Climate and Development

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tcld20

Prevent or repair? Experimental evidence from providing incentives for climate resilient housing in Vietnam

Sofie Waage Skjeflo, Nina Bruvik Westberg, Haakon Vennemo, Tuan Huu Tran, Phong Van Giai Tran & Tran Tuan Anh

To cite this article: Sofie Waage Skjeflo, Nina Bruvik Westberg, Haakon Vennemo, Tuan Huu Tran, Phong Van Giai Tran & Tran Tuan Anh (17 May 2023): Prevent or repair? Experimental evidence from providing incentives for climate resilient housing in Vietnam, Climate and Development, DOI: 10.1080/17565529.2023.2205375

To link to this article: https://doi.org/10.1080/17565529.2023.2205375

CLIMATE AND DEVELOPMENT
https://doi.org/10.1080/17565529.2023.2205375

Taylor & Francis
Taylor & Francis Group

Research Article

Prevent or repair? Experimental evidence from providing incentives for climate resilient housing in Vietnam

Sofie Waage Skjeflo[a], Nina Bruvik Westberg[b], Haakon Vennemo[c], Tuan Huu Tran[d], Phong Van Giai Tran[e] and Tran Tuan Anh[f]

[a]CICERO Center for International Climate Research, Norway; [b]Menon Centre for Environmental and Resource Economics, Norway; [c]Vista Analyse, Oslo, Norway; [d]School of Hospitality and Tourism, Hue University, Hue, VietNam; [e]Swiss Cooperation Office in Vietnam, VietNam; [f]Faculty of Architecture, Hue University of Science, Hue, VietNam

ABSTRACT

We present results from a randomized field experiment in Da Nang in Central Vietnam. We assess the take-up and impacts of a microcredit program that aims to increase the adoption of climate resilient housing among low-income urban households. Households were randomly assigned offers of either a loan and technical assistance package or a cash transfer with a smaller loan and technical assistance. We find large and significant impacts on the resilience of the new or retrofitted houses due to being offered the more generous incentive package. Households that were offered the cash transfer and a smaller loan, are three times as likely to accept. The difference in uptake, and therefore impact, of the two packages shows that there is a need for a subsidy in addition to the technical assistance in order to reach near-poor households. Previous public spending on typhoon relief indicates that such a subsidy could be covered by re-allocating funds from typhoon repairs to damage prevention through resilient housing.

ARTICLE HISTORY
Received 6 September 2022
Accepted 16 April 2023

KEYWORDS
Resilient housing; randomized control trial; climate change adaptation; urban; Vietnam

1. Introduction

Climatic hazards, such as coastal flooding, tropical storms and typhoons,[1] pose a significant and growing threat to low income households in growing cities in Vietnam. With strong rural-urban migration by low-income households (Nguyen et al., 2015), many households cannot afford permanent, high-quality housing, and are at risk of severe structural damage to their homes (UN, 2014). In addition, since the 1986 reform (Doi Moi Policy), there has been a shift from traditional construction materials, such as wood and clay tiles, towards the use of modern materials, such as cement blocks and corrugated steel sheets, but without adjusting construction practices to incorporate resilience to climate hazards (Norton & Chantry, 2008). According to official estimates, almost 1,5 million houses were damaged, and about 50,000 houses totally destroyed due to storms and floods in Vietnam between 1999 and 2013 (Tran, 2016). Most of the damage falls on low-income households. Low-income households frequently reconstruct their houses after storm damage using the same building principles, thereby reproducing their vulnerability (Tran et al., 2013). A number of programs have addressed these issues and made efforts to promote storm- and flood resilient housing for low income households (see for instance Norton & Chantry, 2008; Tran, 2016; Tran et al., 2013). However, there has been little research on the effects of these efforts and how low-income households respond to incentives for climate resilient housing.

Previous studies have focused on the potential role of microcredit in mitigating the impact of climate shocks or disasters (Christian et al., 2019; Jordan, 2021). The focus here is on microcredit that aims to alleviate barriers to investment in climate adaptation. Existing empirical studies of climate adaptation in general, and on adoption of risk mitigating technologies have mainly focused on the agricultural sector [see the review of recent adaptation literature in Vincent and Cundill (2022) and the experimental evidence on adoption of risk mitigating technologies in Bridle et al. (2020)]. As far as we are aware, this is the first randomized evaluation of the impact of a microcredit program on climate resilient infrastructure, providing rigorous evidence of impacts of microcredit in an under-researched setting. The Sixth Assessment Report from the IPCC points to a large and increasing gap between committed and needed adaptation financing (Pörtner et al., 2022, p. 20). The adaptation gap in urban areas is especially large among lower income population groups in North, East and Southeast Asia where urbanisation is rapid (Pörtner et al., 2022, p. 942). Understanding how to incentivize private investments in increased resilience as well as how to efficiently spend public funds is an important step towards closing the adaptation gap.

We present results from a randomized control trial of a microcredit program aiming to increase the adoption of climate resilient housing in the coastal city of Da Nang. The program is implemented by Vietnam Women's Union, a socio-political mass organization operating throughout Vietnam with the aim of enabling women to take part in national development. The underlying motivation of the program is to enable households to invest in resilience rather than relief and repairs, thereby providing long-term benefits to both the

CONTACT Sofie Waage Skjeflo sofie.skjeflo@cicero.oslo.no

household and to society. In line with Tran et al. (2013), we define climate resilient housing as housing that has the capacity to resist, absorb and accommodate the effects of climate hazards and return to a normal condition in a timely manner without significant changes to its basic functions and structure. Two key structural principles of climate resilient housing are presented in Tran and Tran (2014), based on the result of a design competition to identify housing design elements that will significantly reduce the risk of damage from typhoons. The first principle is the secure connection of all building parts of the house by reinforced concrete beams and pillars. The second principle is a solid strong room, known as a safe failure, made by reinforced concrete for escape in case of a disastrous typhoon. Tuan et al. (2015) conduct a cost-benefit analysis of climate resilient housing based on these principles, and find positive returns to investment, even without taking into account non-monetary costs of typhoon damage and potentially increased typhoon intensity due to climate change. A high marginal return to a technology (in this case, climate resilient housing), indicates that there may exist barriers constraining adoption (Foster & Rosenzweig, 2010). In our setting, likely barriers to adoption include information barriers (both lack of knowledge about the returns to investment, and lack of knowledge of how to manage the technology, i.e improve housing resilience in practice) and credit constraints because of lack of affordable credit accessible to low-income households. The program targets near-poor households with sufficient income generating capacity to repay a small loan with favourable conditions. These households lack access to conventional loans but do not qualify for programs aimed at poor households. The program we evaluate aims to mitigate the credit constraint of these households by providing access to credit for housing construction or retrofitting, and providing information and technical assistance to implement climate resilient building principles.

There is an extensive literature exploring ways to remove barriers to adoption of welfare improving technologies, in particular within agriculture and health, using field experiments (Mobarak & Saldanha, 2022). Important findings from this literature is that when benefits accrue over time, but the investment must be paid up front, loans or direct subsidies are potential instruments to overcoming barriers to adoption. A subsidy may also allow potential adopters to experiment with the technology to learn about returns. To overcome information barriers it may be necessary for decision makers to observe the use of the technology, or have information presented in an easily accessible manner.

The purpose of our randomized control trial is to inform program design by investigating the necessary level of incentives provided in order to enable households to invest in climate resilient housing. Here we are interested in the take-up of two incentive packages, one with a subsidized loan and free technical assistance for house retrofitting or reconstruction, and one with a cash transfer in addition to the loan and technical assistance. We are also interested in the characteristics of the households that accept each package, since we want to know which households can be reached through scaling up the program, and which types of households may have to be targeted through other channels. Finally, we examine whether the incentives lead to additional housing construction or more resilient housing construction.

The rest of this paper is organized as follows. Section 2 explains the experiment and presents the data. The take-up of the packages is presented in Section 3, while the short-run impacts are presented in Section 4. Section 5 discusses the implications of the results for the 'returns' to relief versus prevention spending for the government, while Section 6 concludes.

2. Experiment

2.1. Study setting

Da Nang is located in the South Central Coast region of Vietnam, in the tropical storm belt. It is the third largest city of Vietnam, estimated at 1.06 million people in 2017, and a fast growing population with an average growth rate of 2.9 % since 2010 (GSO, 2016a).

Numerous climatic hazards affect Da Nang, such as coastline erosion, landslides, floods and typhoons, with on average three to five tropical storms hitting the city per year (Tran et al., 2013). The peak typhoon season is from September until November. Past typhoons that have heavily affected Da Nang include Xansane in 2006, Ketsana in 2009, Nari in 2013 and Molave in 2020. Typhoon Xansane caused the collapse of 24,000 houses and damaged 325,000 houses in Central Vietnam (Tran, 2016), and 26 people in Da Nang were reported killed, mostly due to collapsing houses.[2] Typhoon Nari caused estimated damage to housing of about 4.6 billion USD, with 4200 severely damaged houses, and 122 completely collapsed houses (Tran, 2013). A series of floods and storms in Central Vietnam, including typhoon Molave, led to more than 300,000 damaged houses in October 2020 (Red Cross , 2022).

In 2011, the Women's Union of Da Nang and the Institute of Social and Environmental Transition (ISET) initiated the project *The Storm and Flood-Resistant Credit and Housing Scheme in Da Nang City*. With funding from the Rockefeller Foundation, a microcredit and technical assistance program aimed at supporting storm resistant shelters in Da Nang City was set up. Between 2011 and 2016, 237 new houses were constructed and 177 houses were retrofitted with support from the Women's Union revolving loan fund, with free technical assistance from local architects. When typhoon Nari hit in 2013, 244 households participating in the program had completed construction, and none of the completed houses suffered damages (Tran, 2013). The program was awarded the UNFCCC Lighthouse Activities Award in 2015 for its efforts to increase urban poor's resilience to climate change.[3]

Previous research indicates that investing in climate resilient features when retrofitting or reconstructing a house is profitable from a cost-benefit perspective. Tuan et al. (2015) use recall data from 98 households in Da Nang that were affected by the Xansane and Ketsana typhoons. The benefit of investing in resilient housing is calculated based on information about direct costs (damage to housing and other assets) and indirect monetary losses (such as loss of work days and medical costs). The avoided cost of typhoon damage is then compared to the additional cost of resilient housing construction based on the housing design described in Tran and Tran (2014), and amounts to about 55 % of the cost of a comparable non-resilient house. Assuming a return time of a category 12 storm (like Xangsane) every 12.5 years, the internal rate of return to climate resilient housing is as high as 20 %, and assuming a return period of 25 years, the internal rate of return is 14 %. According to this study, investing in climate resilient housing, as defined by the principles outlined and assuming a 10 % discount rate for homeowners, is on average profitable. Including non-monetary benefits, such as the value of feeling safe, could further increase the rate of return.[4]

2.2. Experimental design

Da Nang is organized into 8 districts and 56 wards and communes (hereafter called wards).[5] Our experiment takes place in 49 wards, covering seven districts. We exclude five wards in which most households reside in apartment buildings, rather than individual houses, as well as three wards with few inhabitants.[6]

We first made a list of potential beneficiaries from each of the 49 wards. The local Women's Union units were asked to compile a list of six to seven near-poor[7] households per ward that were eligible for participation in the program. The information provided to the wards is described in Appendix 1. This number was chosen due to budgetary constraints. The final number of eligible households is 306. To be eligible, the households had to have housing conditions vulnerable to climate risks, limited access to financial resources for strengthening climate resilient housing, have a stable job but low income, have some savings and be able to mobilize labor for their housing improvement, have capacity for repayment, and have legal or any related documents to prove land ownership. Eligible households were also asked whether they had a need for house retrofitting or reconstruction to ensure storm resilience, and a wish to carry out such retrofitting or reconstruction starting from March 2017. The 306 households were surveyed between late December 2016 and early February 2017. The survey instrument included modules on household composition, income, and assets as well as past storm exposure and housing repairs.

We have two treatment arms: package 1 and package 2. Both packages included a subsidized loan and free technical assistance for house retrofitting or reconstruction. Households in package 2 were given a cash transfer in addition to a smaller loan and free technical assistance. The loan was 30 million Vietnamese Dong (VND) (about 1320 USD or about one third of the cost of an average upgraded house) for households in package 1, while package 2 included a loan of 20 million VND and a grant of 10 million VND. The maximum loan repayment period was 40 months and the monthly interest on the loan was 0.75 %, or about 9 per cent per year. The loans and grants were disbursed to the household when their old house was dismantled or they had started retrofitting. The households started paying principal and interest monthly from the first month that the loan was provided. The WU at the ward level organized a savings group, where a representative from the local WU collected the loan repayments from the participating households, along with a compulsory minimum amount of savings of 0.3 % of their total loan amount each month.

The savings were kept by the WU in a commercial bank account until the loan repayments were completed, and they were then repaid to the household along with the interest earned. The savings groups are supposed to encourage the habit of saving among the participating low-income households. Besides, the saving acts as a from of collateral for the loan fund since it can be used for loan repayment in case of default.

The technical assistance included technical designs of the new house/retrofitted house, as well as technical guidance during the building period. The participating households were visited by a technical team consisting of an architect, ward and city level WU staff and in some cases a representative of the local Department of Land Administration after accepting the package that was offered to them. They then discussed the financial capacity and needs of the household, and the team of architects made a housing design incorporating one or more resilience features. Participating households, in consultation with the architect, were required to incorporate one or more resilience features when rebuilding or retrofitting their house, depending on the existing conditions of their old house. For instance, if the existing house had a weak frame, the architect would require the household to improve the frame before improving the roof to make sure the overall resilience of the home was improved. The technical guidelines were developed under a research project funded by the Asian Development Bank, and includes pamphlets aimed at local officials, builders and households, respectively, explaining the approach and resilience features at different levels of technical detail. Examples of resilience features include the use of reinforced concrete, appropriate spacing between reinforced concrete beams, attachments of the roof to the main frame of the house and appropriate use of building materials. Figure 1 shows an example of instructions for reinforcing concrete and appropriate spacing of reinforced concrete pillars from the technical manual aimed at local builders.

In addition to the technical guidelines that the architects and builders must adhere to, local builders also received training in building resilient houses. The participating households were encouraged to use the trained local builders, and many households followed this encouragement. Some households used family members or other local builders and were instructed to follow the technical guidelines for builders to make sure the housing design was correctly implemented. The technical team visited the household at least once during construction to make sure the guidelines were followed, and there was also a visit at completion. In addition, the house was inspected visually and photographed when collecting the second round of survey data.

The 49 wards were randomly allocated into treatment and control groups after the baseline survey. We chose to randomize at the ward/commune level so as to avoid spillover effects of information, and because the Women's Union organized the microcredit program through their organization at the ward level. Randomization was stratified at the district level, in line with the wishes of the Women's Union. This also

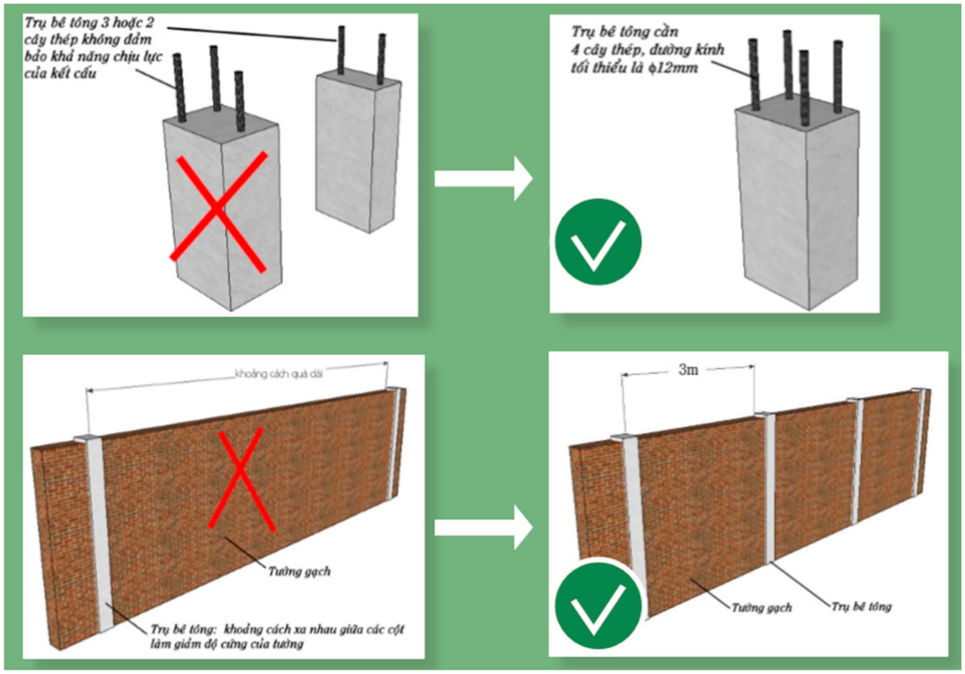

Figure 1. Excerpt from technical manual aimed at local builders. Source: Da Nang Department of Foreign Affairs, Da Nang Department of Construction, Institute for Social and Environmental Transition-International (2017).

contributes to the geographical dispersion of the three groups. Figure 2 shows a map of Da Nang City, with the wards assigned to the two treatment arms and the control group. The control group includes 16 wards with a total of 91 eligible households. The package 1 group includes 101 households across 16 wards, and the package 2 group includes 106 households across 17 wards.

Following the randomization, the local Women's Union units at the ward/commune level were informed which category their households belonged to (package 1, package 2 or control), and the households were then contacted directly by the local Women's Union unit. The households were provided with the information both verbally and by means of an information brochure that detailed the specifics of the package,

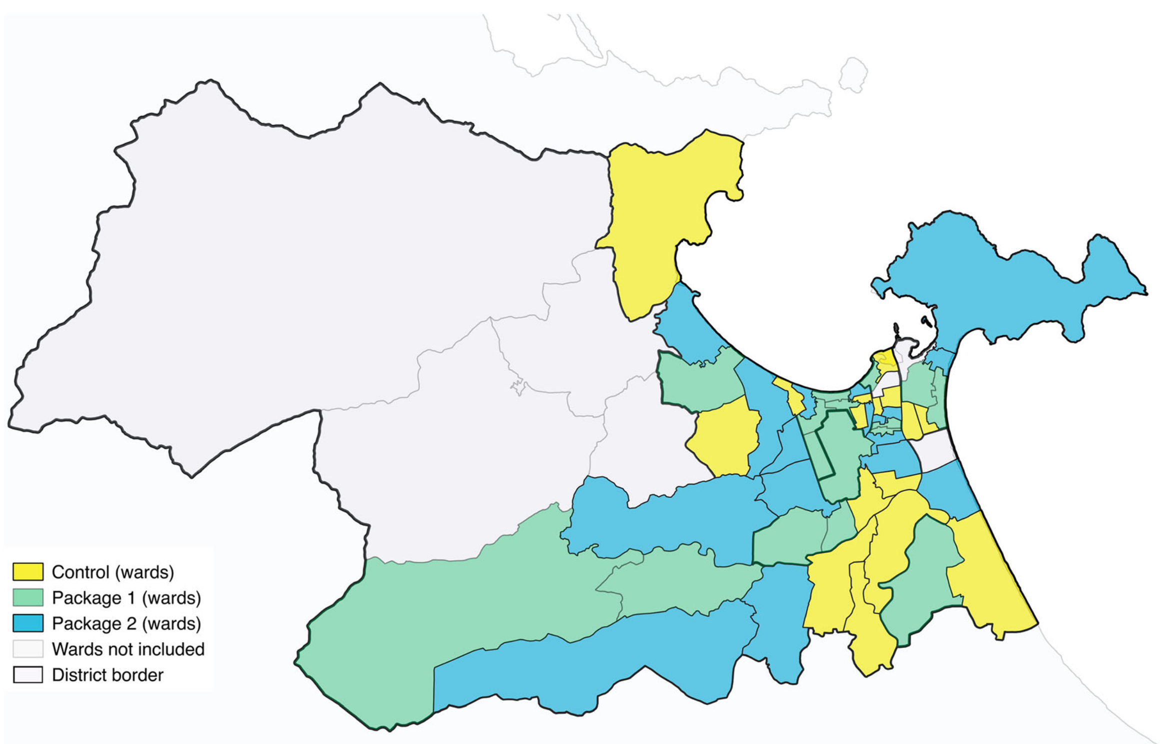

Figure 2. Map of Da Nang City with wards assigned to package 1, package 2 and control.

such as interest rate and repayment conditions of the loan, including the resilience features that would be included in the housing design. They were given a consideration period of roughly two weeks. Our measure of take up reflects their final decision. Construction and retrofitting of houses took place from May 2017 until April 2018.

2.3. Baseline means and balance checks

Table 1 reports baseline means in columns (1)–(3) for the control group and the two treatment arms. Around half of the households are female-headed, in line with the Women's Unions' targeting of women.[8] The household heads are on average between 54 and 56 years old, and have on average six to seven years of education. The households consist on average of four to five people. Average income per person is around 1340–1660 thousand VND per month, which roughly corresponds to the lower and upper limits of the near-poor categorization of Da Nang City. A large share of the households (80% to 90 %) own motorbikes, an important asset in the Vietnamese context, whereas between 52% and 68 % of the households own a TV. Around 46 percent of the households in each of the treatment arms have a prior loan, whereas the same applies for just over 60 % of the households in the control group. These loans are primarily for business activities, house construction/retrofitting/repairs and education expenses. The households have on average lived in their houses 20 years at the time of the baseline interview. About 16 % of the households live in wards in which the previous ISET and WU project was implemented.

In order to assess the resilience of the homes, the household survey includes detailed registration of the 'resilience components' of the houses, before and after the program was introduced, through photographs and a checklist. The purpose of the checklist is to be able to assess the physical resilience of the house. Each component on the checklist gives an indication of how resilient the house is to storms, and is based on the two key principles of resilient housing presented in the Introduction: the secure connection of all building parts of the house by reinforced-concrete beams and pillars and a safe failure room. The first component on the checklist is the existence of a solid room, which is a room in the house built with a reinforced concrete frame and slab. The second and third components are continuous rings of reinforced concrete at the foundation level and the roof level, respectively. The fourth is reinforced concrete (RC) pillars in the walls, the fifth is a reinforced concrete roof, while the final component is roof bracings, attaching the roof to the main frame of the house. Whether or not the household has a 'solid room' is perhaps the most important resilience component, since this room acts as a safe shelter for the household members in case of a catastrophic typhoon. The ring beams at the foundation and at the roof level, and the reinforced concrete pillars are all important for the overall stability of the house. A reinforced concrete roof is considered to be very resilient, whereas a corrugated steel sheet roof or a clay tile roof is vulnerable to strong winds unless combined with roof bracings. Before the implementation of the program, about 10 % of homes had a solid room, 9% and 6 % had a ring beam at the foundation and roof level, respectively. About 11 % had reinforced concrete pillars, and about 3 % had a reinforced concrete roof. Less than 4 % had roof bracings.

We have randomized the offer of the two packages at the ward level. Although all wards have identified households that are near-poor and satisfy the above mentioned criteria, there may be systematic differences between the wards. In column 4, Table 1 we report the *p*-value from a joint orthogonality test (*F*-test) of treatment arms. There seem to be some systematic differences between the groups. The households that were offered package 1 are on average smaller, they have household heads with more years of schooling, they have a higher income and are more likely to own a motorbike and a TV. We also find that a significantly larger share of the households in the control group have a loan from before, and that a larger share of the households that were offered package 2 are located in wards where WU implemented their previous resilient housing program. However, we do not find any significant difference between the groups in terms of resilience features present at baseline. Since we were able to ensure that the randomization and implementation of the experiment was carried out as intended, these systematic differences are likely due to the small sample. Our experimental approach is therefore valid, but we include the baseline variables as controls in our analysis. As a robustness check, we also include results from using a difference-in-differences approach to estimate the impacts of the two incentive packages in Appendix 3.

The 306 households were tracked by the WU and re-interviewed between late March and early April 2018. Since the baseline, eight households in our original sample had moved and could not be re-interviewed. The follow-up survey contained many of the same questions as the baseline survey, and also included photo documentation of the housing conditions focusing on resilience components.

3. Take-up of the incentive packages

Among the 106 households that were offered package 1, 19 households, or about 18 %, accepted the loan and technical assistance offered and carried out the housing retrofit or reconstruction. In the second group, 49 of the 108 households, or 46 %, accepted the technical assistance and the combination of grant and loan. Keeping in mind that the only difference between the two packages is that 10 million VND (or about 440 USD in January 2018) of the 30 million VND loan from package 1 is offered as a grant in package 2, we find the difference in take-up to be surprisingly large. We also find that the households that accept either one of the packages are able to mobilize a large amount of co-financing, both cash and in-kind from other sources.

The most cited reasons for declining the offered packages include not being able to repay a loan, or not wanting to take up a loan because the household is already indebted or because they are simply not interested. Of the 49 households that accepted the second package, 14 households decided that they only wanted the 10 million VND grant and not the loan because they did not think they would be able to repay the loan. As many as 44 additional households initially

Table 1. Baseline means and balance checks.

	(1) Control	(2) Treatment 1	(3) Treatment 2	(4) *p*-value from joint orthogonality test of treatment arms
Female household head	0.554	0.538	0.481	0.551
	(0.052)	(0.049)	(0.048)	
Age of household head	56.185	53.575	54.620	0.393
	(1.440)	(1.247)	(1.313)	
Years of schooling, household head	6.348	8.358	6.778	0.001
	(0.457)	(0.371)	(0.387)	
Household size	4.793	4.028	4.444	0.009
	(0.213)	(0.137)	(0.169)	
Montly income (mill. VND) per person	1.340	1.659	1.611	0.033
	(0.064)	(0.098)	(0.098)	
Owns motorbike	0.837	0.934	0.861	0.088
	(0.039)	(0.024)	(0.033)	
Owns TV	0.522	0.679	0.620	0.074
	(0.052)	(0.046)	(0.047)	
Household member has a loan	0.620	0.462	0.463	0.042
	(0.051)	(0.049)	(0.048)	
Years lived in house	23.451	19.858	22.046	0.247
	(2.058)	(1.146)	(1.336)	
Previous program exposure	0.130	0.113	0.241	0.024
	(0.035)	(0.031)	(0.041)	
Solid room	0.100	0.133	0.083	0.487
	(0.032)	(0.033)	(0.027)	
Ring beam foundation	0.089	0.114	0.065	0.451
	(0.030)	(0.031)	(0.024)	
Ring beam roof	0.078	0.048	0.056	0.662
	(0.028)	(0.021)	(0.022)	
RC pillars	0.089	0.114	0.130	0.664
	(0.030)	(0.031)	(0.032)	
RC roof	0.044	0.000	0.046	0.086
	(0.022)	(0.000)	(0.020)	
Roof bracings	0.000	0.105	0.000	0.324
	(0.000)	(0.096)	(0.000)	
N	92	106	108	

Table 2. Heterogeneity in take-up.

	Accepted package	Accepted package	Accepted package	Accepted package	Accepted package
Package 1	0.146**	0.101*	0.086	−0.074	0.133**
	(0.060)	(0.058)	(0.063)	(0.064)	(0.060)
Package 2	0.436***	0.423***	0.395***	0.313***	0.472***
	(0.072)	(0.078)	(0.122)	(0.094)	(0.087)
Female household head	0.066	0.028	0.067	0.067*	0.067*
	(0.040)	(0.030)	(0.041)	(0.040)	(0.039)
Years of schooling, household head	−0.000	−0.001	−0.005	0.001	−0.001
	(0.006)	(0.006)	(0.003)	(0.006)	(0.006)
Monthly income (mill VND) per person	0.116***	0.116***	0.114***	0.009	0.118***
	(0.034)	(0.034)	(0.034)	(0.022)	(0.035)
Previous program exposure	−0.089	−0.091	−0.087	−0.082	−0.025
	(0.076)	(0.075)	(0.077)	(0.077)	(0.016)
Package 1*Female		0.086			
		(0.072)			
Package 2*Female		0.024			
		(0.069)			
Package 1*Schooling			0.008		
			(0.008)		
Package 2*Schooling			0.007		
			(0.013)		
Package 1*Income				0.150***	
				(0.051)	
Package 2*Income				0.093***	
				(0.034)	
Package 1*Previous					0.100
					(0.187)
Package 2*Previous					−0.186*
					(0.095)
Observations	298	298	298	298	298

Notes: Standard errors in parentheses, clustered at the ward level.
Linear probability model. Dep.var.: take-up is set equal to 1 if household accepted package 1 or 2, and set equal to 0 if the household declined or was not offered a package. Baseline controls (not reported): age of household head, household size, motorbike ownership, TV ownership, previous loan.
* p<0.10, ** p<0.05, *** p<0.01.

accepted the packages, but later withdrew from the project. These households are equally distributed between the group offered package 1 and the group offered package 2. The most frequent reason for withdrawing are sickness or death in the family, lack of funds for reconstruction and not being able to obtain a building permit because the house is located in a government planning zone.[9]

To further investigate the take-up decision, we estimate the following linear probability model:

$$A_{hw} = \alpha_0 + \alpha_1 T1_w + \alpha_2 T2_w + \alpha_3 T1_w C_{hw} + \alpha_4 T2_w C_{hw} + \mathbf{X}'_{\mathbf{hw}}\gamma + \eta_{hw} \quad (1)$$

where the dependent variable A_{hw} indicates whether household h in ward w accepted a package or not, $T1_w$ and $T2_w$ are dummies indicating whether ward w belongs to the group offered package 1 or package 2, respectively. We also estimate interaction terms between the treatment dummies and various household characteristics, denoted C_{hw}. Since the households in the treatment and control groups differed in a number of aspects, the vector $\mathbf{X}'_{\mathbf{hw}}$ includes controls for these baseline variables. η_{hw} is a mean zero error term, and we cluster the standard errors at the ward level.[10]

We investigate whether take-up differs systematically according to various characteristics of the households. Specifically, we are interested in gender, education, income and whether the household lives in a ward that was included in the previous WU program. The WU specifically targets female-headed households and aims to empower women through their programs. It is therefore interesting to know whether the incentive packages succeed in attracting female-headed households. Households with more educated household heads may have more information a priori on the benefits and costs of climate resilient housing, and may therefore be more likely to accept the packages. We expect take-up to increase with household income, since the investment requires both co-financing by the household and capacity to repay the loan. Being exposed to information about the benefits of climate resilient housing through the previous program could increase program take-up among households in wards included in the previous WU program.

The main results on take-up are reported in Table 2. The first column shows the impact of being offered either incentive package on the probability of accepting, when controlling for baseline characteristics. Being offered package 1 increases take-up by 14.6 percentage points, while being offered package 2 increases take-up by 43.6 percentage points. This means that the households offered package 2 are 29 percentage points, or about three times as likely to accept the incentive package than the households that were offered package 1. This difference is highly statistically significant.

Columns (2)–(5) show the results from investigating whether take-up differs depending on the gender and years of schooling of the household head, household monthly income per person and whether the household lives in a ward included in the previous WU program. We find no significant impact of having a female household head on the probability of accepting either package, nor do we find any significant heterogeneity in take-up depending on years of schooling. Higher household income increases the probability of accepting either package.[11] This effect is stronger for package 1, which is not surprising given that this package does not include a grant. Finally, we find a marginally significant negative impact of being located in a previously exposed ward on the probability of accepting package 2, however this result is not robust to using wild bootstrapped standard errors.[12]

4. Short-run impacts on resilience

The purpose of the incentive packages is to give households an incentive to invest in climate resilient housing. We are therefore not only interested in whether the households accepted the offer of loans and/or grants and the technical assistance. We are also interested in what kind of investments the households made to improve the resilience of their homes. We collected detailed data on the type of improvements made, the presence of key resilience components, as well as sources of funding and types of co-funding. To assess the impact of each incentive package on the decision to invest in housing improvements is relatively straight forward since the wards eligible for each of the two packages and the control group were randomly selected. To assess the impact of being offered the incentive packages on the outcomes of interest, we estimate the following reduced form equation:

$$Y_{hw} = \beta_0 + \beta_1 T1_w + \beta_2 T2_w + \mathbf{X}'_{\mathbf{hw}}\gamma + \eta_{hw} \quad (2)$$

where Y_{hw} is an outcome for household h in ward w, $T1_w$ and $T1_w$ are the treatment dummies, and $\mathbf{X}'_{\mathbf{hw}}$ is the vector of baseline controls and η_{hw} the mean zero error term. The parameters β_1 and β_2 are the estimates of intention to treat (ITT) effects, or the impacts of being offered the program on the outcome we are looking at. This is the more policy relevant parameter in our case, since we are interested in understanding the impact of rolling out either one of the incentive packages tested through the experiment to a larger population.

4.1. Housing improvements

The first outcomes we investigate are the types of improvements the households have done to their house between the baseline survey and the follow-up survey. Table 3 shows the results from estimating the impact of being offered each of the incentive packages on the probability of undertaking various improvements, i.e. the intention-to-treat (ITT) effect. There is no statistically significant impact of being offered either of the packages on the probability of building a new house, elevating the house, repairing or replacing the roof or repairing the walls. Since the households selected as eligible for the program are households that expressed an interest for improving the storm resilience of their home, and that had a wish for starting the improvements from March 2017, it is perhaps not surprising that we do not find any significant impact of being offered either package on the probability of undertaking various improvements. We do find a positive and highly statistically significant impact of being offered package 2 on the probability of adding an extra level.[13] The probability of making this type of improvement increases by 7.7 percentage points, compared to the control group, where

Table 3. ITT effects on housing improvements.

	New house	Extra level	Elevated house	Repair roof	Replace roof	Repair walls
Package 1	−0.028	0.024	0.005	0.035	0.005	0.043
	(0.046)	(0.022)	(0.025)	(0.040)	(0.046)	(0.036)
Package 2	0.035	0.077***	−0.001	−0.009	0.088	0.058
	(0.045)	(0.024)	(0.023)	(0.038)	(0.063)	(0.036)
Control group mean	0.143	0	0.022	0.044	0.077	0.011
Observations	298	298	298	298	298	298

Notes: Standard errors in parentheses, clustered at the ward level.
Linear probability model. Dep.var.: indicator of whether improvement took place. 1 if yes, zero if no.
Baseline controls (not reported): gender, years of education and age of household head, household income, previous program exposure, household size,motorbike ownership, TV ownership, previous loan.
* p<0.10, ** p<0.05, *** p<0.01.

none have added an extra level to their house. It is not obvious why being offered Package 2 should have this impact, however it could be that the grant facilitates more expensive improvements. Looking more closely at the households groups, we find that as many as 14 % of the households in the control group have built a new house since the baseline survey was conducted.

4.2. Housing resilience

Although a large share of households in the control group have done housing improvements, this does not necessarily imply that these households have obtained the same level of housing resilience as in the groups that were offered technical and financial support through the program. Summary statistics for the resilience components at follow-up are presented in Table 4, with mean values of indicator variables for the presence of each component. Since housing resilience increases with the number of resilience elements, we also construct an indicator of housing resilience by counting the number of resilience components present, giving an indicator from 0–5.[14] The mean value of the resilience indicator for each group is shown in the final row of the table.

Table 5 shows the impact of being offered either of the incentive packages on the probability of having each resilience component, as well as the total number of resilience components present.

Keeping in mind that these are the results for all households in each group, not only the households that accepted an incentive package, it is perhaps not surprising that we do not find any statistically significant impact of offering package 1 on most of the housing resilience components.[15] The take-up rate in this group is only about 18 %. We do, however, find a positive and significant impact on the probability of installing roof bracings, which is one of the less costly investments that can be made to improve resilience. This seems reasonable, since package 1 is less generous than package 2.

The impact of offering the second incentive package is statistically significant and positive for the probability of having a solid room, a ring beam at the foundation, reinforced concrete pillars and roof bracings. Being offered package 2 increases the probability of having a solid room or ring beam at the foundation by 13.4 percentage points compared to the control group mean of 23 %. The probability of having reinforced concrete pillars increases by 18.5 percentage point, from 16 % in the control group, while the impact on the probability of having roof bracings is as much as 38 percentage points, compared to the control group where 7 % of households have made the same investment. Package 2 also has a positive and significant impact on the total number of resilience elements, as shown in the final column of Table 5. Being offered the second package on average increases the number of resilience components by 0.9. Looking only at the households that accepted the second package, we find that these households on average had 3.4 resilience components after improving their house, compared to the control group mean of 0.8 resilience elements.

Table 4. Summary statistics for resilience components at follow-up.

	(1) Control	(2) Treatment 1	(2) Treatment 2
Solid room	0.231	0.267	0.387
	(0.044)	(0.044)	(0.048)
Ring beam, foundation	0.176	0.218	0.330
	(0.040)	(0.041)	(0.046)
Ring beam, roof	0.154	0.188	0.236
	(0.038)	(0.039)	(0.041)
RC pillars	0.165	0.260	0.368
	(0.039)	(0.044)	(0.047)
RC roof	0.121	0.178	0.124
	(0.034)	(0.038)	(0.032)
Roof bracings	0.066	0.267	0.481
	(0.026)	(0.044)	(0.049)
Number of resilience elements (0-5)	0.791	1.198	1.802
	(0.165)	(0.186)	(0.194)
N	91	101	106

4.3. Spill-over effects

A relatively high share of households that were offered package 1 and package 2 chose not to accept the packages. There could still be positive impacts of the program on these households (spill-over effects). For instance, households could learn how to improve the resilience of their homes by observing the improvements made by the participating households, or they could learn about the benefits of investing in housing resilience. Any such effects are included in the estimated intention-to-treat effects, however it is interesting to investigate whether spill-over effects could partly explain the impacts. We therefore analyse investments in resilience components among households in treatment wards that declined the packages (non-compliers) compared to the control group. The results are shown in Table 6. We see that the share of households with resilience elements present after implementation of the program is lower for households that declined the offer of incentive packages for all resilience elements except roof bracings than for households in the control group. The

Table 5. ITT effects on housing resilience.

	Solid room	Ring beam foundation	Ring beam roof	RC pillars	RC roof	Roof bracings	Number of resilience elements
Package 1	0.008	0.024	0.017	0.079	0.035	0.169***	0.294
	(0.067)	(0.078)	(0.068)	(0.074)	(0.071)	(0.059)	(0.307)
Package 2	0.134**	0.134**	0.073	0.185***	−0.016	0.382***	0.906***
	(0.060)	(0.061)	(0.065)	(0.060)	(0.046)	(0.064)	(0.260)
Observations	298	298	298	297	297	298	298

Notes: Standard errors in parentheses, clustered at the ward level.
Linear probability model. Dep.var.: outcome is set equal to 1 if resilience element is present based on inspection, 0 otherwise.
Baseline controls (not reported): gender, years of education and age of household head, household income, previous program exposure, household size,motorbike ownership, TV ownership, previous loan.
* $p<0.10$, ** $p<0.05$, *** $p<0.01$.

total number of resilience elements present is also significantly lower for households that chose not to accept the packages. Keeping in mind that these households are a more selected group than the control group, this is perhaps not surprising. Often-cited reasons for declining the offer of the packages include not being able to repay a loan, or not wanting to take up a loan because the household is already indebted or because they are simply not interested. We therefore should not expect the same level of investments as in the control group. It is also unlikely that spill-over effects from learning result in investment immediately upon project completion. Interestingly, the share of non-compliers with roof bracings is significantly higher than in the control group. Since this is a simple and relatively cheap technology that can be combined with existing roof covers, it is perhaps more reasonable to expect spill-over effects for roof bracings than other investments in the short run.

4.4. Heterogeneous treatment effects

To investigate whether the impact of the packages differs depending on the type of household they are offered to, we estimate the same reduced-form model as in Equation (2), but with treatment interaction terms with various household characteristics. Specifically, we look at whether it matters if the package is offered to female-headed households, more educated household heads, and higher income households.

Table 7 summarizes the results from estimating models with heterogeneous treatment effects. Full results are shown in Appendix 2. We do not find that the impact on the probability of investing in any of the resilience components depends on the gender of the household head. We find some indications that being offered package 1 increases the probability of investing in some of the resilience components (ring beam at the foundation, reinforced concrete pillars and reinforced concrete roof) for households with more educated household heads. We find a similar effect of income for two of the components – higher income households that are offered package 2 are more likely to invest in reinforced concrete pillars, while higher income households that are offered package 1 are more likely to invest in roof bracings. These results indicate that the packages may be more beneficial in terms of incentivizing investments in resilience components for higher educated and higher income households. The importance of income is not surprising, given that the packages require a substantial amount of co-financing from the households. The importance of education may indicate that even better information is needed to communicate the benefits of the storm resilient building components to near-poor households with less education.

5. Prevent or repair?

The two most severe typhoons that have struck Da Nang in the past 15 years are Nari (in 2013) and Xangsane (in 2006). Typhoon Nari caused the collapse of 122 houses, ripped off the roof of 1100 homes and severely damaged more than 4200 houses in Da Nang. The estimated cost of damages to housing alone was about 96.6 billion VND (4.6 million USD) (Tran, 2013). Da Nang City Government allocated 14 billion VND from the city budget for repairing and reconstructing damaged houses. The even more severe typhoon Xangsane in 2006 caused the destruction of 1129 houses and damaged another 74 000 houses in Da Nang (Reliefweb, 2006). The national government responded by allocating 40 billion VND to Da Nang to repair and rebuild damaged houses. The city government spent nearly 32 billion VND to support housing repair and reconstruction within the affected districts of the city.

The main cost of the program discussed here is the subsidy of 10 mill. VND per household in Package 2. Program administration and training is financed by the interest rate on the loans from the revolving fund. This means that national and local government spending on reconstruction following Xangsane and Nari could have covered incentives for more than 8400 resilient homes for near poor households.[16] The cost efficiency of scaling up the proposed program depends whether or not the program succeeds in targeting homes that are at the highest risk of being damaged. The World Bank's Global Program for Resilient Housing has developed tools for identifying vulnerable homes using drones, street cameras and machine learning algorithms.[17] This type of tool could be useful for large-scale implementation of a similar program in Da Nang or in other areas vulnerable to typhoons.

The City of Da Nang and the National Government of Vietnam have spent significant amounts supporting households that have experienced housing damage due to typhoons over the past 15 years. Support for repairs and reconstruction has been given to households in Da Nang following typhoons, but without requiring any improvement in resilience (Tran, 2013). While programs exist to support resilient housing for *poor* households through grants[18], *near poor* households often lack access to credit, live in vulnerable housing and do not qualify for support, thus falling between two stools. Our

Table 6. Summary statistics for resilience elements, control group versus non-compliers.

	(1) Control group	(2) Non-compliers	(3) *p*-value from *t*-test of difference in means
Solid room	0.231	0.151	0.000
	(0.044)	(0.030)	
Ring beam foundation	0.176	0.115	0.000
	(0.040)	(0.027)	
Ring beam roof	0.154	0.079	0.000
	(0.038)	(0.023)	
RC pillars	0.165	0.138	0.000
	(0.039)	(0.029)	
RC roof	0.121	0.094	0.003
	(0.034)	(0.025)	
Roof bracings	0.066	0.108	0.000
	(0.026)	(0.026)	
Number of resilience elements (0-5)	0.791	0.590	0.000
	(0.165)	(0.117)	
N	91	139	

Table 7. Heterogeneity in ITT effects on housing resilience.

	Solid room	Ring beam, foundation	Ring beam, roof	RC pillars	RC roof	Roof bracings
Package1*Female	No	No	No	No	No	No
Package 2*Female	No	No	No	No	No	No
Package1*Schooling	No	Positive*	No	Positive*	Positive*	No
Package 2*Schooling	No	No	No	No	No	No
Package1*Income	No	No	No	No	No	Positive*
Package 2*Income	No	No	No	Positive**	No	No
Observations	298	298	298	297	297	298

Notes: Standard errors in parentheses.
Linear probability model. Dep.var.: outcome is set equal to 1 if resilience element is present based on inspection, 0 otherwise.
Baseline controls (not reported): gender, years of education and age of household head, household income, previous program exposure, household size, motorbike ownership, TV ownership, previous loan.
'No' means no significant effect, 'Positive' indicates positive and significant effect.
Detailed results available upon request.
* p<0.10, ** p<0.05, *** p<0.01.

experiment shows that access to microcredit, a relatively small grant and free technical support, is sufficient to incentivize near-poor households to invest in climate resilient housing. A re-allocation of funds from the city's disaster relief fund to a program aimed at supporting climate resilient housing could be one way of financing such a program.

6. Discussion and conclusion

We find that households that were offered a cash transfer and a smaller loan and technical assistance are three times as likely to accept our incentive package, than households not offered a cash transfer. There is a clear impact on the resilience of the new or retrofitted households from being offered the more generous package.

Our results show that there is still a technology or information barrier, since households in the control group did not incorporate resilience components in their homes, despite the fact that as many households in the control group as in the treatment groups built new houses. We do not know whether this is because the usefulness of these components is unknown, whether they are perceived as too costly or if the technologies are unavailable to these households.

Either way, our second incentive package is able to alleviate these constraints, and provides a useful starting point for rolling out a program aimed at reducing the climate vulnerability of near-poor households in Vietnam. Potential spill-over effects from the program through learning should be investigated, but this requires new data collection. New data collection would also make it possible to investigate longer run impacts on resilience and other household outcomes. It is, however, important to keep in mind how eligible households were selected. The Women's Union were asked to nominate near-poor households in each ward with a need for house retrofitting or reconstruction to ensure storm resilience, and with the wish to carry out such retrofitting or reconstruction starting from March 2017. The participating households thus do not represent an average near-poor household in Da Nang, but rather households that are eligible for taking part in the Women's Union revolving fund program for resilient housing based on these criteria. If either one of the incentive packages is rolled out to households selected for instance only by choosing random near-poor households, impacts may be smaller than shown in the evaluation of our pilot program. Regardless of this, the difference in uptake, and therefore impact, of the two packages tested indicates that there is a need for a subsidy component in order to reach near-poor households with this type of program. Previous public spending on assisting households with damaged homes from typhoons indicates that such a subsidy could be covered by re-allocating funds from typhoon repairs to damage prevention.

Notes

1. A typhoon is a rotating system of clouds and thunderstorms with wind speeds exceeding 74 miles per hour, originating in the Northwest Pacific region (http://www.nhc.noaa.gov/climo/).

2. Associated Press, https://usatoday30.usatoday.com/weather/storms/\Clinicaltrialid{\Clinicaltrialid-10-03}}-asia-typhoonx.htm
3. http://blog.i-s-e-t.org/we-are-honored-to-accept-the-unfcccs-lighthouse-activities-award/
4. Hudson et al. (2019) show that flood impacts on subjective well-being of residents in Central Vietnam may be important and should be accounted for in risk management strategies.
5. Wards and communes are the same administrative unit, but the name differs between rural areas (communes) and urban areas (wards).
6. We have included the 8 wards in which the WU implemented their Rockefeller Foundation supported project from 2011 to 2016. In our analysis of take-up and short run impacts of the current program, we include a dummy variable for the wards that were included in the Rockefeller project to control for this, and to investigate whether this affects take-up or impacts.
7. The Da Nang City poverty lines were updated in 2016 (Da Nang City People's Council, 2015): Urban poor households: Income per capita per month (ICM) $<$ 1300000 VND, Urban near-poor households: 1300000 VND $\leq$ ICM $\leq$ 1690000 VND, Rural poor households: ICM $<$ 1100000 VND, Rural near-poor households: 1100000 VND $\leq$ ICM $\leq$ 1430000 VND. This corresponds to a near-poor poverty line of about 75 USD per capita per month in urban wards, and 63 USD per capita per month in rural areas of Da Nang. By comparison, the national poverty line for urban areas was set at 760,000 VND per capita per month for urban areas, and 615,000 VND per capita per month for rural areas, according to the General Statistical Office of Vietnam (General Statistics Office of Viet Nam, 2016).
8. Around 30% of households in urban areas of Vietnam were female-headed in 2016 (GSO, 2016b).
9. Government planning zones are areas that may be included in city plans for infrastructure projects or other projects.
10. As a robustness check, we also compute p-values using the wild bootstrap procedure described in Cameron et al. (2008), since the relatively small number of clusters may be a problem for standard cluster-robust standard errors. The significance levels are largely robust, with exceptions noted in the text.
11. Wild bootstrapped standard errors give slightly higher p-values, from 0.005 to 0.08 for the coefficient on package 1*income, and from 0.008 to 0.01 for the coefficient on package2*income
12. Note that all households have expressed an interest in retrofitting or reconstructing their house to ensure storm resilience, regardless of previous program exposure. This suggests that the finding is not because these households have already invested in storm resilient housing.
13. The results are robust to using wild bootstrapped p-values.
14. Since roof bracings are only used with corrugated steel sheet roofs or clay tile roofs it is not possible to have all six resilience elements present.
15. The results are robust to using wild bootstrapped p-values.
16. Reaching poorer households than the ones targeted in this program likely requires a larger grant element or a grant only for some households.
17. https://www.worldbank.org/en/topic/disasterriskmanagement/brief/global-program-for-resilient-housing
18. For instance, the Poverty Reduction Plan of Da Nang City for 2015–2020 (Da Nang City People's Committee, 2015) includes a budget plan for providing grants for more than 2500 retrofitted or reconstructed houses for poor households in the city.

Acknowledgements

We would like to thank the Women's Union of Da Nang for their cooperation and hospitality, as well as The Institute for Social and Environmental Transition (ISET) – Vietnam. We are grateful to the City of Da Nang and all households participating in the project. An early version of this paper received useful comments from participants at the 16th Nordic Conference in Development Economics and from Henrik Lindhjem. We also thank seminar participants at CICERO Center for International Climate Research for useful feedback. All remaining errors are our own.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was supported by the Nordic Development Fund under the Nordic Climate Facility.

Notes on contributors

Sofie Waage Skjeflo is a senior researcher at CICERO Center for International Climate Research Oslo. She holds a PhD in economics from the Norwegian University of Life Sciences from 2015. Her research interests include empirical environmental and development economics, climate adaptation and climate mitigation policies.

Nina Bruvik Westberg holds a PhD in economics from the Norwegian University of Life Sciences (NMBU) and a master's degree in development and natural resource economics. She is currently placed at Menon Economics. Nina works on climate-, environment- and poverty-related issues, including governments', companies' and households' strategies for mitigating and adapting to climate change.

Haakon Vennemo is a professor of economics and partner at the economics consultancy Vista Analyse. He holds a PhD from the University of Oslo. His research interests are development economics, environmental economics and public economics. He has contributed to the literature on co-benefits of climate mitigation action and the marginal cost of public funds, and a range of other topics.

Tran Huu Tuan completed his PhD at the Norwegian University of Life Sciences, Norway. His specialities are Environmental economics and Sustainable tourism. Tuan has about 20 papers published in SCI/Scopus journals. He is currently the Rector of the School of Hospitality and Tourism - Hue University, Vietnam.

Dr Phong Van Giai Tran has been working as a practitioner in the field of climate change resilience and disaster risk reduction in developing countries in Asia and the Pacific, particularly in Vietnam, for more than 20 years. He has intensive knowledge of climate change adaptation and disaster risk reduction theories and practices. He is currently working for the Swiss State Secretariat for Economic Affairs (SECO) in Vietnam.

Tran Tuan Anh obtained his master's degree in 2008 at Chiang Mai University (Thailand) and his doctoral degree in 2015 at RMIT University (Australia). His expertise focuses on housing vulnerability, post-disaster housing reconstruction, and building community resilience with a focus on the Vietnam context. Tuan Anh is currently a lecturer and researcher at Hue University of Sciences (Vietnam).

References

Bridle, L., Magruder, J., McIntosh, C., & Suri, T. (2020). *Experimental insights on the constraints to agricultural technology adoption*. UC Berkeley: Center for Effective Global Action. Retrieved fromhttps://escholarship.org/uc/item/79w3t4ds.

Cameron, A. C., Gelbach, J. B., & Miller, D. L. (2008). Bootstrap-based improvements for inference with clustered errors. *The Review of Economics and Statistics*, *90*(3), 414–427. https://doi.org/10.1162/rest.90.3.414

Christian, P., Kandpal, E., Palaniswamy, N., & Rao, V. (2019). Safety nets and natural disaster mitigation: evidence from cyclone phailin in odisha. *Climatic Change*, *153*(1-2), 141–164. https://doi.org/10.1007/s10584-018-02364-8

Da Nang City People's Committee. (2015). The Resolution to adopt the Poverty Reduction Plan for 2016-2020 in Da Nang (Nghi quyet Thong qua de an giam ngheo giai doan 2016-2020 tren dia ban thanh pho Da Nang).Retrieved from https://thuvienphapluat.vn/van-ban/Van-hoa-Xa-hoi/Nghi-quyet-123-2015-NQ-HDND-thong-qua-De-an-Giam-ngheo-giai-doan-2016-2020-Da-Nang-300937.aspx

Da Nang City People's Council. (2015). The Resolution to adopt the Poverty Reduction Plan for 2016-2020 in Da Nang.

Da Nang Department of Foreign Affairs, Da Nang Department of Construction, Institute for Social and Environmental Transition-International. (2017). *For local officials/staff: Technical handbook on design, construction and renovation of typhoon-resilient low-income housing*. ISET-International.

Foster, A. D., & Rosenzweig, M. R. (2010). Microeconomics of technology adoption. *Annual Review of EconomicsSEP*, *2*(1), 395–424. https://doi.org/10.1146/economics.2010.2.issue-1

General Statistics Office of Viet Nam. (2016). General poverty rate by residence and by region and year.Retrieved from https://www.gso.gov.vn/en/health-culture-sport-living-standards-social-order-safety-and-environment/

GSO. (2016a). *Statistical yearbook of vietnam 2015*. Technical report, General Statistical Office of Vietnam.

GSO. (2016b). *Synthesized data on the viet nam household living standards survey 2016*. Technical report, General Statistical Office of Vietnam.

Hudson, P., Pham, M., & Bubeck, P. (2019). An evaluation and monetary assessment of the impact of flooding on subjective well-being across genders in vietnam. *Climate and Development*, *11*(7), 623–637. https://doi.org/10.1080/17565529.2019.1579698

Jordan, J. (2021). Climate shocks and adaptation strategies in coastal bangladesh: does microcredit have a part to play? *Climate and Development*, *13*(5), 454–466. https://doi.org/10.1080/17565529.2020.1799737

Mobarak, A. M., & Saldanha, N. A. (2022). Remove barriers to technology adoption for people in poverty. *Nature Human Behaviour*, *6*(4), 480–482. https://doi.org/10.1038/s41562-022-01323-9

Nguyen, L. D., Raabe, K., & Grote, U. (2015). Rural–urban migration, household vulnerability, and welfare in Vietnam. *World Development*, *71*, 79–93. https://doi.org/10.1016/j.worlddev.2013.11.002

Norton, J., & Chantry, G. (2008). Vaccinate your home against the storm – reducing vulnerability in Vietnam. *Open House International*, *33*(2), 26–31. https://doi.org/10.1108/OHI-02-2008-B0004

Pörtner, H.-O., Roberts, D. C., Adams, H., Adler, C., Aldunce, P., Ali, E., Begum, R. A., Betts, R., Kerr, R. B., Biesbroek, R., & Birkmann, J (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. IPCC Sixth Assessment Report.

Red Cross. (2022). *Vietnam: Floods – Final Report, Operation n° MDRVN020*. Technical report, International Federation of Red Cross and Red Crescent Societies.

Reliefweb. (2006). *Viet Nam: Summary report on the typhoon n° 6 – Xangsane*.

Tran, T. A. (2016). *Developing disaster resilient housing in Vietnam: Challenges and solutions*. Springer.

Tran, T. A., & Tran, V. G. P. (2014). Opportunities to build disaster-resilient shelter and settlements: Lessons learnt from a housing architecture design competition. *Journal of Civil Engineering and Architecture Research*, *1*(1), 24–31. https://www.researchgate.net/publication/279922776_Opportunities_to_Build_Disaster-Resilient_Shelter_and_Settlements_Lessons_Learnt_from_a_Housing_Architecture_Design_Competition

Tran, T. A., Tran, V. G. P., Tran, T. H., & Mulenga, M (2013). *Community consultation for long-term climate-resilient housing in Vietnamese cities: a comparative case study between Hue and Da Nang*. Asian Cities Climate Resilience, IIED.

Tran, V. G. P. (2013). *Lessons from typhoon Nari. Storm resistant housing shown to be effective*. Technical report, Institute for for Social and Environmental Transition International (ISET).

Tuan, T. H., Tran, P., Hawley, K., Khan, F., & Moench, M. (2015). Quantitative cost-benefit analysis for typhoon resilient housing in danang city, Vietnam. *Urban Climate*, *12*, 85–103. https://doi.org/10.1016/j.uclim.2015.01.002

UN. (2014). *Migration, resettlement and climate change in Viet Nam. Reducing exposure and vulnerabilities to climatic extremes and stresses through spontaneous and guided migration*. Technical report, United Nations Viet Nam.

Vincent, K., & Cundill, G. (2022). The evolution of empirical adaptation research in the global south from 2010 to 2020. *Climate and Development*, *14*(1), 25–38. https://doi.org/10.1080/17565529.2021.1877104

Appendices

Appendix 1. Information to ward leaders/WU at ward level on the selection of eligible households

The Women's Union of Da Nang is carrying out a survey to investigate the need for storm resilient housing in Da Nang City. The project is carried out with funding from the Nordic Development Fund, and will support the Da Nang City's Resilience Strategy. In this first round, the Women's Union is carrying out a mapping of the need for housing retrofitting and reconstructions for households with houses that are vulnerable to storms. The six households will be visited for a more detailed survey at a later point, tentatively in December 2016.

At this point, the Women's Union would like to identify households categorized as *near poor, with a need for house retrofitting or reconstruction to ensure storm resilience, and with the wish to carry out such retrofitting or reconstruction starting from March 2017.* We are therefore asking each ward to provide a list of six households that fit these criteria. If there are more than six households in the ward that fit the criteria, we would also like a specification of how the six households were nominated among the larger group of households.

Appendix 2. Full results from estimating heterogeneous treatment effects

Table A1. ITT heterogeneous treatment effects solid room.

	Solid room	Solid room	Solid room
Package 1	0.037	−0.090	−0.042
	(0.093)	(0.120)	(0.148)
Package 2	0.162**	0.047	0.016
	(0.078)	(0.126)	(0.139)
Package 1*Female	−0.054		
	(0.119)		
Package 2*Female	−0.052		
	(0.120)		
Package 1*Schooling		0.014	
		(0.015)	
Package 2*Schooling		0.014	
		(0.017)	
Package 1*Income			0.041
			(0.094)
Package 2*Income			0.083
			(0.092)
Observations	298	298	298

Notes: Standard errors in parentheses, clustered at the ward level.
Linear probability model. Dep.var.: outcome is set equal to 1 if resilience element is present based on inspection, 0 otherwise.
Baseline controls (not reported): gender, years of education and age of household head, household income, previous program exposure, household size, motorbike ownership TV ownership, previous loan.
* $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A2. ITT heterogeneous treatment effects ringbeam foundation.

	Ring beam foundation	Ring beam foundation	Ring beam foundation
Package 1	0.078	−0.163*	−0.032
	(0.098)	(0.094)	(0.146)
Package 2	0.142**	0.127	0.095
	(0.067)	(0.134)	(0.150)
Package 1*Female	−0.103		
	(0.117)		
Package 2*Female	−0.014		
	(0.119)		
Package 1*Schooling		0.024*	
		(0.013)	
Package 2*Schooling		0.001	
		(0.016)	
Package 1*Income			0.038
			(0.086)
Package 2*Income			0.028
			(0.086)
Observations	298	298	298

Notes: Standard errors in parentheses, clustered at the ward level.
Linear probability model. Dep.var.: outcome is set equal to 1 if resilience element is present based on inspection, 0 otherwise.
Baseline controls (not reported): gender, years of education and age of household head, household income, previous program exposure, household size, motorbike ownership TV ownership, previous loan.
* $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A3. ITT heterogeneous treatment effects ringbeam roof.

	Ring beam, roof	Ring beam, roof	Ring beam, roof
Package 1	−0.004	−0.130	−0.022
	(0.086)	(0.087)	(0.139)
Package 2	0.029	0.067	0.064
	(0.069)	(0.127)	(0.156)
Package 1*Female	0.037		
	(0.109)		
Package 2*Female	0.083		
	(0.103)		
Package 1*Schooling		0.019	
		(0.012)	
Package 2*Schooling		0.001	
		(0.015)	
Package 1*Income			0.026
			(0.090)
Package 2*Income			0.007
			(0.094)
Observations	298	298	298

Notes: Standard errors in parentheses, clustered at the ward level.
Linear probability model. Dep.var.: outcome is set equal to 1 if resilience element is present based on inspection, 0 otherwise. Baseline controls (not reported): gender, years of education and age of household head, household income, previous program exposure, household size, motorbike ownership TV ownership, previous loan. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A4. ITT heterogeneous treatment effects RC pillars.

	RC pillars	RC pillars	RC pillars
Package 1	0.105	−0.120	−0.035
	(0.101)	(0.108)	(0.124)
Package 2	0.189**	0.018	−0.036
	(0.077)	(0.119)	(0.125)
Package 1*Female	−0.049		
	(0.117)		
Package 2*Female	−0.006		
	(0.110)		
Package 1*Schooling		0.028*	
		(0.014)	
Package 2*Schooling		0.026	
		(0.017)	
Package 1*Income			0.089
			(0.072)
Package 2*Income			0.156**
			(0.077)
Observations	297	297	297

Notes: Standard errors in parentheses, clustered at the ward level.
Linear probability model. Dep.var.: outcome is set equal to 1 if resilience element is present based on inspection, 0 otherwise.
Baseline controls (not reported): gender, years of education and age of household head household income, previous program exposure, household size, motorbike ownership TV ownership, previous loan.
* p<0.10, ** p<0.05, *** p<0.01.

Table A5. ITT heterogeneous treatment effects RC roof.

	RC roof	RC roof	RC roof
Package 1	0.044	−0.102	−0.030
	(0.110)	(0.077)	(0.115)
Package 2	−0.060	−0.109	−0.056
	(0.074)	(0.080)	(0.097)
Package 1*Female	−0.020		
	(0.123)		
Package 2*Female	0.086		
	(0.109)		
Package 1*Schooling		0.019*	
		(0.011)	
Package 2*Schooling		0.015	
		(0.012)	
Package 1*Income			0.045
			(0.069)
Package 2*Income			0.030
			(0.073)
Observations	297	297	297

Notes: Standard errors in parentheses, clustered at the ward level.
Linear probability model. Dep.var.: outcome is set equal to 1 if resilience element is present based on inspection, 0 otherwise.
Baseline controls (not reported): gender, years of education and age of household head, household income, previous program exposure, household size, motorbike ownership TV ownership, previous loan.
* p<0.10, ** p<0.05, *** p<0.01.

Table A6. ITT heterogeneous treatment effects roof bracings.

	Roof bracings	Roof bracings	Roof bracings
Package 1	0.120*	0.163	−0.032
	(0.065)	(0.097)	(0.089)
Package 2	0.376***	0.380***	0.261**
	(0.068)	(0.127)	(0.107)
Package 1*Female	0.093		
	(0.100)		
Package 2*Female	0.010		
	(0.091)		
Package 1*Schooling		0.001	
		(0.011)	
Package 2*Schooling		0.000	
		(0.014)	
Package 1*Income			0.138**
			(0.058)
Package 2*Income			0.090
			(0.060)
Observations	298	298	298

Notes: Standard errors in parentheses, clustered at the ward level.
Linear probability model. Dep.var.: outcome is set equal to 1 if resilience element is present based on inspection, 0 otherwise.
Baseline controls (not reported): gender, years of education and age of household head, household income, previous program exposure, household size, motorbike ownership TV ownership, previous loan.
* p<0.10, ** p<0.05, *** p<0.01.

Appendix 3. Robustness checks

Our comparison of household characteristics at baseline shows that there are some imbalances between the three groups. Baseline characteristics are included as controls to correct for any bias this may cause in the estimated treatment effects. However, as an additional robustness check, we use a difference-in-differences approach to estimate the intention-to-treat effects of the two packages. We estimate the following equation:

$$Y_{hw} = \alpha + \beta_1 T1_w + \beta_2 T2_w + \gamma t_w + \delta_1 (T1_w \cdot t_w) + \delta_2 (T2_w \cdot t_w) + \epsilon_{hw} \tag{A1}$$

where Y_{hw} is an outcome for household h in ward w, $T1_w$ and $T1_w$ are dummy variables for the two treatment groups, t_w is an indicator of the two time periods we observe the households (baseline=0 and follow-up=1) and ϵ_{hw} the mean zero error term. α is a constant term, β_1 and β_2 are treatment group specific effects that control for permanent average differences between the groups,γ is a time trend common to the three groups, and δ_1 and δ_2 are the estimates of intention-to-treat (ITT) effects. The results are shown in Table A7. By comparing this table to Table 5 in the main text, we see that the magnitudes and significance levels of the treatment effects are largely robust to estimation by difference-in-differences. One exception is that the impact of being offered package one on the probability of installing roof bracings is no longer statistically significant, while there is a marginally significant impact on the probability of installing a reinforced concrete roof.

Table A7. ITT effects on housing resilience – difference in differences.

	Solid room	Ring beam foundation	Ring beam roof	RC pillars	RC roof	Roof bracings	Number of resilience elements (0–5)
T1	0.039	0.030	−0.029	0.030	−0.045	0.110	0.183
	(0.057)	(0.053)	(0.048)	(0.056)	(0.040)	(0.074)	(0.218)
T2	−0.016	−0.024	−0.022	0.033	0.002	0.000	−0.021
	(0.056)	(0.052)	(0.047)	(0.055)	(0.040)	(0.073)	(0.215)
time trend	0.130**	0.086	0.075	0.075	0.076*	0.066	0.440**
	(0.058)	(0.054)	(0.049)	(0.057)	(0.041)	(0.076)	(0.223)
ITT 1	−0.002	0.012	0.063	0.065	0.102*	0.091	0.224
	(0.080)	(0.075)	(0.067)	(0.079)	(0.057)	(0.104)	(0.308)
ITT 2	0.172**	0.178**	0.104	0.170**	0.001	0.415***	1.032***
	(0.079)	(0.074)	(0.067)	(0.078)	(0.056)	(0.103)	(0.304)
Constant	0.101**	0.090**	0.079**	0.090**	0.045	−0.000	0.352**
	(0.041)	(0.039)	(0.035)	(0.041)	(0.029)	(0.054)	(0.158)
Observations	593	593	593	592	592	593	596

Notes: Standard errors in parentheses
Linear probability model. Dep.var.: outcome is set equal to 1 if resilience element is present based on inspection, 0 otherwise.
Difference in differences
* $p<0.10$, ** $p<0.05$, *** $p<0.01$.

The main finding of positive and significant impacts of being offered package two on most resilience components, as well as the total number of resilience components, still holds.

Appendix 4. Ethics statement

At the time the survey was conducted, no formal ethics approval by local authorities was required. However, the survey was conducted in accordance with the key principles and ethical standards stated in the 1964 Declaration of Helsinki. Eligible members of the Vietnam Women's Union were informed about the program and the purpose of data collection through group meetings at the Ward level as well as upon the visit of the enumerators when collecting the baseline and follow-up data. Households were informed that their participation in the survey and their responses would not influence their possibility of program participation, and that allocation to each group in the project would be determined through a lottery. They were further informed that all participation was voluntary, and asked for oral consent to participate in the survey. Photo documentation of the house condition and GPS coordinates were also collected. Anonymized survey data is available upon request to the corresponding author.