The Impact of Chernobyl on Health and Labour Market Performance in the Ukraine

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This version: September 2009

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We thank Lenina Akkineni for valuable research assistance and Natalia Karchenko at KIIS for most helpful advice on the dataset. We are grateful to Martin Kahanec and participants at the November 2008 IZA workshop on “Analysis of Labour Market Adjustment in Transition and Emerging Economies Using Large Micro-Data Sets” and at a CEP seminar for helpful comments. Lehmann also acknowledges financial support by the European Commission within the project “Economic and Social Consequences of Industrial Restructuring in Russia and Ukraine” (ESCIRRU).

Abstract

Using longitudinal data from the Ukraine we examine the extent of any long-lasting effects of radiation exposure from the Chernobyl disaster on the health and labour market performance of the adult workforce. The variation in the local area level of radiation fallout from the Chernobyl accident is considered as a potential instrument to try to establish the causal impact of poor health on labour force participation, hours worked and wages. There appears to be a significant positive association between local area-level radiation dosage and health perception based on self-reported poor health status, though much weaker associations between local area-level dosage and other specific health conditions or labour market performance. Any effects on negative health perceptions appear to be stronger among women and older individuals.

Key words: Chernobyl, Health, Labour Market Performance

JEL Classification No. H00, J00

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On 26th April 1986, engineers at the Chernobyl nuclear power plant in the Ukraine began a series of tests on one of the nuclear reactors that lead to the world's worst civil nuclear disaster. The amount of radiation released as a consequence of the accident was far in excess of that released from the air bursts of the Hiroshima or Nagasaki atomic bombs, hitherto the focus of much research and knowledge about the consequences of radiation fallout. Yet, while much has been written, and argued, about the medical and physical consequences of Chernobyl[1], less attention has been given to the social and economic consequences of the disaster, despite recent urgings along this line from the United Nations, (UNDP 2002). Since there are now movements in many industrialised countries toward building a new generation of nuclear power facilities as one way to address the issue of climate change, knowledge of any long-term economic consequences of such rare, low frequency events as an accident in a nuclear power plant is important.

Health has long been considered to be an important determinant of labour market outcomes, such as wages, hours of work and employment, (see the references in Lleras-Muney (2005), Currie and Madrian (1999), Strauss and Thomas (1998), Kahn (1998)). Much of the literature is concerned with the difficulty of establishing a causal link between health and performance. There is also a growing literature concerned with the long-term and long lasting consequences of health shocks, summarised recently Maccini and Yang (2008), where shocks can have long-lasting effects on both health and on other economic outcomes that affect long-run economic performance. Faced with a large-scale accident, state resources are almost certainly diverted away from other programmes in order to deal with the immediate consequences of the disaster and this may affect the future pattern of development and growth. Understanding the

[1] For example, Chernobyl Forum (2005) puts the total number of Chernobyl cancer related deaths at 4000. Greenpeace (2006) cites a figure of around 90,000 cancer related deaths with an additional 100,000 from other radiation-related illnesses.

link between health and economic performance and establishing an appropriate policy response is important when budgets are tight and institutional mechanisms are still evolving. Equally, the subsequent performance of individuals may have been impaired directly in some way by the disaster. Investigating the relationship between health and economic performance then helps illuminate the costs of this accident.

In what follows, we examine the relationship between exposure to radiation as a result of the Chernobyl accident and subsequent health and economic performance using longitudinal data on a sample of individuals emanating from the Ukraine. Since radiation fallout was rather randomly distributed across the Ukraine, given the prevailing wind patterns, we treat radiation exposure as an exogenous shock and first look to see whether there is any association between the level of radiation dosage in the local area of residence at the time of the disaster and a variety of self-reported health measures some seventeen years or more after the event.

We then proceed to look whether knowledge of radiation dosage can help identify the causal effect of health on labour market performance. Better health may allow better quality of education and productivity at work. Equally, better education may facilitate better health. As such it has long been known that OLS estimation of the effects of poor health on economic performance would tend to be biased down if there is a negative correlation between unobservables that determine work and poor health.[2] Strauss and Thomas (1998) suggested that local environmental conditions can act as a potential instrument for health, since conditional on health, individual productivity and performance should not be affected by environmental conditions. In this way, Almond (2006) exploits the 1918 influenza epidemic to examine long run consequences for educational attainment and labour market performance. Meng and Xiang (2006) use regional level variation in the 1959-61 Great Famine in China as an exogenous shock to identify health effects on individual economic performance. Miguel & Roland (2006) look at how variation in area-level bombing in the Vietnam war, using distance from the 17th parallel as an

[2] This would be offset by any measurement error in the measure of health.

instrument for the intensity of bombing, affected area-level consumption, literacy and economic performance thirty years on. Maccini and Yang (2008) look at the consequences of geographical variation in early-life rainfall on the subsequent health and educational attainment of individuals across Indonesian birth cohorts. In related work, Kling, Lieberman and Katz, (2007) look at long-term health effects of a set of individuals randomly assigned to a set of U.S. neighbourhoods with differing levels of economic performance, finding no physical health effects, but positive mental health effects of assignment to advantaged neighbourhoods.

In addition, given possible influences of genetic or parental background on both health and performance it is essential to try and control for these influences when trying to establish a causal link. Access to longitudinal data can also facilitate identification of any causal examination of the effects of early health-related incidence on later socio-economic achievement. The Ukraine is fortunate in this regard since there is a panel data set, the Ukrainian Longitudinal Monitor Survey (ULMS), which has self-reported health and socio-economic data for a representative sample of individuals at, currently, three points in time, 2003, 2004 and 2007, and which also allows us to establish the place of residence of respondents at the time of the Chernobyl accident.

In this context, the Chernobyl disaster generated a potentially negative exogenous shock to the health of those exposed to the radioactive fallout. Moreover, the dispersal of the fallout was such that different groups of the population were exposed to different levels of radiation that varied by geography, population density and age. This exogenous variation could then be used to identify health effects on individual economic performance. Indeed, Almond, Edlund and Palme (2007) use regional variation in radiation dosage across Sweden to look at the association between educational attainment at age 18 and differential exposure to the Chernobyl fallout of those who were in utero at the time of the accident. Our study looks for evidence of radiation induced effects in the country at the source of the accident, where arguably awareness and the environmental legacy were most profound and where relatively high radiation levels affected a larger share of the population than any other country with the possible exception of Belarus. To this day a large part of the Ukrainian population remains concerned over the consequences of this event.[3]

One advantage of our approach is that we are given information on an individual's settlement of residence in the Ukraine around the time of the accident. It is therefore possible to assign a settlement-level radiation dosage to establish the association between this dosage and the subsequent health of the adult workforce. We focus on the long-term health impact of the population of working age. This could also potentially provide an instrument to identify the causal impact of health on labour market performance across age groups or different sub-groups of the population. The first step then is to establish whether there is a link between local area level radiation dose received and the list of illnesses recorded in the ULMS. The second step is to see whether radiation dose itself is correlated with other observable socio-economic outcomes over the next twenty years other than through any health effects. Such correlation would invalidate the use of local area level radiation dosage as an instrument on health outcomes. Finally we can begin to try to assess the impact of health on a range of labour market and income generating outcomes that are important in the Ukraine.

Our results show that there is a significant positive correlation between residence in radiation affect areas and self-assessed poor health. Adults living in areas considered to have received sufficiently high radiation fallout as to be continually monitored are up to 10 percentage points more likely to report being in poor health. However, there is a less obvious manifestation of such an effect on a variety of specific self-reported health conditions. This suggests that the main long-term effect of Chernobyl for the majority of the current adult population may be working through perceptions. If the establishment of monitoring zones appears to have had an exogenous effect on health perceptions then this could be used to identify the effect of self-reported poor health on the probability of employment, wages or other activities that generate

[3] The ULMS data used in this study show that in 2003, 58 percent of the adults in the sample believed that their health or that of a family member had been affected by Chernobyl.

income and/or subsistence for the Ukrainian population. In the second half of the paper we explore whether area of residence at the time of Chernobyl is a good instrument for health.

Our paper has the following structure. Section 2 outlines the methodology used in this study along with details of the Chernobyl accident. Section 3 describes the data, while Section 4 discusses the results that while OLS estimates of the effect of poor health on the probability of working, the likelihood of home production of foodstuffs, of informal working, hours worked and on wages are all negative, the IV estimates of the causal effect of poor health do not show any significant difference from the OLS estimates. A final section concludes.

2. Methodology

The essential idea is that differences in health across the population are expected to cause differences in the labour market outcomes of interest. However any endogeneity caused by omitted variables correlated with health, simultaneity between health status and the outcome of interest, or measurement error in the health variable would bias OLS estimation of this relationship. Measurement error would bias OLS estimates toward zero, whilst we might expect that unobserved heterogeneity will bias down OLS estimates of the effect of poor health on labour market performance, if unobserved factors that lower labour market performance are positively correlated with poor health. One possibility to address these biases is to instrument the health variable with another variable correlated with health but not affected by endogeneity or measurement error. We argue that the Chernobyl accident constituted an exogenous exposure to radiation of certain sections of the Ukrainian population which, if correlated with health, could be a potentially useful instrument to assess the effect of health on socio-economic attainment.

In what follows, exposure to radiation from Chernobyl constitutes the “treatment”. The treatment depends partly on the distance from the reactor - though not monotonically since there are several radiation “hotspots” at varying distances from the reactor caused by changes in the wind direction, differential rainfall levels and local topography across areas. In practice, the proxy for this treatment that we focus on is based on the local area radiation level exceeding a specific threshold. The treatment level may also depend on the individual's age at the time of the accident. For example, children who were 0-4 years old at the time of the accident have been particularly vulnerable to thyroid cancer from exposure to radioactive iodine. Indeed the rising incidence of thyroid cancer amongst children has been one of the main demonstrable health impacts of Chernobyl (WHO 2006).

UNDP (2002) shows however that the range of radiation related illnesses is not restricted to cancers. Reports of lung diseases (bronchitis, emphysema), digestive and blood disorders, birth defects, immune deficiencies, fertility problems are all reported to be correlated with exposure to the irradiated areas, (see also Greenpeace 2006). Moreover, exposure to Chernobyl induced radiation can be chronic for many due to continued internal irradiation from consumption of foodstuffs grown in contaminated ground or from leakage of radio-nuclides into ground water from the "graveyards" used to store intermediate waste immediately after the disaster, but unmarked and untreated subsequently. In short, continued exposure to radiation and the long latency period of many of these illnesses suggest the potential existence of long-term "at-risk" populations in the affected areas.

Any study that tries to identify the effects of Chernobyl by comparing groups exposed to more radioactivity than others has to address possible confounding issues. The treatment may generate an endogenous response because, as with the Chernobyl disaster, governments put resources into the most affected areas and individuals (MNS 1991). The Ukrainian government did indeed enact a series of sliding scale interventions regarding compensation, pension, health, housing and education for those deemed to have undergone severe exposure to radiation. So, it is possible that later-life outcomes may be affected by the subsequent interventions as well as the initial treatment. The random pattern of radiation makes it less likely that the fallout was concentrated in areas or individuals that had worse employment prospects relative to others. However, while everybody was evacuated from all areas within 30 kilometres of the Chernobyl plant, the authorities did engage in environmental amelioration in other heavily irradiated areas outside the exclusion zone. It is conceivable that these interventions may have influenced the development of these areas and, hence, the subsequent economic performance of the individuals residing in these areas. Comparing treatment effects across cohorts can be problematic because of the difficulty of separating the effect of the treatment from other (cohort-level) events over time. In what follows we control for a variety of exclusion restrictions, individual and area characteristics in an effort to minimise these confounding effects. The use of longitudinal data may also allow us to control for unobservable effects that could otherwise bias the estimation process.

Measuring Fallout

Radiation fallout from Chernobyl has been measured mainly (Ministry of Emergencies of Ukraine 2006) by the presence of the two radioactive isotopes of most concern to the monitoring authorities – radioiodine (^{131}I) and radiocaesium-137 (^{137}C). Young children were thought to be particularly at risk of thyroid problems following exposure to ^{131}I, found initially in the air and then in contaminated milk . However since it has a half-life of only 8 days the population at risk is likely to vary from that exposed to ^{137}C , which has a half-live of around 30 years and as such carries a more persistent legacy. Consequently, and also because of the fact that its persistence makes it easier to measure, this is the radiation dosage that we use in our analysis. Background levels of ^{137}C before the accident, principally the legacy of nuclear weapons testing by the Soviets in neighbouring Kazakhstan after the Second World War, were estimated at 2 kilo Becquerel (kBq/m^3). While almost all areas of the Ukraine received radiation doses in excess of levels observed before the accident, (see Table 1 for the ULMS sample estimates), areas where exposure levels to ^{137}C were in excess of 1480 kBq/m^3 were subject to immediate evacuation. Following the accident, changes in wind direction, wind speed, local rainfall, allied to the degree of forestation, urbanisation and topography in the locality all contributed to the variation in fallout as document by the pattern of ^{137}C deposits in Figure 1. This pattern of dispersal was rather random, making it less likely that radiation was concentrated in areas of worse employment prospects. If anything, the fact that the majority of the affected areas are in the vicinity of Kiev where all measures of labour market performance are far better than in the rest of the country (Lehmann, Kupets and Pignatti (2005)) would suggest the opposite. Nevertheless, Figure 2 makes clear that exposure to fallout is rather more random than a simple measure of distance from Chernobyl would suggest.

Some 50,000 individuals living in areas with radiation greater than 1480 kBq/m^3 were evacuated within a month of the accident. The majority of evacuees were sent to Kiev, Zhitomir and Chernigov, areas which themselves had received lower, but non-negligible, radiation doses. Individuals resident in other "highly contaminated territories" – those that received between 555 and 1480 kBq/m^3 - were not moved to purpose built towns such as Slavutich until after 1986 (IAEA 2006), which because of the pattern of disposition were again also contaminated by (lower but significant levels of) fallout from Chernobyl. It is this population and areas that were eligible for government assistance. However, any exposure in excess of 37 kBq/m^3 was considered to be high and areas of contamination that received such dosages were subject to monitoring by the Soviet Authorities and continued to be so by the Ukrainian successor governments (European Commission 1998).

In total, government assistance schemes were also targeted at an estimated 800,000 adults, comprising "liquidators" – often military conscripts – who were involved in the clean-up process, the Chernobyl plant workers, the evacuees from the 30km exclusion zone, those living in highly contaminated territories and any children of these adult populations. The liquidators and plant workers were the group estimated to be exposed to the highest radiation dosages, followed by the inhabitants of the 30km exclusion zone, (IAEA 2006). Since 1986 it has become apparent that radiation dosages have fluctuated both across and within areas over time because of differences in topography or climate.[4] As a result some areas where the initial dosage was relatively light have received larger cumulative dosages than areas where the initial exposure was relatively high. Its particular concentration in forested areas has consequences for those consuming mushrooms, berries and game taken from contaminated areas. Potential health risks over and above background radiation from direct exposure to the radiation cloud include continued inhalation/consumption of contaminated particles/foodstuffs, consumption of forest food and time spent outdoors. In short, continued exposure to radiation and the long latency period of many of these illnesses suggest the existence of long-term "at-risk" populations. Our measure of radiation might be thought of as a combination of these acute and chronic effects.

3. Data

We use in our analysis the 2003 and 2004 waves of the Ukrainian Longitudinal Monitor Survey (ULMS), a longitudinal survey of initially 4,300 households and approximately 8,800 individuals aged 16 and over, undertaken for the first time in the spring of 2003.[5] These are the only available data for the Ukraine, Belarus or Russia that allow us to identify both health outcomes and individual location in 1986. A household questionnaire contains items on the demographic structure of the household, its income and expenditure patterns together with living conditions. An individual questionnaire elicits detailed information concerning both the labour market experience of workers in the Ukraine and on, self-defined, health status and specific health conditions, height and weight.[6]

Alongside detailed socio-demographic and income information, the ULMS data also contain responses to a basic question on health status which appears in both surveys "How would

[4] Effective radiation doses are measured in millisieverts, (mSv). The average annual worldwide dose of background radiation is around 2.4mSv (IAEA (2006)). The IAEA estimates that liquidators received accumulated doses of around 100mSV over three years and residents of the monitored areas received, on average, between 10-30 mSV over twenty years. This represents an annual effective radiation dose around 1mSV over and above normal background doses.

[5] This constitutes a 0.02% sample of the adult population of 40 million.

[6] See Table 2 for the full set of self-reported conditions available in the survey. Baker et al. (2004) offer evidence to suggest that specific self-reported health conditions suffer from much the same measurement error and justification biases as self-reported overall health.

you evaluate your health?", to which the possible responses are : very good, good, average, and bad. There is a long-standing debate about the efficacy of using self-reported health measures, particularly ordinal variables which purport to measure an individual's overall perception of their health. Issues of comparability of subjective measures across individuals abound alongside the "justification" hypothesis that sees these variables as rationalisations for a given economic status, such as absence from work. IAEA (2006) suggests that the psychological rather than the physical legacy of Chernobyl may ultimately be more important. If so, then perceptions of health would be as likely to be correlated with perceived exposure to radioactivity from Chernobyl as the actual dosages received. In this way the determinants of self-reported health status may be a relevant variable to examine.

With regard to the issue of Chernobyl, there is a question in the 2003 ULMS which asks respondents where they were living in December 1986, the year of the Chernobyl disaster. The responses allow us to pinpoint the location to the nearest village. Some 760 settlements are identified among the list of responses.[7] Given this information we can map in the radiation dose the settlement is estimated to have received in April 1986 according to EC/ICGE (2001) which provide detailed "contour maps" of ^{137}C deposits in May 1986 for each country in Europe. Given this we can generate variables that measure the initial dosage – at the settlement level - and the cumulative dosage over twenty years at the level of the raion. We also generate dummy variables to group radiation dosages into very high (in excess of 37 ^{137}C kBq/m^3) and the rest. [8] We can also identify individuals living in the monitoring zones at the time of the accident.

Given this information we can then observe individuals and their children 18 years later and examine their circumstances conditional on the radiation dose received around the time in which they were living at the time of the accident. Since the young and those in the womb appear to be more vulnerable to radiation exposure, (Almond et al (2007)), we can interact the dosage

[7] This includes residence outside the Ukraine. Some 5% of the adult sample were living outside the boundaries of present- day Ukraine in 1986.
[8] Note that the 1986 dosage variable is by construction time invariant.

with age at the time of the accident. We can, in principle, identify those who were in utero at the time of the accident, but the sample size for this group is small (144 and just 11 in the monitored raions) and the set of labour market related potential outcomes that can be measured is limited given that none of these children will have graduated from high school by 2003. Instead we generate a dummy variable to indicate whether the individual was a child (under 13) at the time of the accident and interact this with the dummy variable for residence in the affected areas.[9]

Since we only have information from December 1986, we miss sampling the area of residence of the 50,000 or so residents who were living within 30km of the plant and who were evacuated before the end of 1986. Place of residence in the Soviet Union was strictly controlled and as such it is unlikely that individuals could have moved without permission from the authorities. Nevertheless, the behaviour of the group subject to evacuation and subsequent attempts at compensation, may be different from those not evacuated, it is important that we can isolate the two groups in our data set. For example, it is known that special treatment was given to both evacuees and liquidators including extra schooling, additional health care checks and assisted holidays, (Ministry Of Ukraine of Emergencies (2006)) which may affect subsequent outcomes of interest. However, a subsequent 2007 wave of the ULMS does contain information that allows us to identify anyone who was evacuated because of Chernobyl and whether this was in 1986 or later. Similarly we can also identify the liquidators, for whom area of residence at the time of Chernobyl is less important than the radiation dose they received as a consequence of the clean-up operations.[10] Because of these concerns we exclude those in the sample known to have been on military service, liquidators or those who were evacuated in 1986 . The data is however subject to any survivor bias that may be caused by early deaths in the contaminated zones.[11]

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[9] This precludes use of this interaction variable as an instrument in the 1996 data since none of these individuals will be older than 22 in 1996.

[10] Given the nature of the Soviet Union, it is highly unlikely that any other members of the population could have moved or were allowed to move at this time.

[11] The median tenth and ninetieth percentiles of the age distribution are not statistically significantly different across the two zones. Attrition from the panel does not appear to be associated significantly with residence in the contaminated zone. See Table A5 for estimates of the observable determinants of attrition from the sample.

Table 1 documents the dispersion of estimated dosages. Most (66%) individuals in the sample were living in areas that received an (immediate) dose of less than 10 kBq/m^3 of ^{137}C. The median settlement-level dosage is 7 kBq/m^3. Just over 4% of the sample was resident in areas that exceeded the 37kBq/m^3 monitoring threshold and 8% were resident in the monitor zones. Around 22% of adults in the sample and some 16% of the working age adults say that they are in poor health. These estimates are rather high compared to those from the industrialised West.[12]

The labour market related data contained in the ULMS allow us to observe whether an individual is in employment, the number of weekly hours worked, the log of monthly wages and whether the individual is engaged in growing foodstuff for consumption.[13] Mean values of these and some of the other covariates used as controls in the analysis are also given in Table 1. Around 60% of the prime age adult sample is in work and working, on average, some 41 hours a week. Around 38% of the working age sample are engaged in production of own foodstuffs, indicative of the legacy of the transition economy on individual activity. Around 3% of the sample work in the informal sector. Some 0.8% of the sample of adults in 2003 can be identified as liquidators and 0.6% of the sample classify themselves as evacuees.[14]

4. Results

Table 2 shows the results of the first stage of the estimation process, examining whether there is a link between self-reported poor health and Chernobyl-related radiation exposure. Linear probability models are used despite the binary nature of the dependent variable, following Angrist (2000).[15] The set of controls include a quadratic in age, dummies for educational attainment of the individual and their parents, controls for gender, ethnicity and religion. To account for any

[12] The 2007 Health Survey for England suggests equivalent percentages of 7.3% and 5.1% respectively. The 2003 US National Health Interview Survey gives equivalent estimates of 3% and 2% respectively.

[13] We make no attempt to control for the effect of wage arrears on monthly wages. There is no evidence from our data that living in the contaminated zone is correlated with the 12% incidence of wage arrears among those in work.

[14] 0.2% of the sample were evacuated in 1986.

[15] Essentially identification of causal effects is not hindered by a binary dependent variable and 2SLS estimates are always consistent no matter whether the first stage is linear or not.

systematic area effects that may be correlated with the pattern of fallout and area economic performance, there are also dummy variables for residence in the capital, its outlying oblast and residence in the south, east and west of the country.[16] For the sample of all adults, there is a significant positive association in 2003 and in 2004 between poor health and area level dosage – whether measured by residence in 1986 in a designated contaminated zone or by residence in 1986 in areas that received in excess of 37 ^{137}C kBq/m^3.[17] The effects are stronger in 2003 and in that year the estimated effects are stronger for residence in a contaminated zone and for prime age adults. Those prime age adults living in a contaminated raion were some eleven percentage points more likely to report being in poor health than those who were living elsewhere in 1986.[18] The results do not change appreciably if the sample is split by distance from Chernobyl or by area level dosage, but the point estimates are larger for older workers and for women.[19]

Other Health Outcomes

Table 3 replaces the self-reported poor health dependent variable used in Table 2 with other health conditions identifiable in the ULMS data set, using the same set of controls as in Table 2. We also add measures of height, BMI, smoking and drinking behaviour to the set of outcome variables. Without exception the radiation related variable estimates are statistically insignificant.[20] Since it may be argued that the self-reported poor health variable is proxying an accumulation of illnesses rather than a single complaint, we check to see whether the contaminated zone variable is associated with proxies for the aggregation of the set of illnesses in the data. Again we find no significant effect of residence whether the outcome variable is "any health problems" or when we add all the health conditions from heart problems to tuberculosis.

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[16] The default region is therefore the North excluding Kyiv.

[17] If we use the actual dosage variable, then the estimated effect is also positive but less significant than the estimates using the dummy variables. Estimates available on request.

[18] The full set of covariate estimates are given in Table A4 in the appendix.

[19] See Table A5 in the appendix for the estimates split by gender. This is consistent with the literature that finds larger effects of other health shocks for women, (Maccini and Yang (2008). Results for other sample splits are available on request. The addition of an interaction term with the contaminated zone and age removes the significant effect of the contaminated dummy and the interaction term is also insignificant.

[20] Danzer and Weisshaar (2009) report a significant negative association between well-being and an individual's assessment that "their health or that of a family member" had been affected by Chernobyl.

These results therefore suggest that any effect of the Chernobyl radiation fallout is currently manifesting itself mainly through health perceptions of the majority of working age adults rather than through any other demonstrable health outcomes.

Reduced Form Estimation

If we are to use radiation exposure as in instrument for health in an employment or wage equation, it is helpful to try to establish that health is the main effect through which radiation exposure would affect labour supply or wages, since it could conceivably affect other variables known to be associated with labour market performance such as fertility, marital status or education. Any correlation between the intended instrument and these other potential explanatory factors may compromise the validity of the identification exercise. To this end, Table 4 presents the estimated effects of residence in the contaminated zone in 1986 on educational attainment, number of children and marital status. There is no evidence that residence in the contaminated zone is associated significantly with any of these known correlates of the probability of work. This suggests that the main channel through which radiation contamination is influencing behaviour is through its effect on the health perception of the working age population. It would seem then that the best candidate variable to be instrumented by radiation-related variables is the poor health status. However residence in the contaminated zone, but not in the high dosage areas, does appear to be negatively associated with mobility, both any move, and between-region mobility. This suggests that individuals are therefore not moving away from any perceived danger, rather the contrary.

Table 5 presents the results of the reduced form estimates of the effect of radiation dose on employment, wages, hours of work, and the probabilities of being in informal work or of growing agricultural produce at home. While the point estimates of residence in the contaminated zone are generally of the expected sign, in the same direction as those for poor health in Table 2, the estimates are not always significant. There do appear to be statistically significant negative effects of residence in the contaminated zone on hours of work. Residents in these areas work around two hours less than others.

Table 6 presents OLS and IV estimates of the effect of this variable in equations explaining the determinants of seven important labour market performance measures; the incidence of employment, the number of hours worked the incidence of informal working, the incidence of self-production of agricultural foodstuffs and the log of monthly wages for the sample of prime age adults in 2003. The OLS estimates suggest that, with the exception of informal work, poor health status is a negative and significant determinant of these outcomes. The point estimate for the probability of work suggests that those who are in poor health are some twenty-one points less likely to be in work other things equal.[21] When we instrument using the monitor zone dummy variable, while the instruments are significant in the first stage regression, as shown in Table 4, and above the Stock Yogo threshold for weak instruments[22], the second stage IV estimates are in the main poorly determined. The Pagan-Hall tests for heteroskedasticity are all significant, so we apply the robust correction to the IV/2SLS estimator.[23] However the IV estimates of the effect of bad health are either insignificant or significant with confidence intervals around the estimates large enough to incorporate the OLS estimates.[24]

When the data is pooled over 2003 and 2004, (Table 7) the pooled OLS estimates again suggest a negative association between poor health and labour market performance. The random effects estimates tend to shift the estimated negative effect back toward zero, consistent with the idea that unobserved heterogeneity biases down the estimated OLS effects of poor health. However when the poor health variable is instrumented using random effects IV, the poor health

[21] The point estimate on self-reported poor health is the largest and most statistically significant of all the OLS estimates on all the other health variables outlined in Table 4, if entered separately in the employment equation.
[22] Note that these thresholds are not robust to the presence of heteroskedasticity (see Baum, Schaffer, and Stillman (2007)) and so should be used with appropriate caution.
[23] When the model is just identified, as here, 2SLS is equivalent to IV/GMM.
[24] The OLS (and IV) estimates of the effect of health are not affected by the removal of evacuees and liquidators from the sample. This suggests that the possible confounding effects of interventions by the authorities on the relative labour market performance of the populations most exposed to radioactivity are small. The results do not change much if the treatment and control samples are resticted to those falling in the area of common support. All estimates available from authors on request.

variable is insignificant or imprecisely estimated. If anything the point estimates are lower than those of OLS, suggesting that the endogeneity is biasing the OLS estimates of poor health in an upward direction. [25]

5. Conclusion

The evidence presented above appears to suggest that the Chernobyl accident carries a long lasting legacy for many residents of the Ukraine, notably because of its effect on the perception of their health. Adults living in areas considered to have received sufficiently high radiation fallout as to be continually monitored are up to 10 percentage points more likely to report being in poor health. However, there is a less obvious manifestation of such an effect on a variety specific self-reported health conditions. This suggests that the main long-term effect of Chernobyl for the majority of the current adult population may be working through perceptions.

If residence in the monitoring has had an exogenous effect on health perceptions this could be used to identify the effect of self-reported poor health on the probability of employment, wages or other activities that generate income and/or subsistence for the Ukrainian population. While there is also little evidence from the data used here that residence in a contaminated zone has influenced fertility or marriage behaviour, the evidence from the reduced form estimates also suggests that there is only a limited effect of residence in a contaminated zone on variations in labour supply behaviour. As a result, IV estimates from this sample that use residence in the contaminated zones as an instrument for poor health, are either insignificant or significant with confidence intervals around the estimates large enough to incorporate the OLS estimates. However the first stage results are encouraging enough to warrant further investigation of this issue.

[25] The results for the sample of women prime age adults are given in Table A7 of the appendix. In general they are much better determined than the estimates for men.

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Figure 1. Distribution of Radiation Fallout Across Ukraine, April 1986

(Source: Office for Official Publication of the European Community 2001)

Figure 2. Settlement –Level Initial Dosage (^{137}C k/Bq m^3) ULMS Sample

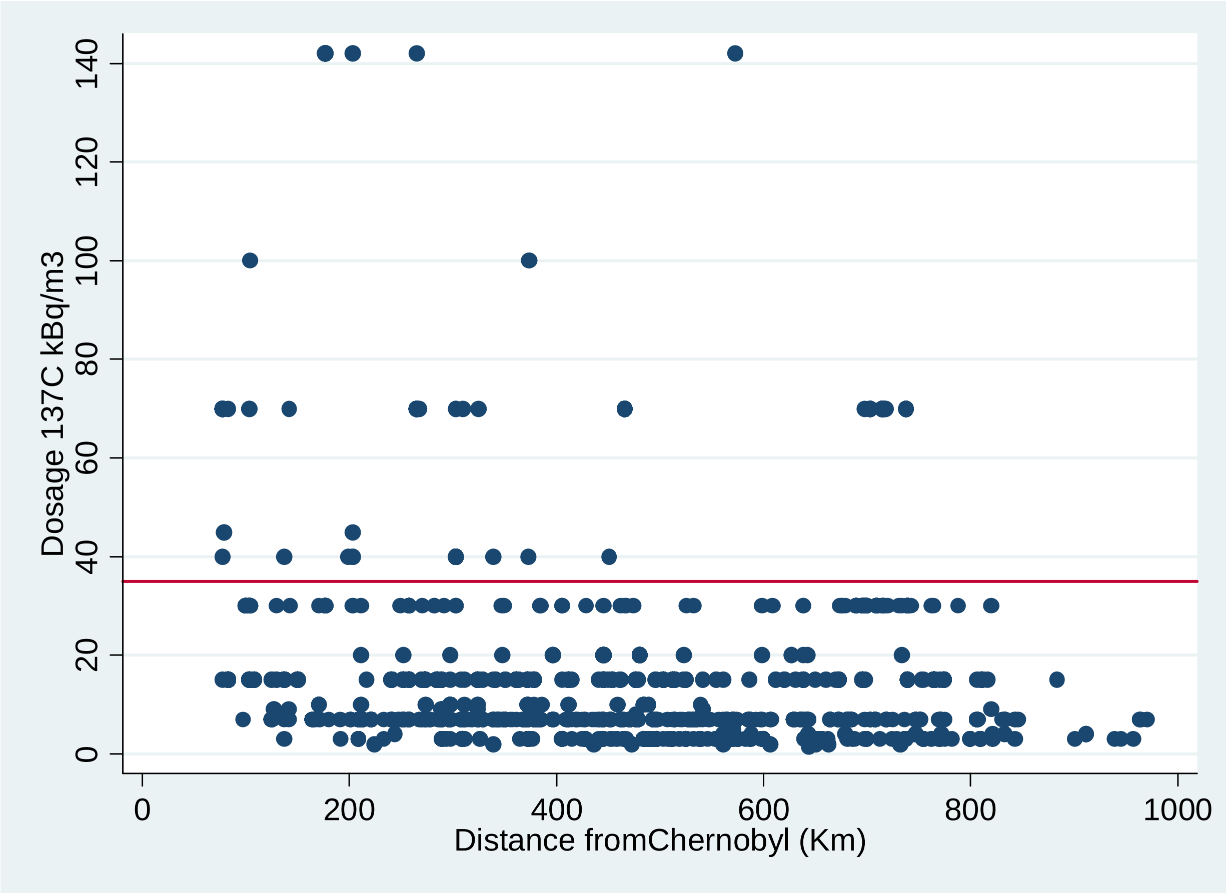

Table 1. Sample distribution of Radiation Dosage & Other Characteristics, 2003

	Percent		
Dosage ^{137}C kBq/m^{3}			
<4	22.2	In Work (Age 16+)	42.9
4-10	46.2	In Work (Age 23-59)	66.1
11-34	27.4		
35-99	3.7	In Bad Health (Age 16+)	22.1
99+	0.5	In Bad Health (Age 23-59)	16.4
Monitor Area	7.5	Actual Weekly Hours>=0	26.2 (22.6)
Monitor Area*Age<13	2.2	Actual Weekly Hours>0	41.8 (12.9)
Liquidator	0.8		
Evacuee	0.6	Gross Monthly Wage (Hrv)	309 (220)
Female	56.8	Informal Work	3.4
		Self Employed	5.3
Age 16-24	17.9	Own agricultural prodn.	38.2
Age 25-44	33.7		
Age 45-60	27.7		
Age 61+	20.7	Mother_graduate	8.2
		Mother_High school	29.2
Kyiv	5.0	Father_graduate	9.8
		Father_ high school	28.1
University	12.8		
Technical Diploma	40.0	Orthodox	61.6
High School	18.5	Other religion	19.3
Russian	16.7		
Other	3.8		

Note: Sample ULMS 2003. Standard errors in brackets.

Table 2. Self-Reported "Bad" Health & Chernobyl Exposure

	Age 16+	Age 16+	Age 23-59	Age 23-59
	1	2	3	4
2003				
Area Dosage>37 $KBqm^2$		0.053 (0.023)*		0.074 (0.029)*
Monitor Area_then	0.070 (0.021)*		0.110 (0.027) *	
N	8363	8363	5286	5286
2004				
Area Dosage>37 $KBqm^2$		0.043 (0.025)		0.059 (0.030)*
Monitor Area_then	0.043 (0.022)		0.062 (0.028)*	
N	6814	6814	4307	4307

Notes; Source ULMS. Each regression controls for age, gender, religion, education, education of parents, ethnicity and region. *= significant at the 5% level.

Table 3. Linear Probability Estimates of Health Conditions & Chernobyl Exposure (Age 23-59)

	Health Status	***Any Health***	***Smoke***	***Drink***	***Heart***	***Lung***
2003						
Monitor Area_then	0.063	0.037	-0.045	-0.006	-0.040	0.009
	(0.045)	(0.032)	(0.026)	(0.029)	(0.022)	(0.014)
	Liver	***Kidney***	***Gastrointestinal***	***Spine***	***Other***	***Diabetes***
Monitor Area_then	0.015	0.030	0.044	0.010	0.026	0.007
	(0.022)	(0.020)	(0.026)	(0.023)	(0.027)	(0.008)
	Heart Attack	***Blood Pressure***	***Stroke***	***Anemia***	***Tuberculosis***	***BMI***
Monitor Area_then	0.002	-0.006	0.007	0.011	0.002	0.076
	(0.003)	(0.023)	(0.007)	(0.014)	(0.003)	(0.321)
	Height (cm)	***Obese (BMI>30)***	***Underweight (BMI<19)***	***Amount Drink***	***Amount Smoke***	$\sum_{i=heart}^{tuberc.} health_i$
Monitor Area_then	-0.003	0.016	0.021	0.009	-0.717	0.111
	(0.004)	(0.026)	(0.014)	(0.108)	(0.476)	(0.076)

Notes; Source ULMS. Each regression controls for age, gender, religion, education, education of parents, ethnicity and region. Means of dependent variables are 0.468 (any health), 0.327 (smoke), 0.667 (drink), 0.144 (heart problems), 0.051 (lung problems), 0.084 (liver), 0.074 (kidney), 0.131 (gastrointestinal), 0.119 (spine), 0.013 (diabetes), 0.168 ("other"), 0.010 (heart attack), 0.150 (blood pressure), 0.010 (stroke), 0.036 (anaemia), 0.006 (tuberculosis), , 25.5 (BMI), 1.69m (Height), 0.155 (obese), 0.041 (underweight).

Table 4. Effect of Residence in Contaminated Zones on Other Outcomes (2003)

	Single			***Divorced***		
	All	Women	Men	All	Women	Men
i) Area Dosage>37 KBqm^2	-0.015	-0.004	-0.020	-0.013	-0.010	-0.016
	(0.017)	(0.021)	(0.027)	(0.020)	(0.031)	(0.023)
ii) Monitor Area_then	-0.001	-0.004	0.004	0.031	0.016	0.052
	(0.019)	(0.024)	(0.031)	(0.020)	(0.027)	(0.027)
N	5303	3041	2262	5303	3041	2262
	Number of children			***Years of education***		
ii) Area Dosage>37 KBqm^2	0.109	0.077	0.143	-0.043	-0.128	0.061
	(0.071)	(0.099)	(0.100)	(0.067)	(0.099)	(0.088)
iii) Monitor Area_then	0.018	0.033	0.007	-0.059	-0.104	-0.008
	(0.062)	(0.083)	(0.091)	(0.059)	(0.077)	(0.097)
N	5303	3041	2262	5303	3041	2262
	Any Move			***Move region***		
ii) Area Dosage>37 KBqm^2	-0.032	-0.061	0.005	-0.021	-0.026	0.014
	(0.031)	(0.041)	(0.048)	(0.024)	(0.031)	(0.037
iii) Monitor Area_then	-0.111	-0.147	-0.066	-0.078	-0.100	0.047
	(0.030)*	(0.038)*	(0.048)	(0.027)*	(0.034)*	(0.045)
N	5303	3041	2262	5303	3041	2262

Notes; Source ULMS. Each regression also controls for region of residence, age, gender, religion, ethnicity and parental education. Sample restricted to ages 23-59

Table 5. Reduced form estimates of Residence in Contaminated Zone on Labour Market Outcomes (2003)

	Work			***Log Monthly Wage***		
	All	Women	Men	All	Women	Men
i) Area Dosage>37 KBqm^2	-0.024	0.038	-0.095	-0.051	-0.142	0.065
	(0.034)	(0.044)	(0.051)	(0.051)	(0.053)**	(0.093)
ii) Monitor Area_then	-0.023	-0.008	-0.049	0.003	-0.098	0.138
	(0.031)	(0.040)	(0.049)	(0.057)	(0.055)	(0.079)
	Hours>=0			**Hours>0**		
i) Area Dosage>37 KBqm^2	-2.371	-1.186	-3.445	-1.370	-2.673	0.801
	(1.578)	(1.913)	(2.599)	(1.265)	(1.632)	(1.খ)
ii) Monitor Area_then	-3.531	-3.321	-3.948	-2.775	-3.365	-1.874
	(1.351)*	(1.716)	(2.206)	(0.893)*	(1.304)*	(1.191)
	Informal Work			**Own Agricultural Production**		
i) Area Dosage>37 KBqm^2	-0.019	-1.186	-3.445	-0.001	0.076	-0.089
	(0.010)	(1.913)	(2.599)	(0.033)	(0.045)	(0.049)
ii) Monitor Area_then	-0.023	-3.321	-3.948	0.021	0.042	-0.004
	(0.013)	(1.716)	(2.206)	(0.029)	(0.037)	(0.047)

Notes; Source ULMS. Each regression also controls for region of residence, age, gender, religion, ethnicity and parental education. Sample restricted to ages 23-59. Sample sizes 5302 (total), 3041 (women), 2261 (men) for working age population, 2968 (total), 1611 (women), 1367 (men) for in work population.
*= significant at the 5% level.

Table 6. OLS & IV Estimates of Effect of "Bad" Health on Labour Market Outcomes, 2003

	Work		***Actual Hours>=0***		***Informal Work***		***Own Ag. Prodn.***	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
	1	2	3	4	5	6	7	8
Bad Health	-0.211	-0.225	-8.697	-32.646	-0.015	-0.208	-0.139	0.220
	(0.018)*	(0.283)	(0.822)*	(13.637)*	(0.005)*	(0.127)	(0.017)*	(0.275)
Pagan-Hall		101.1 (22)*		42.4 (22)*		94.3 (22)*		291.5(22)*
Kleibergen-Papp rk F stat.		16.9		16.9		16.9		16.9
	Informal Work/ In work		***Actual Hours>0***		***Log Monthly Wage***			
	OLS	IV	OLS	IV	OLS	IV		
	9	10	11	12	13	14		
Bad Health	-0.011	-0.459	-0.221	-37.835	-0.096	-0.047		
	(0.011)	(0.310)	(0.758)	(19.064)*	(0.031)*	(0.781)		
Pagan-Hall		88.6 (22) *		18.6 (22)		77.2 (22)*		
Kleibergen-Papp rk F stat.		6.0		6.0		3.7		

Notes. Stock-Yogo (non-robust) 10% and 15% IV relative size thresholds are 16.4 & 8.9 respectively. Sample size=5285 working age, 3007 (employed), 2878 (employees). *= significant at the 5% level.

Table 7. Panel IV Estimates of Effect of "Bad" Health on Labour Market Outcomes

	Work				***Hours>=0***			
	Pooled OLS	Random Effects	Pooled 2SLS	IV Random Effects	Pooled OLS	Random Effects	Pooled 2SLS	IV Random Effects
2003/2004								
Bad Health	-0.216	-0.151	-0.811	-0.754	-8.791	-6.295	-49.232	-47.271
	(0.016)*	(0.014)*	(0.366)*	(0.404)	(0.759)*	(0.689)*	(15.679)*	(21.604)*
Wald rk F			21.9				21.9	
N	8308	8308	8308	8308	8308	8308	8308	8308
	Informal Work				***Own Agricultural Production***			
	Pooled OLS	Random Effects	Pooled 2SLS	IV Random Effects	Pooled OLS	Random Effects	Pooled 2SLS	IV Random Effects
2003/2004								
Bad Health	-0.011	-0.009	-0.301	-0.301	-0.159	-0.119	0.265	0.282
	(0.005)*	(0.005)	(0.135)*	(0.169)	(0.015)*	(0.014)*	(0.293)	(0.373)
Wald rk F			21.9				21.9	
N	8308	8308	8308	8308	8308	8308	8308	8308

Notes. Standard errors clustered by individuals. *= significant at the 5% level.

Figure A1. Employment Rate by Age, Gender & Health Status, Ukraine 2003/4

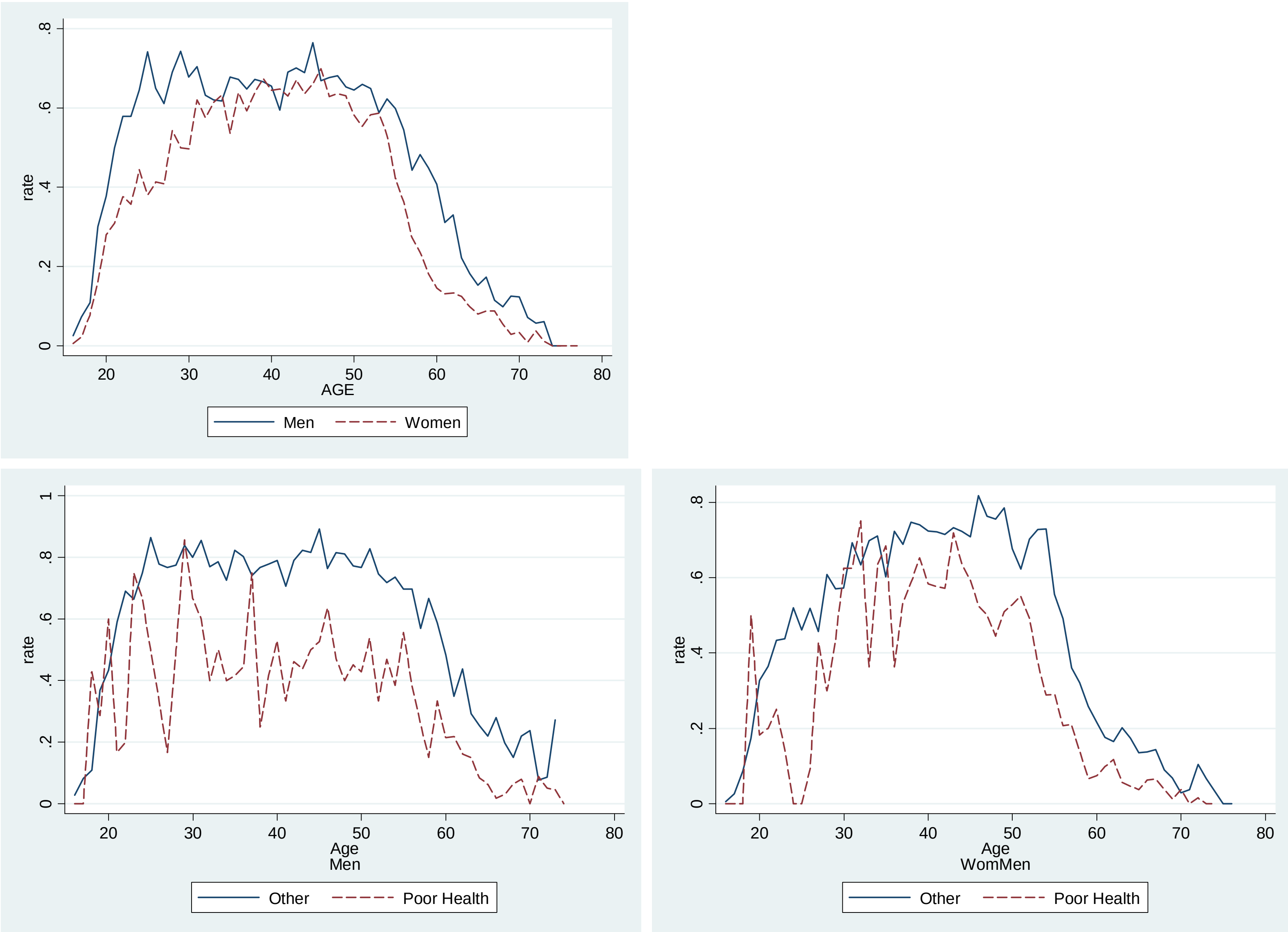

Table A2. Self-reported Health Status

	2003			2004		
	Total	***male***	***female***	***Total***	***male***	***female***
All Adults						
Any	50.0	41.2	56.5	44.3	35.3	50.7
Very Good	1.7	2.7	1.0	1.5	2.4	1.0
Good	22.9	30.3	17.2	23.5	29.8	19.1
Average	52.6	49.8	55.0	53.1	51.2	54.9
Bad	22.5	17.2	26.6	21.4	16.6	25.0
Age 23-55						
Any	48.9	36.7	51.2	38.3	38.0	43.8
Very Good	1.3	2.4	0.7	1.4	2.3	1.0
Good	23.9	32.4	15.4	24.6	31.2	18.7
Average	59.0	53.1	56.2	59.8	54.8	55.9
Bad	15.7	12.1	27.7	14.2	11.8	24.4

Source:ULMS.

Table A3. Self-reported Health Across Waves

		2004			
		Very Good	Good	Average	Bad
	Very Good	22.9	48.6	24.8	3.8
2003	Good	3.3	51.7	41.7	3.4
	Average	0.7	17.6	68.7	13.0
	Bad	0.3	3.1	36.2	60.4
		Any	None		
2003	Any	63.0	37.0		
	None	73.5	26.5		

Table A4. First Stage Estimates of Poor Health Table . 1st Stage Estimates of Poor Health

	Bad Health	Amount drunk	Heart Problems
Monitor zone in 1986	0.108	0.009	-0.040
	(4.04)**	(0.09)	(1.77)
AGE	-0.004	-0.037	-0.010
	(0.97)	(1.91)	(2.68)**
AGE squared	0.001	0.001	0.001
	(2.89)**	(2.62)**	(4.44)**
Female	0.063	1.416	0.100
	(6.31)**	(28.92)**	(11.19)**
Russian	0.021	-0.204	0.006
	(1.48)	(3.01)**	(0.47)
Other ethnicity	-0.019	0.100	0.010
	(0.79)	(0.81)	(0.42)
Orthodox	0.016	-0.015	0.038
	(1.25)	(0.24)	(3.25)**
Other religion	0.002	0.254	-0.003
	(0.12)	(3.03)**	(0.22)
Village	-0.003	0.119	0.012
	(0.22)	(2.20)*	(1.09)
Kyiv	-0.110	-0.620	0.034
	(3.81)**	(4.81)**	(1.21)
Kyivskaya	-0.066	0.228	0.072
	(1.78)	(1.40)	(2.09)*
West	-0.073	-0.207	-0.024
	(4.15)**	(2.79)**	(1.49)
East	-0.053	0.118	-0.007
	(3.30)**	(1.78)	(0.46)
South	-0.062	0.069	-0.037
	(3.37)**	(0.84)	(2.24)*
University graduate	-0.139	-0.063	-0.041
	(7.00)**	(0.71)	(2.13)*
Technical school	-0.079	-0.112	-0.037
	(4.54)**	(1.54)	(2.36)*
High school diploma	-0.033	-0.003	-0.019
	(1.65)	(0.04)	(1.04)
mother_graduate	0.001	0.068	-0.020
	(0.05)	(0.62)	(1.06)
Mother_high school	-0.003	0.038	-0.007
	(0.24)	(0.67)	(0.64)
Father_graduate	-0.008	-0.039	0.019
	(0.51)	(0.42)	(1.10)
linguist	-0.004	-0.127	-0.017
	(0.30)	(2.35)*	(1.56)
Constant	0.132	5.855	0.146
	(1.68)	(14.66)**	(1.97)*

Note sample size 5203. T statistics in brackets.

Table A5. First Stage Estimates of Poor Health by Gender

	Female		Male	
	2003	**2004**	**2003**	**2004**
Monitor Area_then	0.150 (0.038)*	0.090 (0.039)*	0.049 (0.034)	0.022 (0.037)
N	3035	2512	2251	1795

Table. A6. Estimated Sample Attrition Probabilties (Marginal effects)

	Drop Out	Drop Out
Monitor zone in 1986	0.030	-0.037
	(0.021)	(0.023)
AGE		-0.005
		(0.004)
AGE squared		0.000
		(0.000)
Female		-0.029
		(0.011)**
Russian		-0.000
		(0.015)
Other ethnicity		-0.051
		(0.023)*
Orthodox		-0.065
		(0.014)**
Other religion		-0.059
		(0.015)**
Village		-0.112
		(0.011)**
Kyiv		0.246
		(0.045)**
Kyivskaya		0.156
		(0.052)**
West		0.176
		(0.024)**
East		0.032
		(0.019)
South		0.280
		(0.027)**
University graduate		0.020
		(0.022)
Technical school		0.002
		(0.017)
High school diploma		0.006
		(0.019)
Mother_graduate		-0.041
		(0.021)*
Mother_high school		-0.011
		(0.013)
father_graduate		0.021
		(0.021)
linguist		0.021
		(0.012)

Note marginal effects from probit estimates. Robust standard errors in brackets. * significant at 5%; ** significant at 1%. Mean of dependent variable is 0.192.

Table A7. OLS & IV Estimates of Effect of "Bad" Health on Labour Market Outcomes: Women Only

	Work		***Actual Hours>=0***		***Informal Work***		***Own Ag. Prodn.***	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
2003	1	2	3	4	5	6	7	8
Bad Health	-0.166 (0.022)*	-0.078 (0.267)	-6.330 (0.977)*	-23.877 (12.381)	-0.013 (0.007)	-0.035 (0.109)	-0.100 (0.021)*	0.308 (0.265)
Pagan-Hall		84.2 (21)*		44.9 (21)*		52.4 (21)*		162.5(21)*
Kleibergen-Papp rk F stat.		15.5		15.5		15.5		15.5
Panel								
	Work		***Actual Hours>=0***		***Informal Work***		***Own Ag. Prodn.***	
	OLS	Panel IV	OLS	Panel IV	OLS	Panel IV	OLS	Panel IV
	9	10	11	12	13	14	15	16
Bad Health	-0.176 (0.019)*	-0.500 (0.329)	-6.938 (0.813)*	-38.361 (17.551)*	-0.010 (0.006)	-0.110 (0.124)	-0.122 (0.017)*	0.232 (0.311)

Notes. Stock-Yogo (non-robust) 10% and 15% IV relative size thresholds are 16.4 & 8.9 respectively. Sample size=5285 working age, 3007 (employed), 2878 (employees). *= significant at the 5% level