# The Behavioral and Psychological Consequences of a Nuclear Catastrophe: The Case of Chernobyl

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Abstract

In modern economics, preferences are the unmoved movers of economic and social behavior. They are taken as given such that all social phenomena need to be explained by changes in beliefs or constraints. The assumption of given preferences constitutes however merely a convenient assumption that is not supported by evidence. Here, we examine the impact of radiation fallout after the nuclear catastrophe on the preferences and beliefs of the Ukrainian population. As the geographical distribution of radiation is essentially randomly determined by local and regional weather conditions, the radiation fallout after the catastrophe in Chernobyl constitutes a natural experiment. We find that people who were subjects to higher radiation after the catastrophe display stronger risk aversion and a higher discounting of future returns. They save less, are less entrepreneurial, are much less inclined to support democratic political institutions and market economies, and they engage less in political and civic activities. Because we exclude the people in the vicinity of Chernobyl from our sample, the radiation fallout "consumed" by our sample population is very low – comparable to the exposure of an average individual during one year in a non-contaminated environment. It is therefore highly unlikely that the direct health consequences of radiation fall out affect people's economic and political preferences. It rather seems that the impact is purely psychologically mediated and due to the pervasive uncertainty or fear stemming from the imagined future consequences associated with physically unnoticeable and unseizable radiation fall-out.



Keywords: preferences, behavior, risk taking, nuclear accidents, quasi-experiment

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> “The worst disease here is not radiation sickness. […] The truth is that the fear of Chernobyl has done much more damage than Chernobyl itself.”
> (Richard Wilson, professor of physics at Harvard University in the NYT, 1996)

In modern economics, preferences are the unmoved movers of economic and social behavior. They are taken as given such that all social phenomena need to be explained by changes in beliefs or constraints. The assumption of given preferences constitutes however merely a convenient assumption that is challenged by recent empirical evidence. In particular, experimental and quasi-experimental studies suggest that preferences are shaped by institutional, political and cultural factors as well as by market characteristics (e.g., Fehr and Hoff 2011; Fuchs-Schündeln and Schündeln 2015). Behaviorally revealed preferences also seem to adapt to individual economic contexts, e.g., poverty, and are influenced by exposure to war and violent conflict (Callen et al. 2014; Haushofer and Fehr 2014; Voors et al. 2012).

In this paper we demonstrate long-run changes in behaviorally revealed preferences and political and economic beliefs in the aftermath of the Chernobyl catastrophe in 1986, the biggest nuclear catastrophe to date. As the geographical distribution of radiation is essentially randomly determined by local and regional weather conditions, the radiation fallout after the explosion of one of the reactors of the nuclear power plant of Chernobyl constitutes a natural experiment. We use unique and nationally representative survey data from Ukraine about 20 years after the disaster and match local radiation exposure to survey participants based on their place of residence at the time of the nuclear catastrophe. To prevent possible selection bias, we exclude from our sample the 4 percent of the Ukrainian population which was affected by high to very high radiation fallout (e.g., residents in the vicinity of the reactor, clean-up workers). Instead, we focus on the 96 percent of the Ukrainian population which was affected by very low levels of radiation exposure.

We find that 20 years after the disaster, more affected individuals are more risk averse and have a higher discount rate. Moreover, these individuals save less, are more in favor of a

„risk free economic environment“ and a „strong state“ and are less politically active. However, we do not interpret our findings as causal effects of nuclear radiation itself as individuals in our sample were affected by subclinical radiation exposure, comparable to the exposure of an average individual during one year in a non-contaminated environment. It is therefore highly unlikely that the direct health consequences of radiation fall out affect people's economic and political preferences. It rather seems that the impact is purely psychologically mediated and due to the pervasive uncertainty or fear stemming from the imagined future consequences associated with physically unnoticeable and unseizable radiation fall-out. Shortly after the accident, Soviet authorities introduced a series of radiation-protection countermeasures. The intensity of these measures—which mirrored the geographic distribution of radioactive exposure—signaled the likely treatment status to an otherwise uninformed population. The secretive and contradictory information policy of the authorities as well as the lack of consensus among scientists gave room for rumors and fear which spurred extreme uncertainty about the actual and potential consequences of the disaster (Abbott, Wallace and Beck 2006; Bromet 2012; Rahu 2003).

Our paper contributes to the literature threefold: First, we show that a large-scale disaster can shift human behaviour and beliefs related to preferences in the long-run. While recent research has pointed to the endogeneity of preferences in the short-run and different circumstances (civil war), we show the persistence of such shifts after twenty years. Second, we identify an anxiety effect from industrial disasters by focusing on a population that was only subclinically affected by radiation and that did not experience resettlement. In fact, we show that signals from countermeasures taken by the Soviet authorities after the catastrophe led to a situation which we call ‘uncertain treatment’: Individuals neither knew their actual treatment status, nor could reliably understand the consequences of a given radiation intensity. Nevertheless, we find significant long-term effects of such ineffectual treatment pointing to the fear channel. Third, we show that increased fear and anxiety in the aftermath of catastrophes affects economically relevant behavior in the long-run.

The remainder of the paper is structured as follows: Section 1 describes the nuclear catastrophe of Chernobyl as a natural experiment. Section 2 addresses the role of fear following the disaster. It describes theoretically the impact of the disaster on individual behavior through signals received through countermeasures taken by the Soviet authorities. Section 3 describes the unique data set and our methodology for identifying how Chernobyl causally affected behaviorally revealed preferences and beliefs. Section 4 presents and discusses the results. Section 5 concludes.

## 1. The nuclear catastrophe as a natural experiment

### 1.1. Catastrophe of Chernobyl

April 26, 1986, marks the day of the biggest civil nuclear accident to date. The explosion of one block of the nuclear reactor of Chernobyl released unprecedented amounts of radioactive matter, contaminating—among others—vast areas of what later became independent Ukraine. Local wind direction, rainfall patterns and geomorphological surface structures dispersed fallout from radioiodine-131 and radiocaesium-137 in unpredictable manner (Fig. A-1 in the Appendix). The catastrophe was exogenous and unanticipated and the subsequent contamination was not a monotonic function of distance to Chernobyl (Lehmann and Wadsworth 2011; Danzer and Danzer 2016).

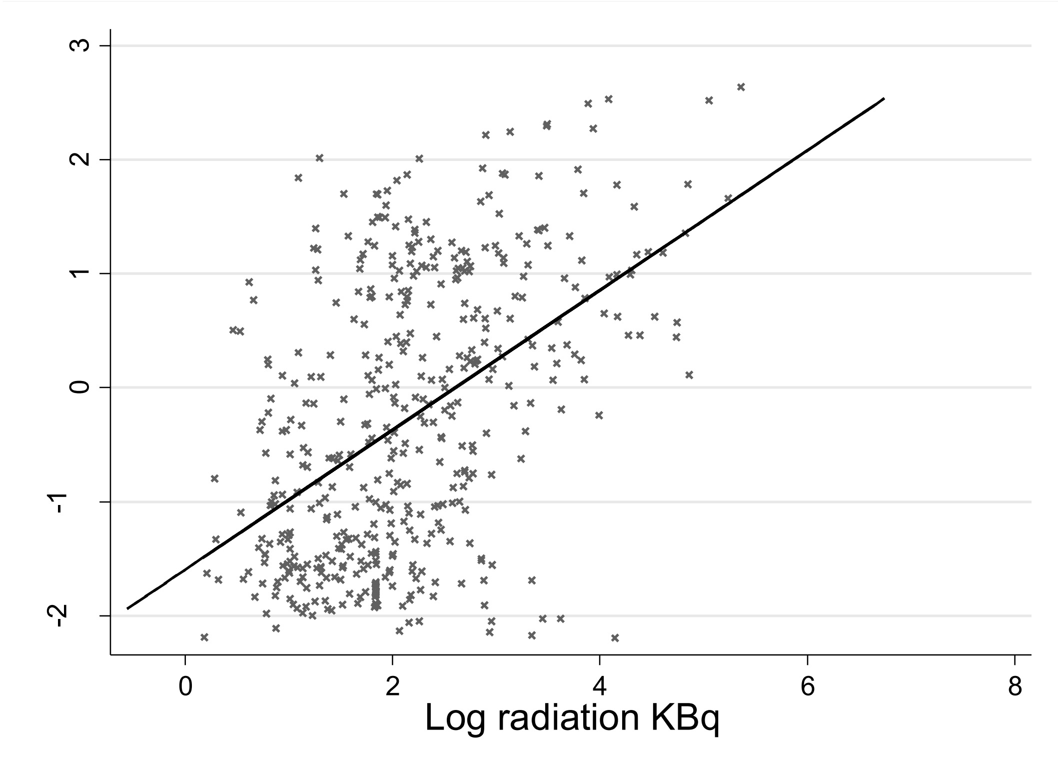
The consequences of the disaster have been persistent and costly. More than 20 years on, annual operation, compensation and health care costs amount to 5-7% of the Ukrainian GDP, with estimated uncompensated mental health costs in almost the same range (Danzer and Danzer 2016). Bearing in mind that the environmental and social impact of Chernobyl remains hard to quantify in the long-run, the uncertainties regarding scale and scope of the disaster were even less well understood at the time of the disaster. Three uncertainties prevailed in 1986: First, the local exposure to radioactivity was unknown to the population. Since the Soviet authorities initially kept the disaster secret and later played it down, ordinary citizens (i.e., those who did not undergo outright screening as liquidator or clean-up worker of the disaster) would not know their radiation dose. Second, if the degree of radiation exposure was known, the actual health consequences for the population were uncertain. With the exception of those suffering from radiation sickness (again, the liquidators) little scientific and medical experience was available to understand the health risks. Third, the possibility of an outbreak of a disease and the individual health implications remain ultimately uncertain due to the nature of radiation as "slow poison". Cancer, the most feared health condition after radioactive exposure, tends to materialize over years or even decades without immediate manifestation. Hence, we call the Chernobyl disaster "uncertain treatment".

The Soviet authorities, which hastily built up a regional network of radiation measurement facilities directly after the disaster, decided not to pass that information on to residents of the most affected areas. Despite the information embargo, the government initiated large-scale countermeasures to curtail the impact of the catastrophe. These security measures implicitly signalized information about the population's degree of radiation exposure. Indeed, the intensity of countermeasures was geographically highly correlated with the level of radioactive fallout (see Appendix A). Among the most salient countermeasures were the distribution of almost 6 million doses of Potassium Iodide prophylaxis (Mettler et al. 1992) and the collection of several hundred thousand thyroid measurements and blood test which had much better coverage in more affected areas (Likhtarev et al., 1994).[4] Fig. 1 shows the positive correlation between radioactive fallout and the intensity of blood measurements (normalized by population per square kilometer) at the level of Ukrainian raions (second level administrative division). When regressing the density of blood tests on the radiation level we find that radiation explains 47% of the geographic variation in the screening intensity.

Almost thirty years after the disaster, it has become clear that the catastrophe affected the Ukrainian population unevenly: On the one hand, there is a highly contaminated group containing fire-fighters, rescue personnel and recovery workers (so called 'liquidators') as well as those who used to live in close proximity to the reactor and have been resettled to other parts of the country. Overall, this group comprises about 4% of the total population and has in part received significant (i.e., clinical, sometimes lethal) radiation doses. On the other hand, there are the remaining 96% of population which has received at most very low radiation levels from radioactive fallout, on average comparable to half the annual level of background radiation prevalent in Ukraine, or 10 chest x-ray scans per year. The state-of-the-art medical literature is explicit that the low doses of ionizing radiation received by the general population are subclinical, i.e., they cause neither physical nor neurological damage (UNSCEAR 2000; 2008). In our empirical analysis we will exclusively focus on the latter group to rule out possibility that the disaster effect reflects a deterioration of the objective health status. Unlike physical health, the Chernobyl disaster has significantly affected mental health with more strongly affected individuals reporting lower levels of life satisfaction and subjective health as well as higher depression rates (Danzer and Danzer 2016; Lehmann and Wadsworth 2011).

[4] Additional salient signals about the local impact of the disaster were the compulsory registration efforts for Chernobyl registries after mid-1986 in all more affected areas (UNSCEAR 2000: 490); the establishment of (partly mobile) cancer screening facilities between 1986 and 1996 which gave rise to rumors about disastrous health consequences (Baloga, Kholosha, and Evdin 2006; Gould 1990); the widespread screening measures for locally (and even privately) produced food and dairy products (Firsakova, 1993; Likhtarev et al., 1994; UNSCEAR 2008: 74); and, finally, the distribution of resettled families across Ukraine.

**Fig. 1. Correlation between regional radiation levels and density of countermeasures**




Source: Data compiled from European Commission (1998).

## 1.2. Radioactive fallout as natural experiment

The geographic distribution of radioactive fallout after Chernobyl was random, due to unanticipated and random weather conditions. This source of exogeneity has been exploited in a number of other studies before (Edlund et al. 2007; Lehmann and Wadsworth 2011; Danzer and Danzer 2016).

The strength of our natural experiment rests on our ability to rule out (1) structural differences between more and less affected areas prior to the disaster, (2) selection into the treatment, (3) selective long-run survival, and (4) differences with respect to physical health.

First, if radiation was truly exogenous, we should not observe significant differences in outcomes across more and less affected regions on the eve of the catastrophe. The assessment in Appendix A shows that this is indeed the case.

Second, residential choices must be unrelated to the distance to the Chernobyl nuclear power plant. Geographic selection of the population with respect to risk preferences is not plausible given Soviet secrecy regarding the location of strategically important and sensitive sites and the lack of knowledge regarding the potential consequences of a nuclear catastrophe. Also, self-selection into recovery work could be problematic as it increased the radiation exposure. Although the deployment of military personnel and firefighters for disaster relief is inconsistent with endogenous self-selection (note, the selection into specific occupations may not be), we exclude liquidators from our analysis altogether.

Third, liquidators may suffer from long-run physical impairments which potentially affect their morbidity and mortality. Hence, liquidators participating in the survey might represent a selected subsample of all liquidators. However, the exclusion of these individuals from our sample also solves this threat to identification.

Fourth, the level of RD is insufficient to argue for a health channel. In line with the previous medical literature and prior evidence by Danzer and Danzer (2016), we find no effect of the radiation dose on physical health outcomes, such as chronic diseases or illness (Table 1). Working age adults who received higher radiation doses are no more likely to report any health impairments of their work ability. This evidence, which is based on our estimation sample, clearly rejects the possibility that radiation is related to physical health outcomes, thus ruling out the health channel for any behavioral effects. In contrast, the observed effects are likely to be due to a psychological channel that operates via the subjective perception of having been affected by the catastrophe.

**Table 1: The impact on health**

| | (1)<br>Chronic disease | (2)<br>Illness | (3)<br>Health impairment of work ability |
|---|---|---|---|
| Radiation dose | 0.005 | -0.008 | 0.029 |
| | (0.041) | (0.045) | (0.035) |
| Male | -0.052* | -0.099*** | -0.007 |
| | (0.027) | (0.023) | (0.038) |
| Age | 0.012*** | -0.002** | 0.011*** |
| | (0.002) | (0.001) | (0.003) |
| Height | -0.002 | 0.000 | -0.001 |
| | (0.001) | (0.001) | (0.002) |
| Education mother high | -0.023 | -0.002 | -0.035 |
| | (0.039) | (0.033) | (0.026) |
| Education father high | -0.031 | -0.024 | -0.024 |
| | (0.027) | (0.028) | (0.028) |
| Household size | -0.014** | -0.009 | -0.014** |
| | (0.007) | (0.006) | (0.006) |
| Log household income | -0.011 | -0.008 | -0.007 |
| | (0.010) | (0.013) | (0.009) |
| Observations | 4,000 | 4,000 | 2,601 |
| R-squared | 0.221 | 0.245 | 0.170 |

Note: All regressions are linear probability models. Chronic disease is a dummy for suffering from at least one of the following: heart disease, illness of the lungs, liver disease, kidney disease, gastrointestinal disease, spinal problems, or another chronic physical disease; illness is a dummy for suffering from at least one of the following: diabetes, myocardial infarction, high blood pressure, stroke, anaemia, or tuberculosis. Regression (3)

is estimated for those in working age (women: age<55; men: age<60).
Robust standard errors clustered by 1986 radiation region in parentheses; *** p<0.01, ** p<0.05, * p<0.1

### 1.3. Chernobyl and fear

The disaster effects we attempt to measure are the result of fear or diffuse *angst* in the general population. As early as 1996, Richard Wilson, professor of physics at Harvard, suggested that the greatest impact of Chernobyl was fear in the population rather than radiation. Anecdotal evidence suggests that individuals with actually very low radiation levels have interpreted the prophylactic safety measures as indicators for serious radiation and health danger (Lee 1996: 301; UNSCEAR 2008). Since the objective level of individual radiation exposure is hard to assess without proper screening, the pure existence and intensity of countermeasures have unleashed psychological reactions: recipients have (wrongly) interpreted the pure fact of receiving treatment as proof of an existing serious health problem. Such perceptions can indeed cause sickness in the expectant, an effect known as nocebo in the medical literature (Hahn 1997). Such psychogenic rather than biological reactions are in line with finding of mental rather than physical health effects after Chernobyl by Danzer and Danzer (2016).

For a lack of suitable survey questions we cannot directly exploit measures of *angst*. Yet, we show that radiation is strongly positively associated with individuals' subjective perception of having been affected by Chernobyl, and negatively correlated with their contemporary satisfaction with life as well as their subjective future survival probability (up to a predefined survival age).

## 2. Methodology: Identifying fear effects

We use data of the Ukrainian Longitudinal Monitoring Survey (ULMS), a rich nationally representative panel data set. In its first wave, the survey contains detailed retrospective residential information concerning the year 1986—a crucial feature for matching individuals' places of residence with detailed official regional radiation data. Although recall periods are long, the retrospective information in the ULMS seems reliable as the survey employed memory-anchor techniques and cross-checked the reported information with information provided in the compulsory Soviet work books whenever available. Further, the ULMS contains individual-level information regarding liquidation work and resettlement—another crucial information to tailor our sample to those individuals who were technically unaffected by the accident. Although the Kiev International Institute of Sociology (KIIS) conducted the panel survey in three years (2003, 2004, and 2007) (for more details see Lehmann, Muravyev and Zimmermann 2012), we will predominantly focus on the wave 2007 which contains a large number of standard preference measures. In fact, the batteries on risk preferences and time discounting were designed after the German Socio-Economic Panel and are directly comparable to the ones used in the growing literature on survey-based measures of preferences (Dohmen et al. 2011).

We restrict the sample to individuals born before April 26, 1986—this excludes children in utero during the accident, since Almond, Edlund, and Palme (2009) demonstrate that prenatal exposure was potentially harmful. After excluding the potentially selectively assigned clean-up workers and the resettled population, the final sample is comprised of 4,000 observations.

Ideally, we would like to measure the extent of *angst* in individuals, but since the survey does not contain any measured of fear or *angst* we use radiation as a proxy. To measure the impact of the disaster, we use official regional radiation data provided in Baloga, Kolosha and Evdin (2006)[5] that we match to individuals based on their place of residence in the year 1986.[6] We focus on average effective total exposure doses of caesium-137, reflecting the energy absorbed by matter (measured in millisieverts, mSv). The radiation data stem from measurements at various locations; for instance, caesium-137 estimates are based on 30,000 white blood cell (WBC) measurements in 1986 across rural and urban locations in Ukraine. As initially stated, radiation doses in our study population are low and amount on average to one mSv for May-December of the year 1986. This equals half the natural annual background radiation.

Our identification strategy exploits the regional variation in radioactive fallout as an indicator for disaster exposure. We estimate the following model:

$$y_i = \beta_0 + \beta_1 Radiation_{86} + X'\gamma + \theta + \varepsilon_i. \qquad (1)$$

[5] Data are taken from the official report "20 Years After Chernobyl Catastrophe. Future Outlook: National Report of Ukraine," Tables 3.3.7 and 3.3.9 (Baloga, Kholosha, and Evdin 2006, pages 45, 47, 48).

[6] This procedure has been also carried out by Lehmann and Wadsworth (2011). However, in contrast to us, they assign a measure of surface contamination with caesium-137 measured in kilobequerels per square meter (kBq/sqm) to each individual. Furthermore, individuals who did not live on Ukrainian territory in 1986 (4.5% of the sample) were assigned zero exposure doses (none of these individuals originated from affected areas of Belarus or Russia). The results are robust to either assigning the minimum radiation value of the sample or omitting these observations (results not reported).

The outcome variable $y$ is either a self-reported preference indicator (e.g., willingness-to-take-risk), a more objective preference indicator derived from stated choices (e.g., the discount rate), or a behavioural indicator (e.g., the savings rate). Radiation is the level of radiation exposure individual $i$ was confronted with according to her place of residence in 1986 (standard errors are clustered at the oblast 1986 level). For ease of interpretation we express the radiation measure in terms of units of natural background radiation. The coefficient of interest is $\beta_1$, which measures the impact of one unit of natural background radiation on our outcome measures $y$ at time $t$. All regressions control for oblast (region) fixed effects $\theta$.

Without adding further controls for potential channels to the regressions, $\hat{\beta}_1$ captures the gross reduced form long-term effect of the nuclear accident on contemporary willingness-to-take-risks, time discounting or political/economic preferences. However, to account for possible channels through which Chernobyl might have affected long-term outcomes, different sets of control variables are included in $X$ one after the other. Initially, predetermined personal characteristics (gender and age[7]) are added to the regressions. This is followed by education and marital status, as well as proxies for the physical health status of individuals.[8] We also add a set of dummy variables for current labour force participation status, household size, log of per-capita household income, living space per capita as a proxy for permanent income or wealth and type of settlement (village, town, or city).

## 3. The behavioral impact of the nuclear catastrophe

### 3.1. The impact on risk taking

Our first assessment concerns the behaviorally relevant and subjectively stated risk preferences as measured by an individual's "willingness to take risks" on different domains. Survey respondents are asked: How do you see yourself. Are you generally a person who is fully willing to take risks or do you try to avoid taking risks? Please give me a number from 0 to 10, where the value 0 means: "Completely unwilling to take risks" and the value 10 means:

[7] While the literature has often assumed a u-shaped pattern between age and subjective well-being, we allow for greater flexibility by using age fixed effects.

[8] The health measures are (1) a dummy variable for all individuals having at least one of seven different chronic physical diseases (*chronic*: heart disease, illness of the lungs, liver disease, kidney disease, gastrointestinal disease, spinal problems, or other chronic illnesses) and (2) the individual's height (*height*). We also add measures of risky behaviour (*smoking* and *drinking*).

"Completely willing to take risks". The question in the ULMS was directly modelled after the GSOEP for which is has been successfully validated in behavioral experiments (Dohmen et al. 2011; for more information regarding the behavioral relevance, also consult the Figure in Appendix A). The cumulative distributions depicted in Fig. 1 illustrate a lower willingness to take risks among those with higher exposure to radioactive fallout: The function of those having received above-median radiation doses has clearly more mass at lower levels of risk taking.

**Fig. 1: Cumulative distribution General Willingness to Take Risk**

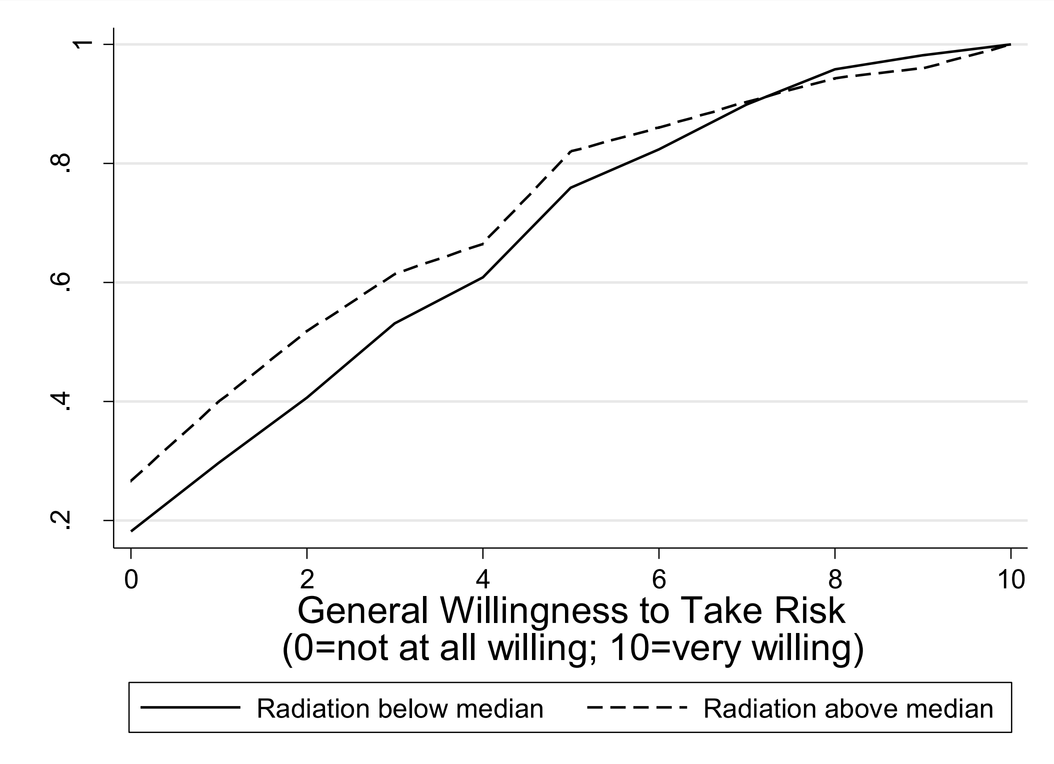



Table 1 shows our main result: RD is associated with lower willingness to take risk, no matter whether we use the general or domain specific concept. In fact, a one unit higher radiation level has similar negative effects on risk taking of 26-38% of a standard deviation across the five sub-domains (driving, finance, sport, job and health).

The results are also robust to the inclusion of further potentially endogenous control variables such as religion and health, as well as to the omission of potentially endogenous variables such as income, marital status, work status or living arrangements.

**Table 1: The impact of the Chernobyl catastrophe on risk taking**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|

| *Dependent variable* | *General WTR* | *WTR: driving car* | *WTR: finance* | *WTR: sport* | *WTR: job* | *WTR: health* |
|---|---|---|---|---|---|---|
| Radiation | -0.504*** | -0.284*** | -0.291*** | -0.384*** | -0.331*** | -0.264*** |
| | (0.103) | (0.099) | (0.080) | (0.116) | (0.109) | (0.094) |
| Male | 0.359*** | 0.458*** | 0.220*** | 0.303*** | 0.201*** | 0.202*** |
| | (0.032) | (0.054) | (0.042) | (0.050) | (0.051) | (0.040) |
| Age | -0.001 | -0.004 | 0.003 | 0.001 | -0.015*** | 0.014*** |
| | (0.004) | (0.005) | (0.003) | (0.004) | (0.004) | (0.003) |
| Height | 0.001 | -0.000 | 0.000 | 0.002 | 0.002 | 0.002 |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| Education mother | 0.135*** | -0.041 | 0.088 | 0.141** | 0.130 | 0.050 |
| | (0.041) | (0.070) | (0.066) | (0.063) | (0.076) | (0.056) |
| Education father | 0.000 | 0.056 | -0.069 | -0.037 | -0.038 | 0.024 |
| | (0.044) | (0.066) | (0.048) | (0.051) | (0.048) | (0.077) |
| Household size | -0.017 | -0.017 | 0.007 | -0.008 | -0.017 | -0.015 |
| | (0.016) | (0.018) | (0.019) | (0.016) | (0.014) | (0.016) |
| Log household inc | 0.040** | 0.038 | 0.034* | 0.045** | 0.063*** | 0.014 |
| | (0.019) | (0.033) | (0.019) | (0.021) | (0.021) | (0.021) |
| Observations | 4,000 | 2,126 | 3,716 | 3,126 | 2,904 | 3,861 |
| R-squared | 0.202 | 0.209 | 0.166 | 0.221 | 0.183 | 0.151 |

Notes: The dependent variables are standardized with mean zero and standard deviation one. Radiation is measured in units of natural background radiation (2 mSv). Regression control further for marital status, work status, health status, household living space per capita, month and year fixed effects, region and settlement type fixed effects. Robust standard errors clustered by 1986 residential region are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

As a robustness check of the impact of RD on risk taking we present evidence for two lottery measures. The first one stems from a survey question in which respondents are asked to divide a total amount of 100.000 Hryvnias (~20,000 US$) into a sum they would like to keep for sure and into a remaining amount to be put into a lottery which features a 50% chance to double the allocated amount and a 50% chance to lose half of the allocated amount. Respondents can allocate any multiple of 20.000 Hryvnias to the lottery. The expected value of putting the entire amount into the lottery is 125.000 UAH, which should prompt a risk neutral agent to allocate the entire amount to the gamble. The second measure stems from a hypothetical prize offer with two payment options: Respondents can either take a sure payment (of 40, 70, 100 or 130 UAH) or flip a coin and win either 200 UAH (~30 US$) if heads come up and receive nothing if tails comes up. We define a dummy variable for those individuals who are extremely risk averse, i.e. who already chose the sure payment of 40 UAH compared to the expected payout of 100 in the coin flip.

Respondents from areas with one more unit of RD allocate around 7,000 UAH (or 6% of the total amount) less to the risky lottery than comparable individuals with less radiation (Table 2). Similarly, more affected individuals are roughly 10 pp more likely to be extremely risk averse and, hence, prefer very low but safe payments compared to risky choices.

**Table 2: Lottery questions**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Amount put into gamble (in UAH) | | Extremely risk averse (0/1) Marginal effects from Probit | |
| Radiation | -7,423.9** | -7,605.8* | 0.098** | 0.142** |
| | (3,053.9) | (4,295.6) | (0.043) | (0.052) |
| Income pessimism | | -2,010.2 | | -0.023 |
| | | (2,507.3) | | (0.036) |
| Prefer centrally planned economy | | 3,935.9 | | 0.015 |
| | | (2,760.9) | | (0.025) |
| Trust in politicians | | 764.8* | | -0.024** |
| | | (442.0) | | (0.009) |
| Financial situation worse in 5 yrs | | 46.6 | | -0.000 |
| | | (52.1) | | (0.001) |
| Chance to work in the future | | 15.0 | | -0.001*** |
| | | (32.3) | | (0.000) |
| Male | 3,133.9 | 444.7 | -0.116*** | -0.108*** |
| | (2,020.1) | (2,007.5) | (0.022) | (0.027) |
| Age | 229.5 | 334.2 | -0.005** | -0.005* |
| | (187.5) | (218.6) | (0.002) | (0.003) |
| Height | 149.0 | 181.3 | 0.000 | 0.001 |
| | (116.7) | (129.9) | (0.001) | (0.002) |
| Education mother | 2,606.5 | 39.2 | -0.041 | -0.026 |
| | (2,332.1) | (2,645.4) | (0.039) | (0.046) |
| Education father | -652.1 | -1,317.3 | 0.001 | -0.007 |
| | (2,460.8) | (2,290.2) | (0.037) | (0.045) |
| Household size | 569.2 | 643.1 | 0.004 | 0.001 |
| | (774.7) | (1,016.0) | (0.008) | (0.010) |
| Log household income | 439.0 | 137.0 | -0.023* | -0.030 |
| | (581.3) | (1,156.7) | (0.012) | (0.019) |
| Observations | 3,611 | 2,040 | 3,455 | 2,000 |
| R-squared | 0.092 | 0.145 | 0.158 | 0.232 |

Notes: Radiation is measured in units of natural background radiation (2 mSv). Regression control further for marital status, work status, health status, household living space per capita, month and year fixed effects, region and settlement type fixed effects. Robust standard errors clustered by 1986 residential region are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

### 3.2. The impact on time discounting

We also test for the effect of radiation on personal time discounting. We use two separate questions on individual saving behavior. Individuals are proposed to receive either

10.000 Hryvnias 12 months after the survey date or a lower amount immediately (or, alternatively, in 11 months); then, they are asked to name the lowest amount of money they would accept now (in 11 months) rather than the full amount in 12 months. To make the two measures comparable, we annuitize both discount rates. Note, that average discount rates are quite high in Ukraine. One more RD increases discount rates by 68 points or 14-19 percent of a standard deviation. As a robustness check we also expand these regressions to control for the subjective survival probability up to a specific cut-off age (only available for respondents aged 45 and above), for personal future income expectations, or for the expectation whether to work in the future or not; our results remain highly significant and positive after including these controls.

**Table 3: Time discounting**

| | (1)<br>Annualized monthly discount rate | (2)<br>Annual discount rate | (3)<br>Standardized annualized monthly discount rate | (4)<br>Standardized annual discount rate |
|---|---|---|---|---|
| Radiation | 67.538*** | 66.729*** | 0.140*** | 0.190*** |
| | (17.881) | (17.658) | (0.037) | (0.050) |
| Male | -21.140 | -11.551 | -0.044 | -0.033 |
| | (16.612) | (14.337) | (0.035) | (0.041) |
| Age | 0.236 | 0.892 | 0.000 | 0.003 |
| | (1.116) | (1.219) | (0.002) | (0.003) |
| Height | 1.021 | 0.717 | 0.002 | 0.002 |
| | (0.638) | (0.496) | (0.001) | (0.001) |
| Education mother | 44.803 | 54.737 | 0.093 | 0.156 |
| | (42.158) | (43.624) | (0.088) | (0.124) |
| Education father | 18.936 | 13.531 | 0.039 | 0.038 |
| | (26.069) | (26.447) | (0.054) | (0.075) |
| Household size | 9.275 | 11.444 | 0.019 | 0.033 |
| | (7.647) | (7.824) | (0.016) | (0.022) |
| Log household income | -14.556** | -15.512** | -0.030** | -0.044** |
| | (6.442) | (6.715) | (0.013) | (0.019) |
| Observations | 2,583 | 2,583 | 2,583 | 2,583 |
| R-squared | 0.056 | 0.0575 | 0.056 | 0.057 |

Notes: Radiation is measured in units of natural background radiation (2 mSv). WTR and dependent variables in columns (3) and (4) are standardized with mean zero and standard deviation one. Regressions control further for marital status, work status, health status, household living space per capita, month and year fixed effects, region and settlement type fixed effects. Robust standard errors clustered by 1986 residential region are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

### 3.3. The impact on saving behavior

If more affected individuals have higher discount rates, we might expect that this translates into lower saving rates. To test this, we generate two behavioral measures from the ULMS survey: First, we use a binary indicator for whether the respondent's household has saved last year; second, we generate the fraction of income saved during the last year. For both variables the RD has a negative impact on savings (Table 4). More affected households are 10 pp less likely to save and their savings rate is 1.5-2 % lower for one dose of background radiation. These effects remain unchanged if we control for the standardized general willingness to take risks (which itself is insignificant).

**Fig. 3: Cumulative distribution annual household saving rate**

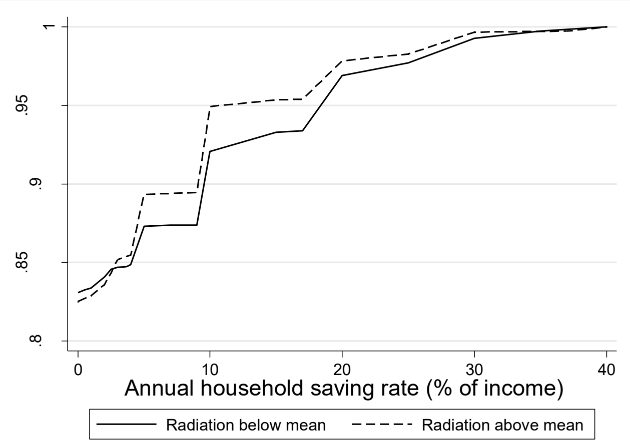



**Table 4: Saving behavior**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Saved last year (0/1) | | Fraction of income saved last year (%) | |
| Radiation | -0.103** | -0.105** | -1.469* | -1.531* |
| | (0.044) | (0.045) | (0.827) | (0.834) |
| Stand. general WTR | | -0.004 | | -0.140 |
| | | (0.012) | | (0.177) |
| Male | 0.005 | 0.007 | -0.105 | -0.052 |
| | (0.014) | (0.014) | (0.319) | (0.330) |
| Age | 0.001 | 0.001 | 0.008 | 0.006 |
| | (0.001) | (0.001) | (0.015) | (0.015) |
| Height | -0.001 | -0.001 | -0.009 | -0.009 |
| | (0.001) | (0.001) | (0.028) | (0.028) |
| Education mother | 0.002 | 0.002 | 0.087 | 0.103 |
| | (0.030) | (0.031) | (0.470) | (0.472) |
| Education father | -0.018 | -0.018 | 0.274 | 0.278 |
| | (0.024) | (0.024) | (0.525) | (0.529) |
| Years of schooling | | | | |

| | | | | |
|---|---|---|---|---|
| Household size | -0.024** | -0.024** | -0.333* | -0.335* |
| | (0.009) | (0.009) | (0.177) | (0.175) |
| Log household income | 0.064*** | 0.065*** | 0.918* | 0.925* |
| | (0.021) | (0.021) | (0.466) | (0.468) |
| | | | | |
| Observations | 3,186 | 3,186 | 3,186 | 3,186 |
| R-squared | 0.0856 | 0.086 | 0.078 | 0.079 |

Notes: Radiation is measured in units of natural background radiation (2 mSv). Regressions control further for marital status, work status, health status, household living space per capita, month and year fixed effects, region and settlement type fixed effects. Robust standard errors clustered by 1986 residential region are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

We support this evidence with results from a hypothetical saving question which is available at the individual level in ULMS 2007. Specifically, respondents are asked to choose the percentage which they intend to save out of a hypothetical donation of 1,000 UAH (0%, 1%-25%, 26%-50%, 51%-75%, 76%-99%, 100%). As dependent variables we use a dummy variable indicating that respondents chose to save more than half (i.e. the latter three answer categories) as well as the complete categorical variable. We estimate regressions akin to (1) with Probit and Ordered Probit models. Respondents having received more radiation are 15 pp less likely to save more than half of the full amount. The Ordered Probit model reveals a sizeable and significant positive effect on the likelihood to save 0% (+10 pp), while the propensity to save more than 25% is significantly reduced. The effect is strongly negative for the propensity to save the entire amount (–6 pp). Hence, the results of the hypothetical saving question at the individual level are fully in line with actual savings behavior (at the household level).

**Table 5: Hypothetical saving question**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | ***Save more than half (0/1)*** | | ***Savings rate (1-6)*** | |
| | *LPM* | | *Ordered Probit* | |
| Radiation | -0.150** | -0.159** | -0.239* | -0.262** |
| | (0.061) | (0.062) | (0.128) | (0.132) |
| Stand. general WTR | | -0.018 | | -0.049 |
| | | (0.014) | | (0.036) |
| Male | 0.015 | 0.022 | -0.005 | 0.013 |
| | (0.029) | (0.029) | (0.064) | (0.067) |
| Age | -0.011** | -0.011** | -0.027** | -0.028** |
| | (0.005) | (0.005) | (0.014) | (0.014) |

| | | | | |
|---|---|---|---|---|
| Height | -0.003 | -0.003 | -0.005 | -0.005 |
| | (0.002) | (0.002) | (0.004) | (0.004) |
| Education mother | -0.017 | -0.014 | -0.035 | -0.027 |
| | (0.044) | (0.044) | (0.102) | (0.104) |
| Education father | -0.012 | -0.012 | -0.045 | -0.045 |
| | (0.029) | (0.029) | (0.065) | (0.065) |
| Household size | -0.017* | -0.017* | -0.054*** | -0.054*** |
| | (0.009) | (0.009) | (0.020) | (0.020) |
| Log household income | -0.011 | -0.011 | -0.007 | -0.005 |
| | (0.013) | (0.013) | (0.029) | (0.029) |
| Marginal effect, outcome 1 | | | 0.095* (0.051) | 0.104** (0.052) |
| Marginal effect, outcome 2 | | | 0.000 (0.000) | 0.000 (0.000) |
| Marginal effect, outcome 3 | | | -0.006* (0.003) | -0.006* (0.003) |
| Marginal effect, outcome 4 | | | -0.016* (0.009) | -0.017* (0.009) |
| Marginal effect, outcome 5 | | | -0.014* (0.008) | -0.016* (0.008) |
| Marginal effect, outcome 6 | | | -0.059* (0.031) | -0.065** (0.032) |
| | | | | |
| Observations | 3,728 | 3,728 | 3,728 | 3,728 |
| R-squared | 0.095 | 0.096 | | |
| Pseudo R-squared | | | 0.0358 | 0.0362 |

Notes: Radiation is measured in units of natural background radiation (2 mSv). WTR is standardized with mean zero and standard deviation one. Regressions control further for marital status, work status, health status, household living space per capita, month and year fixed effects, region and settlement type fixed effects. Robust standard errors clustered by 1986 residential region are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

### 3.4. The impact on political ideology and participation in civic life

With respect to the preferred political system, respondents with higher levels of radiation are clearly more strongly in favour of a Soviet system without any democratic elements. In fact, the Soviet system is with more than 40 percent they by far most strongly desired political system in this group, on the expenses of support for democracy (Fig. 4a). Similar preferences prevail for the economic system: Almost 40 percent of respondents in the group above median radiation favour a centrally planned economy, while the corresponding value in the group below median is roughly 10 percentage points lower (Fig. 4b). While the centrally planned economic system of the USSR has been characterized by restricted consumer choices, it is also associated with protection from market risks and a caring state safeguarding its citizens. Table 6 lends further support to the idea that greater affectedness by the disaster led to prevalence of political and economic apathy.

**Fig. 4a: Preference for political system**

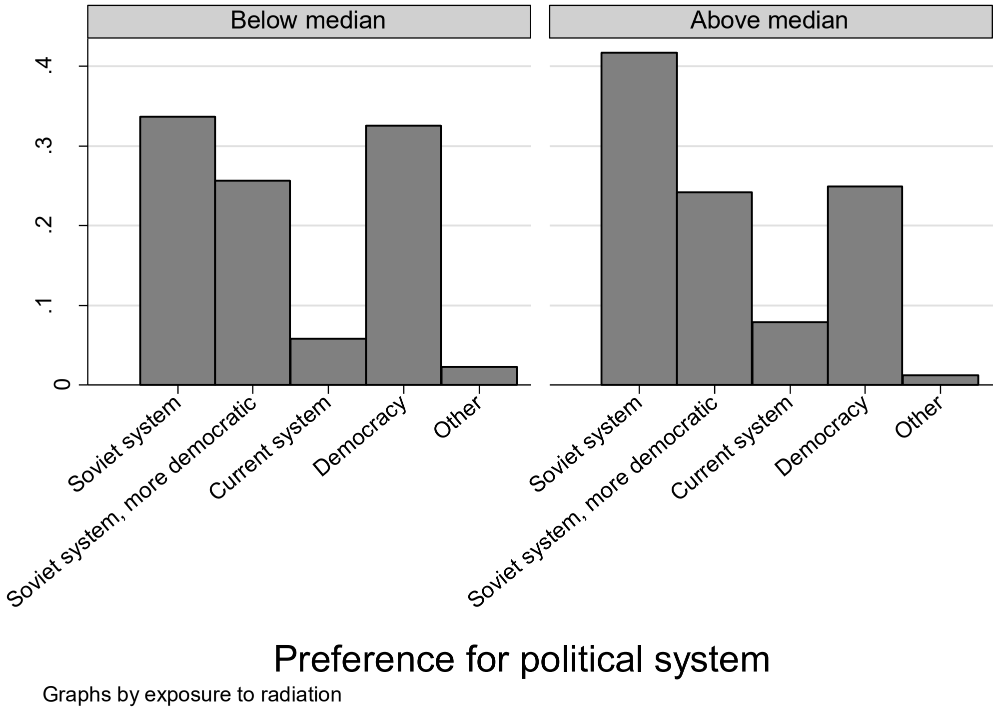
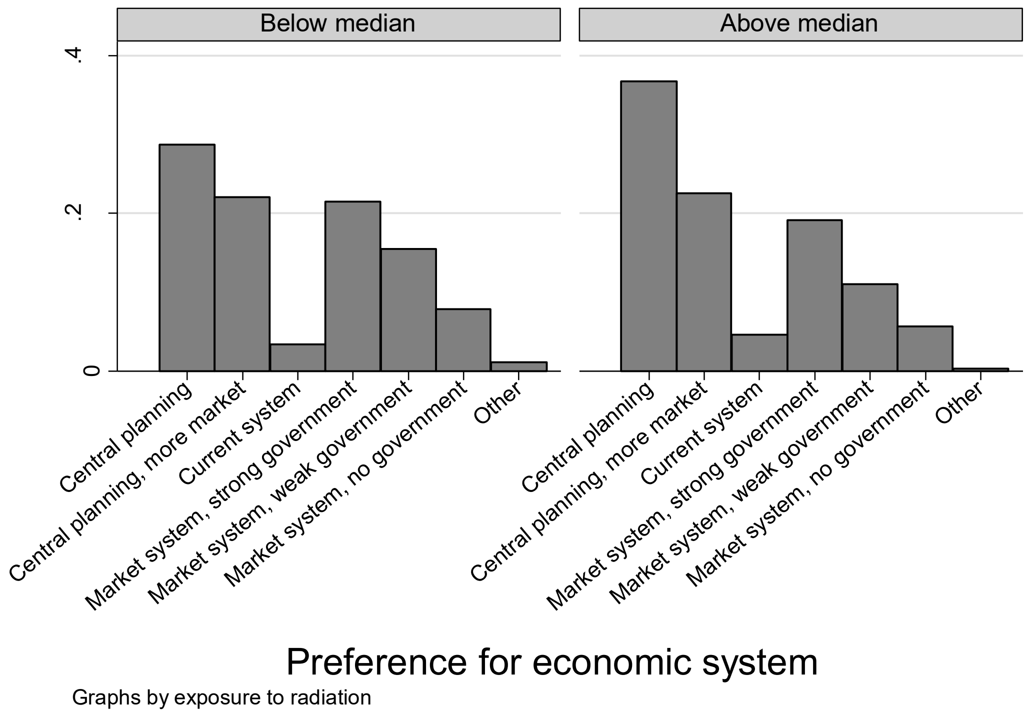



**Fig. 4b: Preference for economic system**



## Table 6A: The effect of Chernobyl on political ideology

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | ***Centrally planned economy w/o risk (0/1) (I08=1)*** | | ***Pro market economic system (scale 1-6) (I08)*** | | ***Political system: Soviet style (0/1) (I07=1)*** | |
| | LPM | | Ordered Probit | | LPM | |
| Radiation | 0.106*** | 0.093** | -0.366*** | -0.327*** | 0.095** | 0.089** |
| | (0.034) | (0.035) | (0.100) | (0.098) | (0.040) | (0.041) |
| Stand. general WTR | | -0.026** | | 0.086*** | | -0.012 |
| | | (0.011) | | (0.028) | | (0.012) |
| Male | -0.013 | -0.005 | 0.104** | 0.076 | -0.037 | -0.033 |
| | (0.019) | (0.019) | (0.050) | (0.051) | (0.023) | (0.022) |
| Age | 0.005*** | 0.005*** | -0.020*** | -0.019*** | 0.006*** | 0.005*** |
| | (0.001) | (0.001) | (0.003) | (0.003) | (0.001) | (0.001) |
| Height | -0.001* | -0.001* | -0.001 | -0.001 | -0.001 | -0.001 |
| | (0.001) | (0.001) | (0.003) | (0.003) | (0.001) | (0.001) |
| Education mother | -0.086*** | -0.083*** | 0.162*** | 0.151*** | -0.042 | -0.040 |
| | (0.028) | (0.029) | (0.056) | (0.057) | (0.029) | (0.029) |
| Education father | -0.010 | -0.011 | 0.068 | 0.070 | -0.031 | -0.032 |
| | (0.028) | (0.028) | (0.070) | (0.069) | (0.029) | (0.029) |
| Household size | 0.002 | 0.002 | -0.013 | -0.011 | 0.011 | 0.011 |
| | (0.006) | (0.006) | (0.017) | (0.017) | (0.007) | (0.007) |
| Log household income | -0.020* | -0.019* | 0.037 | 0.035 | -0.027* | -0.027* |
| | (0.010) | (0.010) | (0.030) | (0.030) | (0.016) | (0.016) |
| Marginal effect, outcome 1 | | | 0.108*** (0.029) | 0.096*** (0.029) | | |
| Marginal effect, outcome 2 | | | 0.038*** (0.011) | 0.034*** (0.011) | | |
| Marginal effect, outcome 3 | | | -0.003** (0.001) | -0.003** (0.001) | | |
| Marginal effect, outcome 4 | | | -0.054*** (0.014) | -0.048*** (0.014) | | |
| Marginal effect, outcome 5 | | | -0.060*** (0.017) | -0.053*** (0.017) | | |
| Marginal effect, outcome 6 | | | -0.029*** (0.009) | -0.026*** (0.009) | | |
| Observations | 3,284 | 3,284 | 3,284 | 3,284 | 3,287 | 3,287 |
| R-squared / Pseudo R-squared | 0.212 | 0.215 | 0.098 | 0.100 | 0.204 | 0.204 |

Notes: Radiation is measured in units of natural background radiation (2 mSv). WTR is standardized with mean zero and standard deviation one. Regressions control further for marital status, work status, health status, household living space per capita, month and year fixed effects, region and settlement type fixed effects. Robust standard errors clustered by 1986 residential region are in parentheses. Columns (3) and (4): Outcomes indicate answers: (1) "Centrally-planned economy which was in our country until perestroika." (2) "Centrally-planned economy, but with elements of a market economy." (3) "The economic system which exists today." (4) "Market economy with strong government regulation." (5) "Market economy with relatively small government interventions." (6) "Free market economy without government regulation." *** p<0.01, ** p<0.05, * p<0.1

**Fig. 4c: Preferred relationship between Ukraine and Russia**

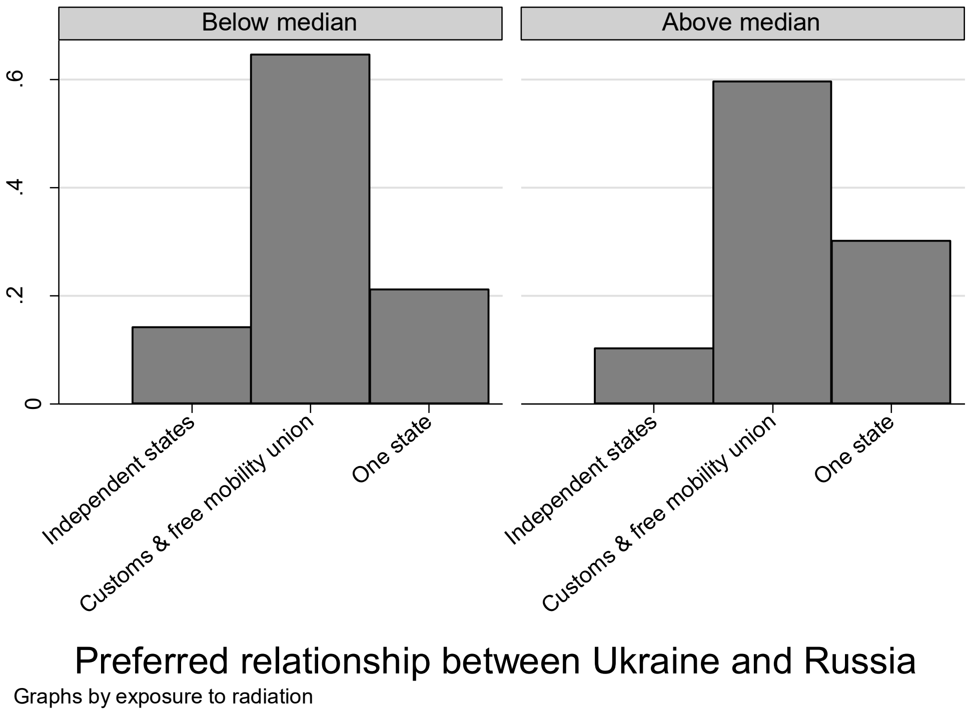



**Fig. 4d: Preferred integration of Ukraine**

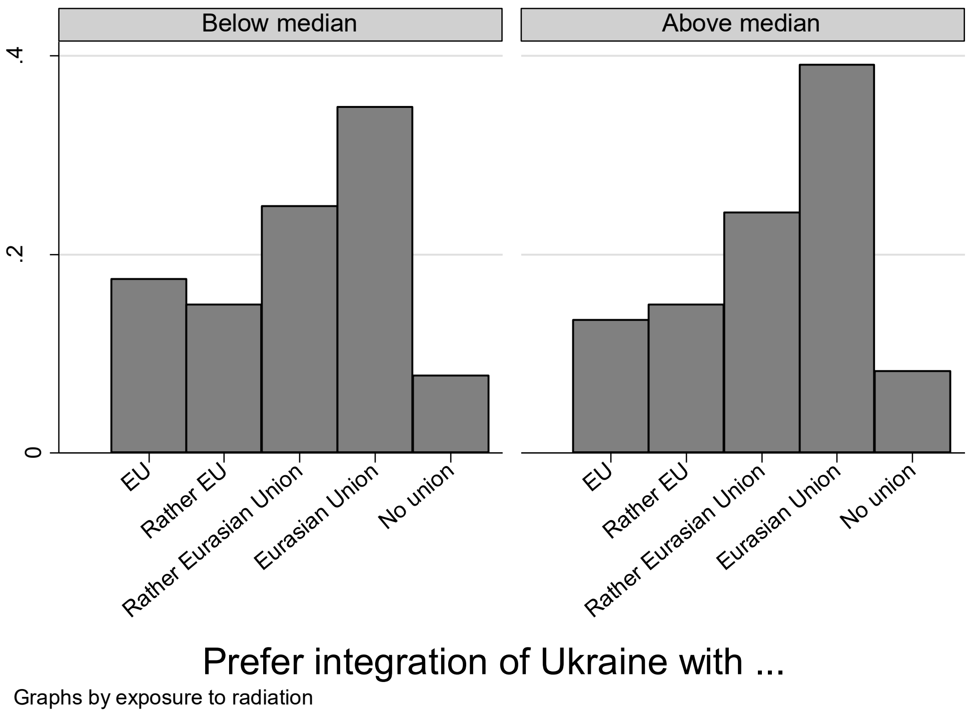


**Table 6B: The effect of Chernobyl on external relations of Ukraine**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | ***Ukraine should unite with Russia (0/1)*** | | ***Closer relationship Ukraine-Russia (scale 1-3)*** | | ***Integration into Eurasian Union rather than EU (0/1)*** | |
| | *LPM* | | *Ordered Probit* | | *LPM* | |
| Radiation | 0.108*** | 0.114*** | 0.261*** | 0.269*** | 0.046* | 0.050* |
| | (0.027) | (0.027) | (0.096) | (0.095) | (0.024) | (0.026) |
| Stand. general WTR | | 0.011 | | 0.015 | | 0.007 |
| | | (0.014) | | (0.036) | | (0.014) |
| Male | -0.033* | -0.037* | -0.048 | -0.053 | 0.008 | 0.006 |
| | (0.017) | (0.018) | (0.044) | (0.049) | (0.024) | (0.024) |
| Age | 0.004*** | 0.004*** | 0.011*** | 0.011*** | 0.002 | 0.002 |
| | (0.001) | (0.001) | (0.003) | (0.003) | (0.002) | (0.002) |
| Height | 0.001 | 0.001 | -0.003 | -0.003 | -0.003* | -0.003* |
| | (0.001) | (0.001) | (0.003) | (0.003) | (0.001) | (0.001) |
| Education mother | -0.030 | -0.032 | -0.138* | -0.140* | -0.051** | -0.052** |
| | (0.025) | (0.026) | (0.079) | (0.079) | (0.019) | (0.019) |
| Education father | -0.017 | -0.017 | -0.061 | -0.062 | -0.017 | -0.017 |
| | (0.025) | (0.025) | (0.088) | (0.088) | (0.026) | (0.026) |
| Household size | 0.001 | 0.001 | -0.000 | -0.000 | 0.005 | 0.006 |
| | (0.005) | (0.005) | (0.016) | (0.016) | (0.007) | (0.007) |
| Log household income | -0.028*** | -0.029*** | -0.037 | -0.038 | -0.010 | -0.010 |
| | (0.008) | (0.008) | (0.035) | (0.035) | (0.010) | (0.010) |
| Marginal effect, outcome 1 | | | -0.036*** (0.013) | -0.037*** (0.013) | | |
| Marginal effect, outcome 2 | | | -0.038*** (0.014) | -0.039*** (0.014) | | |
| Marginal effect, outcome 3 | | | 0.074*** (0.027) | 0.076*** (0.027) | | |
| Observations | 3,791 | 3,791 | 3,791 | 3,791 | 3,554 | 3,554 |
| R-squared / Pseudo R-squared | 0.196 | 0.197 | 0.179 | 0.179 | 0.226 | 0.226 |

Notes: Radiation is measured in units of natural background radiation (2 mSv). WTR is standardized with mean zero and standard deviation one. Regressions control further for marital status, work status, health status, household living space per capita, month and year fixed effects, region and settlement type fixed effects. Robust standard errors clustered by 1986 residential region are in parentheses. Columns (3) and (4): Outcomes indicate answers: (1) "Relationship between Ukraine and Russia should be the same as with other states, with closed borders, visas and customs." (2) "Ukraine and Russia should further develop their independent but friendly relationship, with open borders and no visas or customs." (3) "Ukraine and Russia should unite in one state." *** p<0.01, ** p<0.05, * p<0.1

Overall, our results suggest that RD decreases the support for a market system and increases support for central planning and heavy government interventions. The results from the ordered probit regressions shows that a one unit RD increase is associated with a rise in the support for a centrally planned economic system by 10 pp and a reduction of support for a market economy by 3-6 pp (depending on the degree of government intervention allowed).

RD also decreases support for Western type democracy and increases support for a Soviet type political system. Since the answer categories regarding the preferred political system are not ordinal in ULMS, we use a probit approach to measure the impact of radiation on the support for a Soviet style political system (+10 pp per unit of background radiation).

Finally, RD decreases support for joining the EU and increases support for living in a political union with Russia (+7 pp in the ordered probit model and +11 pp in the LPM) and to intensify the integration into the Eurasian Union comprising Russia, Belarus and Kazakhstan (+5 pp) (Table 6B).

People in centrally planned economies and Soviet type political systems had very restricted opportunities to show political initiative and to participate voluntarily in political and civic life. Thus, it may be that case that support for the Soviet style political and economic system may also be associated with a reduced willingness to participate in political and civic activities due to RD. ULMS 2007 features a question regarding whether and how respondents were willing to defend their civic rights in case they were outraged. In particular, participants of the survey could indicate one or several legal or illegal actions (such as election campaign, collecting signatures, legal meetings and marches, legal strikes (legal activities), boycotts, illegal meetings and marches, illegal strikes, hunger strikes, picketing government offices, seizure of buildings, military units creation (illegal or extreme activities)).

**Table 7: Participation in political activities**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | ***Legal polit. activity (Dummy=1 if any of I11 1-4 answered positively)*** | | ***Illegal polit. activity (Dummy=1 if any of I11 5-11 answered positively)*** | |
| Radiation | -0.173*** | -0.132*** | -0.076** | -0.056 |
| | (0.041) | (0.037) | (0.035) | (0.034) |
| Stand. general WTR | | 0.079*** | | 0.038*** |
| | | (0.009) | | (0.008) |
| Male | 0.035 | 0.007 | 0.037** | 0.024 |
| | (0.021) | (0.021) | (0.015) | (0.014) |

| | | | | |
|---|---|---|---|---|
| Age | -0.001 | -0.000 | -0.001** | -0.001 |
| | (0.001) | (0.001) | (0.000) | (0.000) |
| Height | -0.002 | -0.002 | 0.000 | -0.000 |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Education mother | 0.059** | 0.047* | 0.009 | 0.003 |
| | (0.025) | (0.026) | (0.024) | (0.024) |
| Education father | -0.061** | -0.061** | -0.026 | -0.026 |
| | (0.025) | (0.025) | (0.018) | (0.018) |
| Household size | -0.001 | 0.001 | -0.003 | -0.003 |
| | (0.008) | (0.007) | (0.004) | (0.004) |
| Log household income | 0.032** | 0.029** | 0.017*** | 0.016*** |
| | (0.012) | (0.011) | (0.005) | (0.005) |
| Observations | 3,936 | 3,936 | 3,936 | 3,936 |
| R-squared | 0.189 | 0.209 | 0.0813 | 0.094 |

Notes: Radiation is measured in units of natural background radiation (2 mSv). WTR is standardized with mean zero and standard deviation one. Regressions further control for marital status, work status, health status, household living space per capita, month and year fixed effects, region and settlement type fixed effects. Robust standard errors clustered by 1986 residential region are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Indeed, RD reduces the willingness to participate in legal political activities and the willingness to participate in extreme or illegal forms of political activity such as boycotts or seizure of buildings (Table 7). However, this latter effect vanishes if we control for WTR which is significantly correlated with both kinds of activities.

In the table showing the previous two effects (on legal and illegal political acitivity) we should include two further regressions with "I am not interested to take part in social and political life and the work of voluntary organizations" as the dependent Dummy variable. We use regressions (3) and (4) from current table 13 on page 20 for this table.

## 4. Discussion and interpretation of results

The radiation levels received by the Ukrainian low-dose population remained too low to explain physical health conditions. While this implies that the estimated behavioral effects cannot be interpreted as consequences of physical health damage (e.g., neurological damage), all existent evidence points to a psychological explanation.

Unfortunately, we cannot measure fear or *angst* directly; however, if the estimated radiation effects were channeled through fear, we should be able to measure fear-related subjective long-run reactions to the exposure to radiation. In Table 8 we show that objective exposure to the disaster is highly correlated with the subjective perception to have been affected by the disaster: individuals in areas with higher levels of radiation are more likely to report victimization from the disaster. This also turns into lower perceived contemporary quality of life (as measured by life satisfaction) and lower expected survival probability for the future (as benchmarked against an age-specific survival threshold).

**Table 8: Effect of radiation on subjective affectedness and well-being**

| | (1)<br>***Subjective measure of having been affected (0/1)*** | (2)<br>***Chance to survive up to target age (0%-100%)*** | (3)<br>***Normalized life satisfaction*** |
|---|---|---|---|
| Radiation | 0.101** | -9.180** | -0.161** |
| | (0.045) | (4.249) | (0.069) |
| Male | -0.089*** | -0.979 | -0.036 |
| | (0.015) | (1.592) | (0.031) |
| Age | 0.004*** | 0.023 | -0.011*** |
| | (0.001) | (0.152) | (0.002) |
| Height | -0.001 | 0.032 | 0.004 |
| | (0.001) | (0.090) | (0.003) |
| Education mother | 0.060* | -0.445 | 0.070 |
| | (0.031) | (3.475) | (0.058) |
| Education father | -0.006 | 2.012 | 0.165*** |
| | (0.026) | (3.321) | (0.053) |
| Household size | -0.007 | -0.213 | -0.032** |
| | (0.006) | (0.576) | (0.013) |
| Log household income | 0.013 | 3.484*** | 0.135*** |
| | (0.011) | (0.951) | (0.029) |
| Observations | 4,000 | 1,766 | 4,000 |
| R-squared | 0.182 | 0.222 | 0.138 |

Notes: Radiation is measured in units of natural background radiation. Life satisfaction is standardized with mean zero and standard deviation one. Regressions control further for age bracket dummies (according to the question on survival probability), marital status, work status, health status, household living space per capita, month and year fixed effects, region and settlement type fixed effects. Robust standard errors clustered by 1986 residential region are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

To bolster our proposition that countermeasure signals rather than actual radiation were inducing fear effects after the disaster, we propose the following test: we choose regions which by coincidence received highly comparable amounts of radioactive fallout and at the same time different treatment intensities in countermeasures; if the variation in countermeasures still explained the disaster effect, signals rather than radiation must matter. For doing so we restrict our sample to regions with very similar radiation exposure. For instance, we select all regions which received radiation in the very low dose bracket between 0.265 and 0.285 mSv and exploit the variation in the countermeasure intensity as variable of interest in the original estimation equations. Countermeasures are proxied by the number of blood tests per 1 000 inhabitants per square kilometre. Although this is an outright demanding test with only 470 observations, most of our previous results remain qualitatively identical with high significance levels.[9]

**Table 9: The effect of exposure signals on preferences and attitudes**

| | (1) | (2) | (3) |
|---|---|---|---|
| VARIABLES | General WTR | Discount rate 1y | Legal polit. activity |
| Density of blood tests | -0.646*** | 6.385*** | -0.085 |
| | (0.208) | (1.464) | (0.072) |
| Observations | 480 | 404 | 471 |
| R-squared | 0.362 | 0.287 | 0.124 |

Notes: Radiation is measured in units of natural background radiation (2 mSv). WTR is standardized with mean zero and standard deviation one. Regressions control further for gender, age, height, mother's and father's education, household size, log household income, marital status, work status, health status, household living space per capita, month and year fixed effects, region and settlement type fixed effects. Robust standard errors clustered by 1986 residential region are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Our results are robust to several sensitivity checks: First, we split our sample into predominantly Ukrainian-speaking areas (West and Center) vs. Russian-speaking areas to detect any regional peculiarities but find no significant differences between the two regions. Second, we construct an indicator for whether individuals live in areas of Ukraine which historically belonged to the Austro-Hungarian Empire to detect potential subgroup differences with respect to preferences. While we find level differences for some preference indicators in regions with Austro-Hungarian heritage (in line with previous findings by Becker et al. 2016), the interaction term of Empire × radiation is never significant (see Appendix). Third, we directly control for the distance to Chernobyl. This again does not change our results. This result becomes comprehensible once we acknowledge the patchy pattern of radiation exposure: Kiev city and Donezk city received the same level of radiation (0.5 mSv) although Kiev is located only 94km from Chernobyl, while Donezk is 655km away. And while Luhansk, which is 716km away, received even 20% more radiation, Chernihiv at only 78 km from Chernobyl received 10% less.

## 5. Preference shifts vs. reduced life expectancy

So far, we have established that individuals exposed to greater, yet subclinical, radiation doses respond to questions in a way suggesting a shift in risk aversion and discount rate parameters. Yet, our findings could also be rationalized with constant preferences and a (perceived)

[9] A second exercise with the alternative radiation bracket between 0.5 and 0.6 yields very similar results (N = 617).

reduced life expectancy.[10] Hence, can we disentangle changes in preferences from changes in preference-relevant circumstances? Not necessarily. In fact, we expect the results to reflect a mixture of preference shifts and movements along preference curves. For instance, if individuals suffer from clinical mental disorders, their behavior could either stem from becoming more risk averse due to a preference shift or from preceived greater risk exposure when risk parameters have remained stable.

While the latter explanation may seem appealing, there are three reasons to believe we are really capturing preference shifts instead of movements along the preference curve. First, the incidence of diagnosed mental disorders which can be related to Chernobyl is overall low (3% of the population). Despite the fact that this number might be seriously underestimated, independent population studies the prevalence of mood disorders does not exceed 10% in Ukraine. Second, we find evidence for greater risk aversion even for outcomes that are not directly associated with life expectancy or life risks, such as preferences for the political and economic system, the willingness to take risk in leisure or car driving, or the willingness to participate in political activities. Furthermore, we find disaster effects even for future income pessimism—conditional on health conditions and the WTR etc. Third, we condition our WTR and discount rate regressions on subjective life expectancies/survival risks (for the subsample aged 45+ since the survey questions regarding subjective survival rates were answered only by respondents aged 45 and above). The results reveal that differences in life expectancy cannot explain our main findings. Once we condition on a measure of expected remaining lifespan, the coefficients decline by only one (discount rate regression) to six (WTR regression) percent.

Above all, given the aforementioned large body of medical literature regarding the absence of physical health effects in the population with subclinical doses, any reduction in life expectancy would be perceived rather than real. In effect, the Chernobyl disaster would induce individuals and households to save suboptimally little. Whether this is related to the higher dependency of more affected working-age individuals on governmental transfers as reported by Danzer and Danzer (2016) cannot be tested with the available data.

**Table 9: WTR and discount rate regressions, controlling for survival risk**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dependent variable | General WTR | General WTR | Discount rate 1y | Discount rate 1y |

[10] In a finite horizon Ramsey problem with identical preferences, shorter lifetime would imply a lower savings rate.

| | | | | |
|---|---|---|---|---|
| Radiation dose | -0.692*** | -0.646*** | 0.389** | 0.387** |
| | (0.081) | (0.094) | (0.177) | (0.157) |
| Control for survival risk | No | Yes | No | Yes |
| Observations | 1,766 | 1,766 | 1,324 | 1,324 |
| R-squared | 0.193 | 0.208 | 0.092 | 0.102 |

Notes: Radiation is measured in units of natural background radiation (2 mSv). WTR is standardized with mean zero and standard deviation one. Regressions control further for gender, age, height, mother's and father's education, household size, log household income, marital status, work status, health status, household living space per capita, month and year fixed effects, region and settlement type fixed effects. Robust standard errors clustered by 1986 residential region are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

## 6. Conclusion

This paper illustrates persistent changes in behaviorally revealed preferences and beliefs in the aftermath of the nuclear disaster of Chernobyl. In particular, we show causal evidence on significant and long-term reductions in individual willingness to take risk and increased time discounting among individuals with relatively more exposure to the catastrophe. These individuals exhibit also lower savings rates and prefer "risk-free" economic and political systems. Importantly, however, we have performed our analysis on a nationally representative survey of those Ukrainians who were physically at most subclinically affected by the disaster (which is true for about 96 percent of the population). In other words, none of the survey respondents suffered from direct physical health consequences of radiation. This said, the results of lower willingness to take risks and greater time discounting point to psychological effects—anxiety and fear— as mediating channel. This conjecture is supported by a large array of supplementary evidence showing that received risk signals matter more than actual radiation threat, respondents feel victimized, subjective well-being indicators react strongly, respondents expect lower survival probabilities and strong effects are prevalent even for outcomes which cannot be explained by a risk-enhanced environment.

In sum, preferences seem to respond to uncertain low-impact treatments, as long as humans perceive a threat or risk. The effects are surprisingly persistent and thus add new evidence and unique insights into the formation of preferences. As we show that this man-made catastrophe also affects economically relevant behavior as well as political attitudes the results are also politically relevant.

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Appendix: Accuracy of signals

Throughout the paper, radiation doses are used as proxy for the disaster signals received by the Ukrainian population in the aftermath of the catastrophe. While accurate information on the geographic distribution of Iodine-prophylaxis and other countermeasures is unavailable, we can compare the density of C-137 blood measurements (per inhabitant per square kilometer) with the actual radiation doses received (Figure A-1)

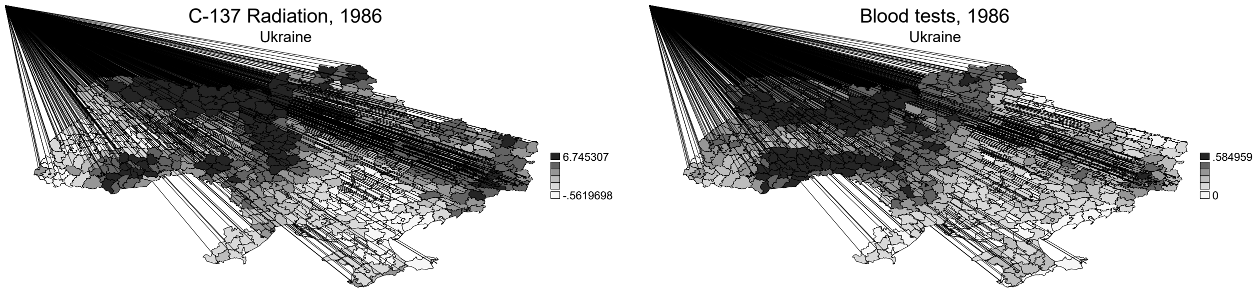


Fig. A-1 Geographic distribution of C-137 radiation and blood test densities
Note. Measurements are taken at the administrative district (raion) level.

A univariate regression of blood test densities per square kilometer on C-137 radiation doses reveals that the latter explains 47% of the variation in the former, suggesting a very close correlation. Using blood measurements instead of radiation doses in our main regressions confirms the results of our analysis (Table A-1). Given that individuals have received multiple different signals over an extended period of time, we prefer the initial radiation shock as treatment variable in our paper.

Table A-1: The impact of blood measurements

| *Dependent variable* | (1) ***General WTR*** | (2) ***Standardized annual discount rate*** | (3) ***Subjective affected-ness*** | (4) ***Life satisfaction*** | (5) ***Survival probability*** |
|---|---|---|---|---|---|
| Blood measurements (pop/sqkm) | -0.030*** | 0.006** | 0.027*** | -0.011 | -0.770*** |
| | (0.007) | (0.003) | (0.003) | (0.011) | (0.228) |
| Male | 0.364*** | -0.036 | -0.086*** | -0.051 | -0.858 |
| | (0.032) | (0.039) | (0.015) | (0.036) | (1.758) |
| Age | -0.001 | 0.003 | -0.009*** | 0.006* | -1.202*** |
| | (0.004) | (0.003) | (0.002) | (0.004) | (0.149) |
| Height | 0.001 | 0.002 | -0.001 | 0.005* | 0.030 |
| | (0.002) | (0.001) | (0.001) | (0.003) | (0.087) |
| Education mother high | 0.133*** | 0.157 | 0.063* | 0.093 | -0.371 |
| | (0.042) | (0.124) | (0.033) | (0.074) | (3.821) |
| Education father high | 0.003 | 0.042 | -0.005 | 0.200*** | 2.387 |
| | (0.044) | (0.076) | (0.029) | (0.070) | (3.394) |
| Household size | -0.017 | 0.031 | -0.008 | -0.038** | -0.090 |
| | (0.016) | (0.022) | (0.006) | (0.015) | (0.553) |
| Log income | 0.038* | -0.042** | 0.014 | 0.160*** | 3.440*** |
| | (0.019) | (0.018) | (0.010) | (0.035) | (0.916) |
| Observations | 4,000 | 2,556 | 4,000 | 4,000 | 1,766 |
| R-squared | 0.198 | 0.056 | 0.192 | 0.151 | 0.238 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Exact wording of survey questions (ULMS 2007):

Imagine you have been assured that 10.000 Hryvnias will be paid out to you in 12 months from now. Alternatively, you can get a lower amount immediately.
**What is the lowest amount of money you would accept to be paid <u>now</u> rather than receiving 10.000 Hryvnias <u>in 12 months</u> from now?**

**If you were given 1000 Hryvnias today, what would you do with the money in the next weeks?**
I would…

1. … **spend the entire amount**
2. … **spend between 75% and 99%** of the money in the next weeks and save the rest
3. … **spend between 50% and 74%** of the money in the next weeks and save the rest
4. … **spend between 25% and 49%** of the money in the next weeks and save the rest
5. … **spend less than 25%** of the money in the next weeks and save the rest
6. … **save the entire amount**