Thailand Vietnam Socio Economic Panel

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Ralitza Dimova, Ulrike Grote, Arnab Basu

University of Manchester, United Kingsom, Georg-August-Universität Göttingen, Cornell University, Ithaca, USA

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Thailand Vietnam Socio Economic Panel (TVSEP)
TVSEP Database Centre
Leibniz Universität Hannover
Königsworther Platz 1
30167 Hannover, Germany

Contact: thanh.nguyen@iuw.uni-hannover.de

# Long-term behavioral responses to man-made disasters: Insights from the Agent Orange experiment in Vietnam[♣]

Ralitza Dimova[ς], Ulrike Grote[*], Arnab Basu[+]

**Abstract**

Do man-made disasters induce permanent behavioral changes? Using unique panel data from Vietnam that experimentally elicit a particular behavioral preference, namely, risk tolerance, we analyze (i) whether individuals located in areas exposed to greater levels of contaminants from Agent Orange spraying during the Vietnam War are relatively more risk tolerant vis-à-vis those who are located in less affected areas, (ii) whether risk tolerance declines and the willingness to invest increases with the decreasing intensity of the harm over time, and (iii) the socio-economic factors that impede out-migration from the heavily contaminated areas. We find that individuals located within Agent Orange affected areas have greater risk tolerance, but this risk tolerance exhibits a downward trend. Continued residency within the disaster-affected areas is primarily influenced by the ownership of physical assets.

**Keywords**: Vietnam, Agent Orange, Risk Profiles, Propensity Score Matching

**JEL**: C93, D1, Q51

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[ς] University of Manchester, Manchester, UK; corresponding author, email: ralitza.dimova@manchester.ac.uk

[*] Leibniz Universität Hannover, Hannover, Germany

[+] Cornell University, Ithaca, NY, USA

## 1. Introduction

A relatively new area of social science research involves the behavioral response of individuals to natural and man-made disasters. Zeroing in on a particular dimension of behavioral preferences – the risk tolerance of individuals - a small number of studies have shown that individuals affected by man-made disasters exhibit different levels of risk tolerance from those that remain unaffected (or minimally affected) by these unanticipated negative shocks. Indeed, as the frequency of various disasters (indirectly or directly caused by human actions) increases – from climate change induced severe droughts, floods and hurricanes to oil spills, nuclear accidents, and wars - two questions remain unaddressed in the behavioral economics literature. First, while risk tolerance of individuals is expected to be different for those affected by disasters, compared to their unaffected peers, how does risk tolerance evolve over time? Does the evolution of risk tolerance mirror the gradual dissipation of harm associated with a disaster? Second, and beyond the question of differences and evolution of risk tolerance, what socio-economic factors contribute to the inability of individuals to migrate out of a disaster-prone area? Within the backdrop of the Vietnam War, we make a first attempt to address these questions by analyzing the risk tolerance of individuals differentially affected by the spraying of Agent Orange, a dioxin-based defoliant which continues to contaminate soil and water long after the war's end. Not only do we find that individuals residing in areas heavily sprayed with Agent Orange are more risk tolerant than their peers in areas less affected by the contaminant, but this risk tolerance shows a downward trend mirroring the decay in intensity of the contaminant over time. In contrast to the willingness to take risks, however, the willingness to invest in business continues to remain low among people residing in the highly contaminated areas. Among the factors inhibiting out-migration from the man-made disaster areas, ownership of land and other durable assets emerges as the biggest factor.

While our study is the first to analyze the evolution of behavioral preferences and residence choices of individuals severely affected by contamination from Agent Orange use, there are studies that have analyzed the impact of the Vietnam War on the long-term well-being of its citizens. These studies fall into two groups: one analyzing the specific impact of Agent Orange usage and the other analyzing the broader impact of bombings. Studies focusing on the intensity of Agent Orange use find that health problems (including blood pressure-related illnesses and mobility limitations) are higher in populations residing in areas sprayed more intensively[1]. On the other hand, while a comparison of heavily bombed areas with less bombed counterparts shows no adverse long-term impact on poverty and literacy rates, population densities, or consumption levels[2], a similar geographical comparison highlights a higher incidence of mental distress among individuals residing in the heavily bombed areas[3].

Noteworthy here is that, compared to other studies conducted in the specific context of the Vietnam War, our results highlight broader behavioral consequences for individuals exposed to potential adverse health and loss of life risks due to man-made disasters. Specifically, we explore the idea that staying out of a disaster afflicted area is a self-insurance mechanism, with self-insurance in turn being negatively correlated with the individual's level of risk tolerance. In addition, we analyze whether the differential risk tolerance across the treatment (heavily sprayed by Agent Orange) and the control (minimally affected by Agent Orange) provinces in Vietnam is robust to a matching test that aims to resolve observed differences in an individual's potential to sort into or out of the disaster afflicted province, and whether and how it changes over time in line with the reduction of the threat. Our baseline results grant support to our hypotheses that individuals residing in the heavily sprayed province are more risk tolerant but with a downtrend trend, and these results are robust to alternative methodological approaches, relying on spraying intensity, instrumented with the minimum distance of the affected districts from a military airbase.

Our findings speak to literature that can be grouped into two areas: (i) risk tolerance and migration in the face of man-made disasters, and (ii) willingness to pay (WTP) to avoid health and loss of life risks. We next turn to a short review of these points.

### 1.1 Risk tolerance and migration in the face of man-made disasters

The most popular direct consequence of the impact of man-made disasters on risk preferences is in the context of conflict. Empirical evidence is mixed, with studies finding both a positive and negative association in some cases. Individuals exposed to terrorist attacks in Afghanistan displayed more risk-tolerant behavior[4] while individuals in Sri Lanka who were affected by the civil war showed lower levels of risk aversion[5]. A similar result is obtained from Syria where individuals (both combatants and non-combatants) residing within rebel-held areas exhibited a higher tolerance to risk[6]. However, Burundians directly affected by the civil war (1993-2003) displayed less risk aversion to gains but not towards losses when compared to those unaffected by the war[7]. In contrast, there is evidence that people affected by post-election violence in Kenya and severe drug-related violence in Colombia have higher levels of risk aversion[8,9].

In addition to influencing risk preferences directly, disasters affect the willingness of individuals to migrate out of affected areas. Estimates suggest that at the end of 2021, there were 59.1 million internally displaced people; 53.2 million because of conflict and violence and 5.9 million due to natural and other man-made disasters[10]. Disaster-related migration – specially in the Asian context – depends on a host of other push and pull factors like disaster-induced poverty in sending areas and the existence of social networks and job opportunities in destination areas[11]. In addition, two other factors related to our study play an important role: (i) ownership of immovable assets such as land, and (ii) risk tolerance of migrants. The situation with respect to immovable assets such as land is particularly complex given ill-defined property rights in less developed economies. Research in Ethiopia has shown that people do not migrate out of fear that their property rights will be dissipated in their absence[12]. Thus, the decision to out-migrate from an area affected by man-made disasters is complicated by weak institutional and governance frameworks in developing countries[13].

The literature on the links between risk preferences and migration is less prolific and, to the best of our knowledge, focusing exclusively on economic as opposed to disaster-driven migration. The typical assumption is that migrants are more tolerant to risk, as well as more mobile and talented, than the rest of the population in the country of destination[14 15 16]. More recent research finds that adaptation to the host country closes the risk tolerance gap between migrants and the local population in the receiving country[17].

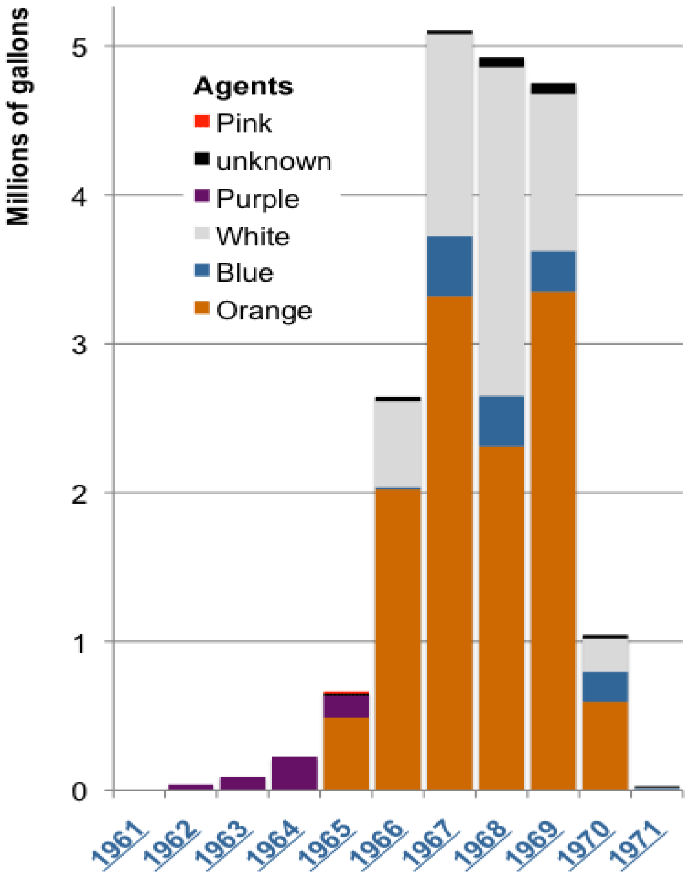
### 1.2 The willingness to pay to avoid risks for health or life

One of the most interesting conceptualizations of behavioral response to man-made disasters comes from the literature on the Willingness to Pay (WTP) for self-insurance against risks associated with residing near nuclear power plants and radioactive waste disposal sites. A popular way of estimating this WTP is via observing residential prices at different radii around the hotspot. Theoretically, an individual's choice of residential location reflects their risk profile as follows: greater distance reduces the exposure to a nuclear accident – and individuals locating further away should exhibit a higher WTP to insure against this eventuality. As such, location is a proxy for self-insurance, implying that individuals who choose to be farther from a potential disaster zone should demonstrate greater risk aversion. There is a wealth of empirical evidence to support this hypothesis. For instance, research based on a series of publicly known shipments of spent nuclear fuel in the US state of South Carolina found that real estate values near densely populated urban areas with high risk of exposure have fallen substantially, while real estate values in areas with lower risk perceptions are unaffected[18]. However, the problem with analyses based on real estate prices is that disaster risk is one of many factors that determine where one resides. A further complication is the fact that the cost of sorting in and out of an affected area is not necessarily trivial[19]. A preferred alternative would be to either estimate the WTP directly to avoid the health risk associated with radiation exposure, or to assess the subjective assessment of the risk by individuals. Research on the WTP to cover the financial risks of a potential nuclear accident in Switzerland shows that the distance to an environmental disaster could have a nuanced effect on the WTP for risk reduction[20]. Distance is a significant negative predictor of marginal WTP for insurance coverage but not for solving the waste disposal problem after controlling for attitudes towards nuclear energy and nuclear sorting. Surprisingly though, distance is not a relevant predictor for WTP to solve nuclear-related risk issues in South Africa[21]. On the subjective risk assessment side, there is a small body of literature that relates to the controversy surrounding the 1987 US Congress decision to ship nuclear waste from 33 states across the US over a 24-year period to the Yucca Mountain nuclear waste repository in the State of Nevada. Based on a survey of mortality risk from exposure to radioactive waste along some transport routes, research shows that distance from the transport route has a negative and significant effect on the perceived risk of mortality[22]. More recent risk assessment studies related to sites near nuclear power plants conducted after the Fukushima nuclear accident in Japan show that individuals in China are willing to pay higher electricity prices to avoid risks related to the construction of nuclear power plants in the neighborhood[23].

## 2. Brief overview of the use of Agent Orange

Over the period 1965-1972 during the Vietnam War, the US military sprayed 80 million liters (or roughly 21.6 million gallons) of the defoliant Agent Orange on rainforests, wetland mangroves, agricultural land, rivers and streams with the twin objectives of improving visibility for military operations and disruption of food supply for the VietCong. Several other defoliants, some without or with low levels of dioxin concentration, named after the color of the band on the containers - such as Agent White, Agent Pink, Agent Blue and Agent Purple - were also used at various stages of the war. Agent Orange was the deadliest and consisted of equal amounts of two herbicides 2,4-dichlorophenoxyacetic acid $C_8H_6Cl_2O_3$ (2,4-D) and 2,4,5-trichlorophenoxyacetic acid $C_8H_5Cl_3O_3$ (2,4,5-T) and dioxin, 2,3,7,8-tetrachlorodibenzodioxin ($C_{12}H_4Cl_4O_2$) – commonly known as TCDD. While the half-life of the herbicides in Agent Orange is days and weeks after application to vegetation, the half-life of the dioxin TCDD depends on where it is deposited and varies from 1 to 3 years on soil surfaces that have been fully exposed to sunlight, to as long as 20 to 50 years or more when buried in tropical subsoils, and more than 100 years in river and sea sediments[24]. Given that the levels of TCDD in Agent Orange was 50 times the level found in commercial weed killers sold in the US, it is unsurprising that significant adverse health impacts - from birth defects to cancer and premature deaths - in the more heavily sprayed areas of Vietnam are being reported long after the end of the spraying missions[25]. Figure 1 shows the massive use of Agent Orange over the 1965-1970 phase of the war, with some studies estimating an even higher use of this defoliant[26].

**Figure 1: Millions of gallons of Agent Orange used between 1961-1971 in Vietnam**
(Source: The Chicago Tribune, Jul 17, 2014)

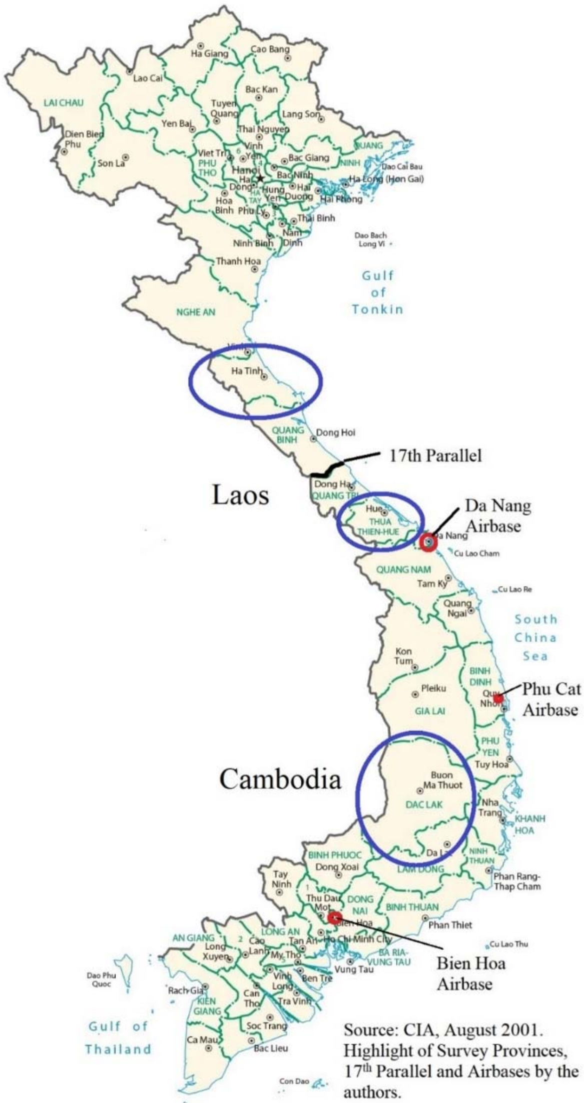



Noteworthy here is that the spraying of Agent Orange under 'Operation Ranch Hand' was carried out by C-123 aircrafts equipped with spray apparatus[27] operating out of one of the three airbases - Bien Hoa, Phu Cat and Da Nang[28]. The locations of these airbases are identified in Figure 2 below.

## 2.1 Data, empirical challenges and descriptive statistics

For our analysis, we use the Thailand-Vietnam Socio-Economic Panel (TVSEP), conducted in five rounds between 2008 and 2017. The TVSEP is a unique panel dataset with negligible attrition (1.14% average annual attrition over these five rounds) which tracks experimentally elicited behavioral responses and socio-economic indicators over time from approximately 2,000 individuals residing in three provinces of Vietnam: Ha Tinh (above the 17$^{th}$ parallel), Thua Thien-Hue and Dak Lak (both below the 17$^{th}$ parallel). The selection of these three provinces in the TVSEP surveys was based on the following common features[29]: (i) low average per capita income, (ii) high dependence on agriculture, (iii) remoteness and peripheral location along the country's border (either with Laos (Ha Tinh and Thua Thien-Hue) or Cambodia (Dak Lak)), (iv) underdeveloped infrastructure and (v) vulnerability to adverse weather shocks (droughts, floods, storms). Figure 2 shows the location of the three provinces in the TVSEP surveys.

**Figure 2: TVSEP survey provinces and 'Operation Ranch Hand' airbases**




Interestingly, however, the three provinces in the TVSEP survey were differentially affected by the exposure to Agent Orange: Ha Tinh is in North Vietnam and was not affected by Agent Orange spraying, Dak Lak was minimally affected while Thua Thien-Hue ranks third in terms of the most heavily sprayed provinces during the war (920,497 gallons of herbicides was sprayed over 1,244 square kilometers or over 25% of this province). This spatial variation in Agent Orange exposure guides our selection of treatment and control provinces for empirical analysis. We first exclude the province of Ha Tinh in North Vietnam, which had a different institutional set-up that may have shaped risk tolerances differently and independently of the non-exposure to Agent Orange. Between the provinces of Thua Thien-Hue and Dak Lak, we define Thua Thien-Hue (heavily sprayed) as the treatment area and Dak Lak (minimally sprayed) as the control area for our baseline analysis.

We next turn to the descriptive statistics for the treatment and control provinces in Table 1 below. Individuals residing in the heavily sprayed treatment province display a greater level of risk tolerance and a lower willingness to invest as compared to their counterparts in the minimally sprayed control province. Individuals in the treatment province are also less educated and have higher dependency ratios. They are less likely to be farmers and more likely to have a permanent non-farming job than individuals in the control province. It is worth noting that there are no statistically significant differences between the number of covariate shocks experienced by individuals belonging to the two provinces. However, individuals belonging to the treatment province are more likely to report household shocks.

**Table 1: Descriptive statistics (treatment and control provinces)**

| | Treatment province | | | Control province | | | T-test |
|---|---|---|---|---|---|---|---|
| | N | mean | sd | N | mean | sd | t-stat |
| **Individual and household characteristics** | | | | | | | |
| Age | 1761 | 48.27 | 12.851 | 2264 | 46.067 | 11.650 | 11.8244 |
| Years education | 1761 | 6.996 | 3.847 | 2264 | 7.635 | 3.573 | -6.6656 |
| Healthy | 1761 | .333 | 0.471 | 2264 | .29 | 0.454 | 2.2384 |
| Farmer | 1761 | .622 | 0.485 | 2264 | .735 | 0.441 | -9.6802 |
| Non-agro job | 1761 | .066 | 0.248 | 2264 | .032 | 0.176 | 5.5161 |
| Married | 1761 | .896 | 0.305 | 2264 | .878 | 0.328 | -4.0791 |
| Female | 1761 | .39 | 0.488 | 2264 | .375 | 0.484 | 4.1697 |
| Household size | 1761 | 5.135 | 1.723 | 2264 | 4.977 | 1.787 | -0.9939 |
| Dependency ratio | 1761 | 1.556 | 0.692 | 2264 | 1.478 | 0.623 | 3.1406 |
| Household shock | 1761 | .446 | 0.611 | 2264 | .433 | 0.581 | 3.5173 |
| Covariate shock | 1761 | .626 | 0.714 | 2264 | .644 | 0.611 | 0.1678 |
| Risk tolerance | 1761 | 5.617 | 2.619 | 2264 | 4.68 | 3.130 | 8.8142 |
| Investment/10000 | 1761 | 1.592 | 1.669 | 2264 | 1.975 | 2.039 | -8.3322 |
| **Village characteristics** | | | | | | | |
| Two-lane road | 1761 | .789 | 0.408 | 2264 | .325 | 0.469 | 42.7404 |
| Irrigation | 1761 | .587 | 0.492 | 2264 | .455 | 0.498 | 7.6766 |
| Public water | 1761 | .648 | 0.478 | 2264 | .163 | 0.369 | 41.5371 |
| Electricity (% hh) | 1761 | 97.846 | 10.090 | 2264 | 95.717 | 15.386 | 6.5951 |
| **District characteristics** | | | | | | | |
| Gallons Agent Orange | 1322 | 194904.8 | 124458.4 | 1044 | 24816.57 | 14257.29 | 52.7877 |

Risk tolerance is measured on an 11-point Likert scale via the question, "Are you generally a person who is fully prepared to take risks, or do you try to avoid taking risks? Please choose a number on a scale from 0 (unwilling to take risks) to 10 (fully prepared to take risks)." Thus, higher values of the variable indicate higher levels of tolerance to risk. Investment is based on the question "If you won 60 Mio. Dong how much would you invest". Household shock stands for the number of self-assessed shocks affecting the households, while covariate shocks capture self-assessed shocks affecting more than one household in the neighborhood. The rest of the variables are self-explanatory of either continuous nature (age, years of education, household size and dependency ratio) or dummy variables (self-assessed health status, gender, employment and marital status).

The individual and household statistics show interesting patterns that correlate with the possibility for sorting individuals across treatment and control provinces. On the one hand, characteristics such as a lower level of education make individuals less geographically mobile and hence less likely to escape a disaster area. On the other hand, farmers in the treatment province are most vulnerable to the negative effects of Dioxin contamination and hence logically less likely to stay. Interestingly, individuals in the treatment province are reportedly healthier than individuals in the control province, which is an additional sign of potential self-selection. These patterns, especially the lower level of education in the treatment province and the greater willingness to take risks in combination with a lower willingness to invest are particularly interesting in view of the clear evidence of a better infrastructure in the treatment province. In the next section, we undertake a matching test based on observed characteristics that correlate with the propensity of individuals to migrate in and out of the treatment province.

## 3. Empirical strategy

Following the discussion in the preceding section, we define Thua Thien-Hue as the treatment province and Dak Lak as the control province, and estimate the following model:

$$Y_{it} = \alpha_0 + \alpha_1 AgentOrangeArea + \alpha_2 AgentOrangeArea * Trend + X'_{it} + \varepsilon_{it}$$

$Y_{it}$ denotes the risk profile of an individual 'i' captured via responses to three distinct questions at a given round 't' of the survey. The risk profile in the TVSEP surveys is measured on an 11-point Likert scale via the question, "Are you generally a person who is fully prepared to take risks, or do you try to avoid taking risks? Please choose a number on a scale from 0 (unwilling to take risks) to 10 (fully prepared to take risks)". This method of risk tolerance elicitation has been validated in several contexts and has generally been found to be less noisy than certain other experimental measures[30,31,32]. In our analysis, we use both this ordinal measure of risk tolerance and a dummy variable that takes the value of 1 if the respondents place themselves in categories 0-4 (less risk tolerant), and 0 otherwise (more risk tolerant). We use an additional survey question that asks, "If you won 60 Mio. Dong how much would you invest in a business?" which constitutes our third risk tolerance measure. The vector $X'_{it}$ contains a set of typical individual and household characteristics (gender, age, marital status, occupation, education, household composition (size and dependency ratio) and exposure to shocks). To explore the evolution of risk tolerance over time, we include a linear trend, and the interaction of this linear trend with location within the treatment province. Following the intuition of the willingness to pay to avoid the risk to health and life literature, we hypothesize that $\alpha_1 > 0$ in the case of our ordinal risk tolerance variable and $\alpha_1 < 0$ in the case of our binary risk tolerance dummy. We test the additional hypothesis that risk tolerance should exhibit a downward trend over time in consonance with the decreasing intensity of harm inflicted by exposure to Agent Orange, namely, $\alpha_2 < 0$.

To purge the sample of heterogeneity that could among other things be correlated with the ability of individuals to sort themselves out of the province heavily sprayed by Agent Orange, we perform propensity score matching across the two provinces and re-run the regressions for the matched sample. To achieve good balancing, only those variables that are unaffected by the participation in (or anticipation of) the treatment is included in the analysis[33]. More precisely, the included individual characteristics are age, gender, marital status, household composition and wealth, and included infrastructure indicators are the size of the village (in terms of population), access to irrigation, roads, public water, and electricity. All these variables are identified in the first year of the TVSEP panel and emerge as the variables that influence simultaneously the treatment decision (residence within the heavily sprayed Agent Orange province) and the outcome variables of interest (risk tolerance, risk aversion dummy and willingness to invest). The results from the probit estimation in the first stage of the propensity score matching methodology (Table 2) indicate that variables such as asset ownership (in the form of both land and other durable goods) are the factors reducing the capacity of individuals to sort themselves out of the treatment province. Table S1 and Figure S1 in the supplementary section attest to the good balancing achieved with the chosen variables. The Variance Ratios of all variables other than land ownership, reported in Table S1, are close to one. However, in the case of acres of owned land, matching leads to a reduction from 5 to 3. Exclusion of this variable does not affect our results and approximately 100 observations remain outside of the common support. We keep the first-year observations that share a common support and apply the matching rule to the rest of the sample to generate a balanced panel of individuals that share a common support over the entire panel. This method allows us to account for non-random selection of individuals into the treatment province based on observed characteristics.

**Table 2: Observed characteristics associated with self-sorting in and out of the treatment province**

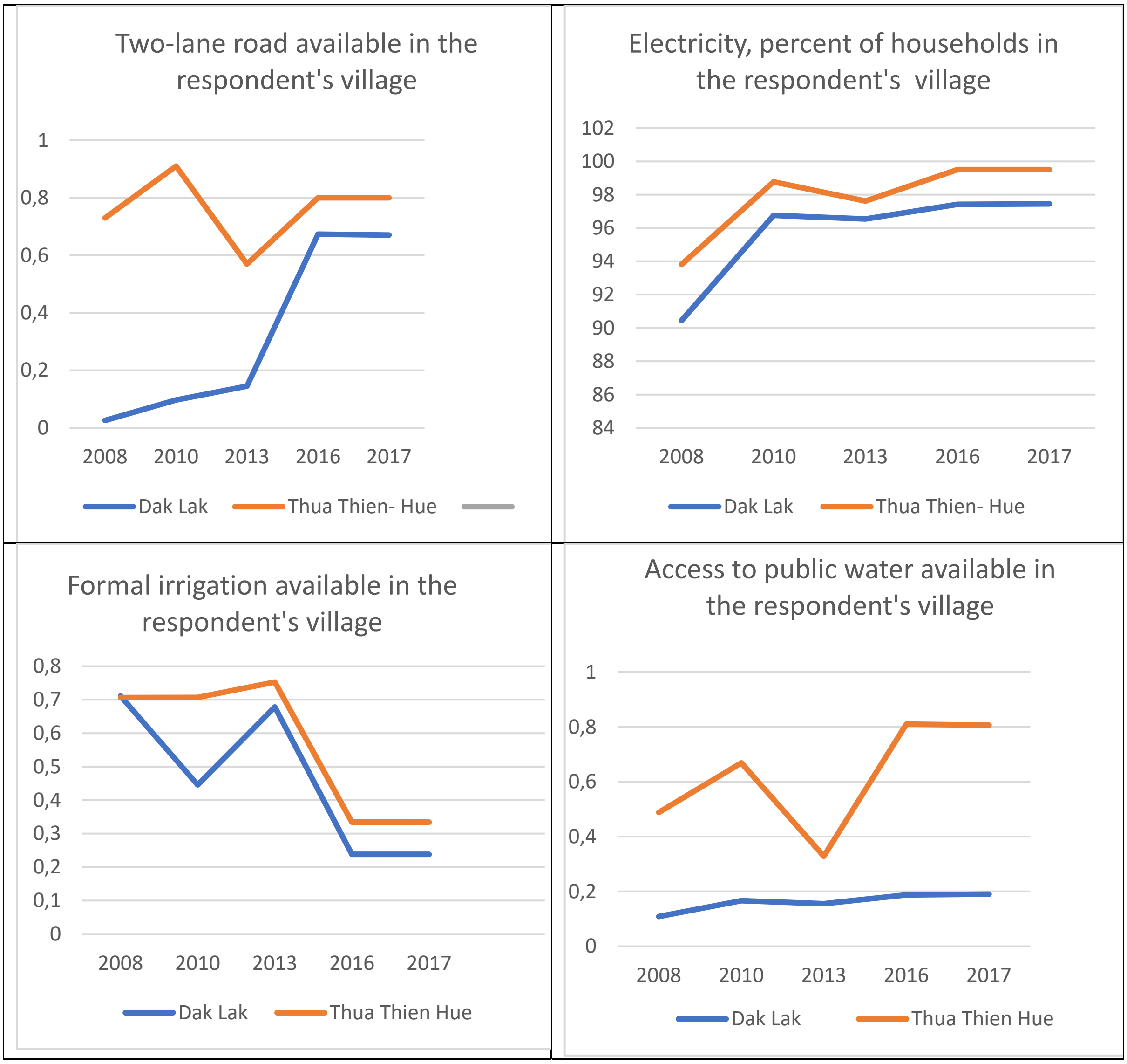
| | Treatment Province |
|---|---|
| Age | .004 |
| | (.005) |
| Years education | -.015 |
| | (.018) |
| Female | -.107 |
| | (.136) |
| Married | .062 |
| | (.232) |
| Household size | .043 |
| | (.036) |
| Dependency ratio | .04 |
| | (.094) |
| Acres land owned | -.073*** |
| | (.022) |
| Assets index | -.217*** |
| | (.043) |
| Irrigation | -.311** |
| | (.134) |
| Two-lane road | 2.743*** |
| | (.154) |
| Public water | 1.853*** |
| | (.151) |
| Electricity (% hh) | .002 |
| | (.003) |
| _cons | -1.686*** |
| | (.533) |
| Observations | 917 |
| Pseudo $R^2$ | .564 |

*Robust standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

Unfortunately, propensity score matching accounts only for selection on observed characteristics and ignores several potential econometric problems that could have important implications for the interpretation of our results. In what follows we discuss each of these problems and provide corresponding robustness checks in section 5.

The first problem that needs addressing is our identification strategy, namely that treatment assignment is exogenous to different risk tolerances. In a first step, we check whether the villages within the districts of our treatment and control provinces differ in important infrastructure indicators over the course of the surveys. As Figure 3 shows, there is convergence only for two-lane roads. All other indicators show parallel trends, with Thua Thien-Hue (the treatment province) having generally better characteristics. It is thus safe to conclude that a possible convergence of the risk tolerances in these two provinces is not driven by the convergence of these indicators. Moreover, to account for the possibility that differences in risk preferences in the two areas are influenced by differences in such infrastructure indicators, we control for district fixed effects in our analysis.

**Figure 3: Convergence of key indicators in the provinces**




Note: The information, presented on this diagram is provided by village heads. In the case of roads, irrigation and public water it is measured as availability at the village level, thus indicating proportion of villages in each of the provinces of interest that have access to either of these indicators. In the case of electricity availability, this is a mesure of percentage of individuals in each village that have access to water.

Second, it is important to isolate the effect of potential exposure to Agent Orange from other elements of the war such as combat and bombings on the formation of risk tolerances. To address this issue, we partition the data to include only those born after 1975 for a robustness check, and compare the results obtained from this partitioned set with the full sample. This partitioning procedure has been conducted in empirical analysis of the link between exposure to Agent Orange and health outcomes before[34], and given the end of the war in April 1975, we can attribute the observed risk tolerances of the partitioned sample to exposure from Agent Orange alone.

The partitioned data is then used to locate individuals who were differentially exposed to dioxin contamination by ranking the districts within Thua Thien-Hue (9 districts) and Dak Lak (13 districts) according to the intensity of Agent Orange spraying using publicly available data from the Agent Orange Data Warehouse[35]. This disaggregation allows for a stronger test of causality between potential exposure to Agent Orange and risk tolerances as compared to our baseline treatment-control province-based analysis conducted with the unpartitioned sample. As we note in Table 1, this level of disaggregation is also important since districts within the treatment province are approximately 10 times more affected by Agent Orange spraying than districts within the control province. However, due to significant re-configuration of villages between the time of the war and the time of the surveys in 2008, it is impossible to work with spraying intensity at the village level. We thus aggregate the gallons of Agent Orange sprayed to the district level; and even at the district level, re-configuration within the provinces results in a loss of five districts from our sample used for the baseline treatment-control province-based analysis.

Third, a serious endogeneity concern is that the intensity of Agent Orange spraying was non-random. This issue of endogeneity has been addressed through an instrumental variables (IV) approach by various authors exploring the impact of either Agent Orange spraying or bombings during the Vietnam War on long-term health and socio-economic indicators. Common instruments (variables that are correlated with the intensity of Agent Orange spraying or bombings but not with the outcome variables like health or poverty) include the proximity of a commune (sub-district) to the presence of a North Vietnamese Army (NVA) base identified in U.S. intelligence reports or the distance of a district from the 17$^{th}$ parallel near which the intensity of bombings was the highest. We instead use as an instrument a variable that is directly related to the effective delivery of Agent Orange: the minimum distance (in Kilometers) of a district's center from one of the three airbases - Bien Hoa, Phu Cat and Da Nang - from which Agent Orange spraying missions under 'Operation Ranch Hand' was conducted.

Finally, selective migration at the time of spraying could invalidate the instrument by affecting the composition of the sample. For example, more risk-averse individuals and their families might have migrated during the war (and because of Agent Orange spraying), generating a significant association between risk preferences and the minimum distance from an airbase. To verify that this is not an issue, we construct district level birth cohort sizes for the years of intense Agent Orange spraying (1965-1970) and regress them on the gallons of Agent Orange sprayed in the respective districts over the corresponding years as an additional robustness check.

## 4. Baseline results

Detailed empirical analysis of the determinants of risk tolerance and willingness to invest across the treatment and control provinces is presented for the whole sample, as well as for the matched sample accounting for the potential of individuals to self-sort across these provinces (Table 3).

**Table 3: Sorting of individuals across the treatment and control provinces**

| | Full sample | | | Matched sample | | |
|---|---|---|---|---|---|---|
| | Risk tolerance | Risk-averse dummy | Willingness to invest | Risk tolerance | Risk-averse dummy | Willingness to invest |
| Agent Orange area | 4.572*** | -.709*** | .251 | 2.862*** | -.42*** | 1.552 |
| | (.32) | (.061) | (.166) | (.923) | (.136) | (1.266) |
| Trend | 1.267*** | -.189*** | .92*** | 1.287*** | -.191*** | .903*** |
| | (.038) | (.006) | (.022) | (.042) | (.007) | (.026) |
| Agent Orange area*trend | -1.202*** | .161*** | -.159*** | -1.186*** | .171*** | -.18*** |
| | (.056) | (.009) | (.029) | (.069) | (.012) | (.036) |
| Age | .009** | 0 | -.001 | .011** | -.001 | 0 |
| | (.004) | (.001) | (.002) | (.005) | (.001) | (.002) |
| Years of education | .059*** | -.007*** | .006 | .049*** | -.007*** | .01 |
| | (.011) | (.002) | (.006) | (.014) | (.002) | (.007) |
| Healthy | .239*** | -.007 | .358*** | .315*** | -.01 | .363*** |
| | (.091) | (.016) | (.053) | (.116) | (.02) | (.068) |
| Farmer | -.21** | .045*** | .047 | -.201 | .044** | .038 |
| | (.099) | (.017) | (.05) | (.123) | (.021) | (.063) |
| Non-agro employee | -.079 | -.002 | .243** | -.103 | -.002 | .26** |
| | (.201) | (.033) | (.112) | (.256) | (.043) | (.126) |
| Married | .632*** | -.088*** | .049 | .606*** | -.086*** | -.071 |
| | (.141) | (.024) | (.071) | (.179) | (.03) | (.091) |
| Female | -.274*** | .037** | -.441*** | -.362*** | .04** | -.418*** |
| | (.091) | (.016) | (.045) | (.11) | (.019) | (.054) |
| Household size | -.023 | .002 | -.021* | -.058** | .007 | -.023 |
| | (.024) | (.004) | (.011) | (.029) | (.005) | (.014) |
| Dependency ratio | -.122* | .024** | -.107*** | -.16* | .03** | -.094** |
| | (.069) | (.011) | (.033) | (.084) | (.014) | (.039) |
| Household shock | .027 | .014 | -.247*** | .067 | .01 | -.29*** |
| | (.072) | (.012) | (.035) | (.087) | (.014) | (.044) |
| Covariate shock | .105 | .003 | -.13*** | .24*** | -.013 | -.121*** |
| | (.067) | (.011) | (.032) | (.08) | (.014) | (.041) |
| Constant | -.012 | 1.076*** | -.475** | .254 | 1.083*** | -1.443 |
| | (.398) | (.069) | (.201) | (.592) | (.096) | (1.271) |
| Observations | 4025 | 4025 | 4025 | 2720 | 2720 | 2720 |
| R-squared | .301 | .233 | .531 | .37 | .285 | .54 |

*Robust standard errors are in parentheses, 21 district fixed effects controlled for*
**** p<.01, ** p<.05, * p<.1*

The results are consistent across the two sets of estimates as well as with common intuition. Importantly, as indicated by the results reported in columns 1 and 2 of each set, individuals in the treatment province are characterized by significantly greater levels of risk tolerance, even though their willingness to invest is not significantly different from that of the individuals in the control province (at least in the conventional statistical sense). The interaction between treatment province and trend shows a decrease in risk tolerance, but continued lower willingness to invest among residents of the treatment province compared to residents of the control province. The rest of the results are broadly consistent with intuition: risk tolerance is an increasing function of education and health, females are less risk tolerant and less willing to invest, dependency ratios decrease the tolerance to risk, and shocks of both idiosyncratic and covariate nature tend to decrease the willingness to invest.

## 5. Robustness checks

Since our province-based baseline treatment-control analysis does not allow us to account for the effect of unobserved heterogeneity, in Table 4 we first provide a robustness check based on partitioning the sample to those born after 1975 and accounting for the actual intensity of spraying at the district level. The first three columns of Table 4 report the results based on the un-instrumented gallons of Agent Orange spraying while the last three columns report the results after instrumenting the spraying intensity in a district with the minimum distance of the center of the district from one of the three airbases used for the spraying missions. Table S2 shows that our instrument is a highly significant predictor of the intensity of Agent Orange spraying thereby establishing its validity. The results, reported in Table 4 are consistent with our baseline results in Table 3, the only difference being that the interaction between the gallons of Agent Orange sprayed and the trend for the measure of willingness to invest is not significant. The results, based on the un-partitioned sample are provided in the Appendix (Table S3) and are consistent with those reported in Table 4.

**Table 4: Robustness checks with intensity of spraying and instrumentation (partitioned sample)**

| | Uninstrumented | | | Instrumented | | |
|---|---|---|---|---|---|---|
| | Risk tolerance | Risk averse dummy | Willingness to invest | Risk tolerance | Risk averse dummy | Willingness to invest |
| Gallons AO | .766*** | -.128*** | .091 | 1.502*** | -.181*** | .098 |
| | (.165) | (.027) | (.057) | (.309) | (.047) | (.106) |
| Trend | 1.115*** | -.178*** | .841*** | 1.472*** | -.204*** | .844*** |
| | (.129) | (.019) | (.061) | (.157) | (.026) | (.077) |
| Gallons*trend | -2.225*** | .387*** | -.262 | -4.154*** | .525*** | -.279 |
| | (.475) | (.075) | (.219) | (.83) | (.126) | (.325) |
| Age | .068*** | -.013*** | .029** | .062*** | -.012*** | .029** |
| | (.022) | (.004) | (.012) | (.023) | (.004) | (.011) |
| Years education | .04 | -.008* | .009 | .022 | -.007 | .009 |
| | (.029) | (.005) | (.013) | (.03) | (.005) | (.013) |
| Healthy | .107 | -.002 | .447*** | .08 | 0 | .447*** |
| | (.233) | (.04) | (.118) | (.236) | (.04) | (.117) |
| Farmer | -.338 | .064 | .261** | -.443 | .072 | .26** |
| | (.286) | (.047) | (.128) | (.293) | (.048) | (.127) |
| Non-agro employee | -.419 | .005 | .323 | -.383 | .002 | .323 |
| | (.545) | (.077) | (.231) | (.562) | (.076) | (.229) |
| Married | -.259 | .076 | .173 | -.164 | .07 | .173 |
| | (.323) | (.056) | (.143) | (.338) | (.056) | (.141) |
| Female | .044 | -.014 | -.339*** | -.009 | -.01 | -.339*** |
| | (.21) | (.036) | (.104) | (.21) | (.035) | (.104) |
| Household size | .015 | .011 | -.041 | .049 | .008 | -.041 |
| | (.085) | (.014) | (.036) | (.085) | (.014) | (.036) |
| Dependency ratio | -.253 | .002 | -.029 | -.203 | -.002 | -.029 |
| | (.178) | (.031) | (.098) | (.181) | (.031) | (.097) |
| Household shock | .028 | .025 | -.163** | .031 | .024 | -.163** |
| | (.149) | (.025) | (.066) | (.153) | (.025) | (.065) |
| Covariate shock | -.119 | .025 | -.173*** | -.175 | .029 | -.174*** |
| | (.143) | (.024) | (.061) | (.142) | (.024) | (.061) |
| _cons | -.261 | 1.235*** | -1.743*** | -1.479 | 1.323*** | -1.754*** |
| | (.943) | (.156) | (.436) | (1.048) | (.17) | (.459) |
| Sargan overid test | | | | 1.7516 | .224531 | 1.7688 |
| | | | | (p = 0.1857) | (p = 0.6356) | (p = 0.4130) |
| Observations | 638 | 638 | 638 | 638 | 638 | 638 |
| R-squared | .213 | .21 | .558 | .213 | .21 | .558 |

*Robust standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*
*Note that the Gallons AO variable in both this table and all other tables where it appears is rescaled by dividing it by 10000.*

A second robustness check relates to the possibility of migration invalidating the instrument. To check for this, we link the cohort of individuals born in the 1965-70 period (when intensive Agent Orange spraying was undertaken) by year of birth and district of residence to the intensity of Agent Orange spraying by year and district. Controlling for district level indicators (number of two-lane roads and access to electricity, public water, and irrigation), our results indicate that there is no significant association between the intensity of spraying and the size of the district level birth cohorts in both the un-instrumented (column 1) and the instrumented (column 2) regressions in Table 5.

**Table 5: Testing for the potential effect of selective migration at the time of spraying**

| | OLS<br>Cohorts size | IV<br>Cohorts size |
|---|---|---|
| Gallons AO | .225 | -5.265 |
| | (.291) | (4.784) |
| Irrigation | -8.436 | -37.635 |
| | (5.317) | (29.224) |
| Two-lane road | 17.404*** | 51.776 |
| | (5.845) | (35.543) |
| Public water | -.796 | -3.807 |
| | (4.98) | (15.104) |
| Electricity percent | .83** | 2.71 |
| | (.374) | (1.916) |
| Constant | -77.631** | -250.284 |
| | (35.091) | (176.994) |
| Observations | 45 | 45 |
| R-squared | .416 | . |
| Sargan overid | | (p = 0.4821) |

*Robust standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

## 6. Conclusion

To the best of our knowledge, this is the first paper to analyze both risk tolerances of individuals residing in a province heavily affected by the spraying of Agent Orange during the Vietnam War as well as tracking the evolution of these risk tolerances over time.

Our finding that residing in a man-made disaster zone is positively associated with greater risk tolerance is similar to existing studies that have assessed risk tolerances of individuals living near nuclear waste sites or exposed to civil wars. The finding that changes in the risk tolerances of individuals residing within the disaster zone mirror the decreasing impact of the disaster over time is new, and provides one of the first examples of risk tolerances adapting to changes in the physical environment. We are also able to identify the self-insurance motive behind residence choices via a matching model to show that large land and durable asset holdings significantly influence the propensity of individuals to sort out of the disaster-affected province. Finally, we shed light on some interesting behavioral responses to man-made disasters, such as the fact that while risk tolerance might fall over time, the willingness to invest may continue to show a downward trend. While we only indirectly touch on the debate about migration from areas affected by disasters, our results highlight the complexity of this choice and its connection to socio-economic inequalities. Importantly, assets increase the chances that better-off individuals will migrate out of the affected area.

## Supplementary Robustness Check

### Table S1: Balancing test 1

| | Standardized differences | | Variance ratio | |
|---|---|---|---|---|
| | Raw | Matched | Raw | Matched |
| Age | 0.065 | 0.254 | 1.171 | 1.448 |
| Years education | -0.111 | 0.065 | 1.119 | 1.091 |
| Female | 0.111 | 0.219 | 1.057 | 1.132 |
| Married | -0.019 | -0.251 | 1.055 | 1.836 |
| Household size | -0.049 | -0.180 | 0.827 | 0.990 |
| Dependency ratio | 0.166 | -0.229 | 1.338 | 1.095 |
| Acres owned land | -0.056 | -0.069 | 5.967 | 3.040 |
| Assets index | -0.061 | 0.240 | 0.997 | 0.783 |
| Irrigation | -0.089 | -0.245 | 1.087 | 1.311 |
| Two lane road | 1.893 | -0.012 | 6.699 | 0.991 |
| Public water | 0.967 | 0.341 | 2.728 | 1.664 |
| Electricity percent | 0.183 | 0.056 | 0.767 | 1.164 |

### Figure S1: Balancing test 2

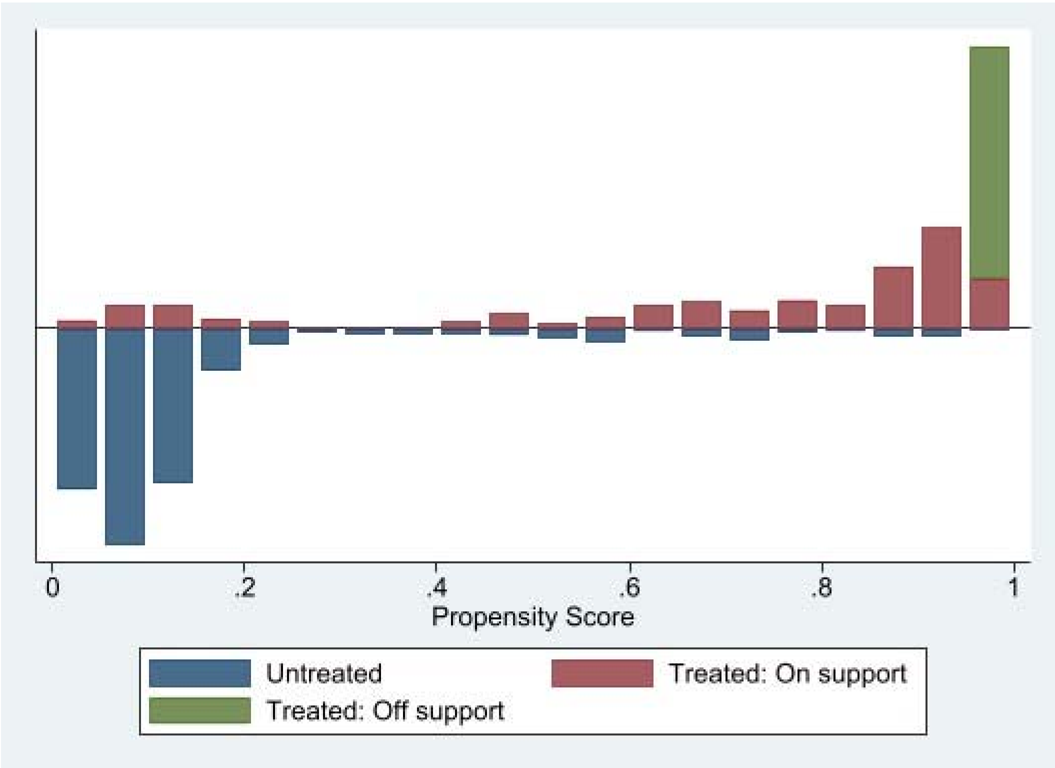


**Table S2: Test for significance of the instrument**

| | Gallons AO sprayed |
|---|---|
| Minimum distance from a military base | -.012*** |
| | (0) |
| _cons | 2.53*** |
| | (.041) |
| Observations | 3923 |
| R-squared | .164 |

*Robust standard errors are in parentheses*

**** p<.01, ** p<.05, * p<.1*

## Table S3: Replication of Table 4 with the full sample

| | Uninstrumented | | | Instrumented | | |
|---|---|---|---|---|---|---|
| | Risk tolerance | Risk-averse dummy | Willingness to invest | Risk tolerance | Risk-averse dummy | Willingness to invest |
| Gallons AO | .83*** | -.138*** | .057* | 3.074*** | -.389*** | .083 |
| | (.094) | (.016) | (.031) | (.236) | (.035) | (.078) |
| Trend | .89*** | -.146*** | .896*** | 1.644*** | -.23*** | .904*** |
| | (.053) | (.008) | (.026) | (.08) | (.013) | (.037) |
| Gallons*trend | -2.25*** | .392*** | -.279** | -8.361*** | 1.075*** | -.348 |
| | (.278) | (.044) | (.131) | (.654) | (.097) | (.237) |
| Age | .012*** | -.002** | -.005** | .019*** | -.003*** | -.005** |
| | (.004) | (.001) | (.002) | (.005) | (.001) | (.002) |
| Years education | .048*** | -.006*** | .006 | .045*** | -.006** | .006 |
| | (.014) | (.002) | (.007) | (.015) | (.002) | (.006) |
| Healthy | .476*** | -.056*** | .397*** | .477*** | -.056*** | .397*** |
| | (.11) | (.019) | (.06) | (.122) | (.02) | (.06) |
| Farmer | -.388*** | .062*** | .177*** | -.417*** | .065*** | .176*** |
| | (.119) | (.019) | (.057) | (.128) | (.02) | (.057) |
| Non-agro employee | -.211 | -.016 | .071 | -.277 | -.008 | .071 |
| | (.272) | (.04) | (.134) | (.288) | (.04) | (.134) |
| Married | .581*** | -.113*** | .064 | .681*** | -.124*** | .065 |
| | (.163) | (.027) | (.079) | (.187) | (.029) | (.079) |
| Female | -.2* | .021 | -.411*** | -.221* | .023 | -.411*** |
| | (.112) | (.019) | (.052) | (.126) | (.02) | (.051) |
| Household size | .032 | 0 | -.008 | .046 | -.001 | -.007 |
| | (.03) | (.005) | (.013) | (.032) | (.005) | (.013) |
| Dependency ratio | -.136* | .027** | -.113*** | -.136 | .027* | -.113*** |
| | (.083) | (.013) | (.038) | (.088) | (.014) | (.038) |
| Household shock | .071 | .006 | -.268*** | .059 | .008 | -.269*** |
| | (.07) | (.012) | (.031) | (.076) | (.012) | (.031) |
| Covariate shock | .031 | .014 | -.159*** | -.071 | .025** | -.16*** |
| | (.07) | (.012) | (.031) | (.074) | (.012) | (.031) |
| _cons | 1.202*** | .936*** | -.463** | -1.928*** | 1.285*** | -.499** |
| | (.442) | (.07) | (.196) | (.53) | (.083) | (.213) |
| | | | | 2.81025 | .40347 | 43.3595 |
| | | | | (p = 0.0937) | (p = 0.5253) | (p = 0.0000) |
| Sargan overid | | | | | | |
| Observations | 2975 | 2975 | 2975 | 2975 | 2975 | 2975 |
| R-squared | .158 | .144 | .502 | | .062 | .502 |

*Robust standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

Note: The willingness to invest measure does not pass the Sargan test for overidentification. In addition, the R-squared for the instrumented risk tolerance measure is not reported by STATA. This happens if the R-squared (or the model sum of squares (MSS)) is negative. For 2SLS/IV estimations there is no guarantee that the sum of residuals squared (RSS) are less than the total sum of squares (TSS). Since R-squared = MSS/RSS with MSS = TSS – RSS, a negative MSS leads to R-squared being unreported.

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