependent variable:</i> |
|------------------------------------|----------------------------------|
| | Household has property insurance |
| Treatment | −0.0958** (0.0462) |
| Year 2010 | −0.0042 (0.0034) |
| Total losses | −0.0000001 (0.000001) |
| Treatment * Year 2010 | 0.0958*** (0.0093) |
| Year 2010 * losses | −0.00001* (0.00001) |
| Treatment * Total losses | 0.00001** (0.00001) |
| Treatment*Year 2010 * Total losses | 0.000005 (0.00001) |
| Household characteristics | Yes |
| Household fixed effect | Yes |
| Adjusted R ² | 0.6158 |
| Observations | 7174 |

Notes: *p<0.1; **p<0.05; ***p<0.01. Robust standard errors in parentheses.

was adopted, the treatment households and the control households did not significantly differ in terms of having property insurance. Therefore, the parallel trend assumption holds, which allows us to apply the DDD technique to our robustness check.

3.1 Difference-in-difference-in-differences estimations

Our DDD estimations aim to examine the impact of the changes in insurance regulation in Vietnam in 2011 on the relationship between total losses from natural disasters and the probability of having property insurance. The first difference refers to before the change in regulation vs. after the change in regulation. The second refers to before-after difference in Vietnam compared to that in Thailand. The third difference incorporates the heterogeneous effect of total losses caused by natural catastrophes. It compares the treatment effect (time and group differences) between households experiencing total losses.

As the outcome effects develop over time and the total losses variable is a continuous variable, we follow Joshi (2019), Tang *et al.* (2020), Yu *et al.* (2021), and Wooldridge (2007) to apply the DDD approach with the pre-treatment periods 2008, 2010 and post-treatment periods 2013, 2016, and 2017. The estimation approach is described in the following equation:

$$\begin{aligned}
B_{i,j,t} = & \alpha_i + \gamma \cdot L_{i,j,t} + \delta \cdot P_{i,j,t} + \zeta T_j \\
& + \eta L_{i,j,t} * P_{i,j,t} + \theta L_{i,j,t} * T_j + \mu P_{i,j,t} * T_j \\
& + \lambda L_{i,j,t} * T_j * P_{i,j,t} + \beta \cdot X_{i,j,t} + \epsilon_{i,j,t}, \quad (\text{A1})
\end{aligned}$$

where $B_{i,j,t}$ is the binary variable indicating whether household i in country j in year t has property insurance, $L_{i,j,t}$ is the total losses from natural disasters, $P_{i,j,t}$ is the variable Post, which equals 1 if years are after 2011 and 0 otherwise, T_j is the treatment variable which equals 1 if a household is in the treatment group and 0 otherwise, $L_{i,j,t} * R_{i,j,t}$, $L_{i,j,t} * T_j$ and $P_{i,j,t} * T_j$ are interactions, $L_{i,j,t} * T_j * P_{i,j,t}$ is the triple interaction term, $X_{i,j,t}$ is the household characteristics, and $\epsilon_{i,j,t}$ denotes the unexplained residual.

The coefficient λ is the overall DDD effect of the regulation. This coefficient represents the differential change in the probability of having property insurance due to the intervention after controlling for natural disaster losses effects.

The estimation approach disaggregating the effect of the change in insurance regula-

tion by years is described in the following equation:

$$\begin{aligned}
B_{i,j,t} = & \alpha_i + \gamma \cdot L_{i,j,t} + \sum_{t=2013}^{2017} \delta_t Y_t + \zeta T_j \\
& + \sum_{t=2013}^{2017} \eta_t L_{i,j,t} * Y_t + \theta L_{i,j,t} * T_j + \sum_{t=2013}^{2017} \mu_t Y_t * T_j \\
& + \sum_{t=2013}^{2017} \lambda_t L_{i,j,t} * T_j * Y_t + \beta \cdot X_{i,j,t} + \epsilon_{i,j,t}. \quad (\text{A2})
\end{aligned}$$

The coefficients λ_t with $t = 2013, 2016$ and 2017 are the DDD effects of the regulation in 2013, 2016 and 2017. These coefficients indicate the differential change in the probability of having property insurance due to the intervention after controlling for natural disaster losses effects in these years. We estimate equation (A1) and equation (A2) using Linear Probability Model and report robust standard errors. The estimation results are presented in table A6.

Table A6. Difference-in-difference-in-differences estimations

| | <i>Dependent variable:</i> | |
|--------------------------------------|----------------------------------|-------------------------|
| | Household has property insurance | |
| | (1) | (2) |
| Treatment | 0.0332 (0.1734) | 0.0335 (0.1976) |
| Post | 0.0047 (0.0030) | |
| Total Losses | 0.000001 (0.000002) | 0.000001 (0.000002) |
| Post * Total losses | -0.000003* (0.000002) | |
| Treatment * Post * Total losses | 0.00002*** (0.00001) | |
| Treatment * Year 2013 * Total losses | | 0.00004** (0.00002) |
| Treatment * Year 2016 * Total losses | | 0.00002*** (0.00001) |
| Treatment * Year 2017 * Total losses | | 0.00003** (0.00001) |
| Household characteristics | Yes | Yes |
| Household fixed effects | Yes | Yes |
| Time fixed effect | Yes | Yes |
| Adjusted R ² | 0.4487 | 0.4677 |
| Observations | 17923 | 17923 |

Notes: *p<0.1; **p<0.05; ***p<0.01. Robust standard errors in parentheses.

Our estimation results confirm the positive and significant effect of the change in the Insurance Business Law on the likelihood of a household having property. The coefficient of the triple interaction in column (1) indicates that after the insurance regulation changed in Vietnam, households in Vietnam who experienced greater total losses from natural disasters are more likely to purchase property insurance than households in Thailand. For each additional US\$1,000 in PPP-adjusted total losses experienced by a household in

Vietnam, the likelihood of having property insurance increases by 2 percentage points in the post-policy periods, compared to the pre-policy periods and households in Thailand. Regarding the coefficients of triple interactions disaggregated by years in column (2), they are both positive and statistically significant. Therefore, we can conclude that our DDD estimations reinforce our earlier finding that the change in the Insurance Business Law in Vietnam has a positive and statistically significant effect on the probability of having property insurance.

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