Forecasting pathways of psychosocial anxiety, depression, and post-traumatic stress in Ukraine following the Chornobyl nuclear accident

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Abstract

Background: In the 25 year review of the effects of the Chornobyl nuclear disaster, the mental health impact was found to be the largest public health consequence of the accident for Ukraine.
Objectives: Our objective was to examine the psychosocial impact of the Chornobyl nuclear accident on the general population. We focus on psychosocial anxiety, depression, and post-traumatic stress reported by respondents over three decades using techniques designed to facilitate recall of events.
Methods: We conducted a survey of 702 residents of Kiev and Zhitomyr oblasts. By attaching computer-generated random numbers to telephone area codes, we obtained a representative telephone sample of the Ukrainian residents of those oblasts. Interviews were conducted with willing respondents. Time series of salient psychosocial symptoms were constructed for analysis.
Analysis: We examine pathways of psychosocial depression, anxiety, and PTSD among Ukrainian males and females, using GETS-AutoMetrics variable selection and dynamic simultaneous equation models to analyze symptoms, we demonstrate that we can empirically test and model the immediate impact of the collapse of the U.S.S.R. from other effects, contrary to previous contention. **Conclusion:** In modeling nuclear disaster impact with dynamic simultaneous equation models, we demonstrate circumvention of confounding crises, generated by Russian gas cut-offs to Ukraine in 2006 and 2009, by early estimation termination and scenario forecasting for medical emergency analysis. We thank the National Science Foundation for funding HSD Grant 082 6983.
Keywords and phrases: nuclear incident, nuclear accident, psychosocial impact of Chernobyl, Chornobyl accident impact, nuclear incident impact, nuclear emergency planning, scenario forecasting, Chornobyl public health impact, confounding variable circumvention, Chornobyl impact on public health.

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Disclaimer

Although this was a joint project with all of the persons mentioned, the analysis of strategic political, economic, or military matters in this paper reflect solely the opinion of the first author and not those of any other persons on the project. We did not set out expecting or planning to analyze all events that impacted our area of focal concern. Nor did all persons want to get into those areas. Because our attempt to provide a candid and complete explanation of what happened could not take place without consideration of the strategic political and economic policy impacts of activities that may have led to the increases or surges at the end of the our endogenous series. End-effects can seriously bias forecasts. We need to protect our analysis from confounding by the salient external events impacting psychosocial and post-traumatic stress. Originally, we set out to show whether or not the target population was biologically threatened by external exposure or perceived Chornobyl-related health risk. We found that the level of risk from external dose was not above the threshold of biological reactivity. My belief was that a full and complete explanation was in order. Overspecializing or excluding those strategic military and political factors would deprive the explanation of its full scope and force. Thus, the commentary on these matters was my work and responsibility alone and for this reason, all other grant participants should be absolved of this responsibility. Finally, this position taken by this author does does not necessarily represent that of any governmental agency or administration.

1 Introduction

1.1 Historical background

1.2 The accident and its fallout

On 26 April 1986, the most serious accident in the history of the nuclear power industry took place. Following testing protocol, there was a failure of a cooling process, a meltdown and gas explosion took place in reactor four at Chornobyl, in the northern Kiev oblast in Ukraine. Fires burned for 10 days during which a variety of radioactive isotopes were released into the air. The varying winds carried this fallout until precipitation deposited it onto the surface of the land and waterways across Russia, Scandinavia, and Europe, and later around the world. The devastation from the explosion in reactor number four is shown in Figure 1.

When radionuclides were released, ionizing radiation was released. Alpha (α), beta (β), and gamma (γ) radiation were all emitted. Alpha radiation consists in the emission of an alpha particle (identical to a Helium nucleus), in which two protons are bonded with two neutrons. Beta radiation entails the emission of an electron or a positron. "Gamma-rays have the smallest wavelengths and the most energy of any other wave in the electromagnetic spectrum (52)." Large amounts of radioactive isotopes were given off by this accident. The duration of the radiative emissions is measured in half-lives, the length of time takes for the radiation emitted to to decrease by one-half of its current emissions. Among the early isotopes released into the atmosphere were ^{131} Iodine, with a half-life of eight days, ^{137}Cesium, with a half-life of 30.17 years was perhaps the largest emission. Other radionuclides released included ^{134}Cesium (with a half-life of 2 years), ^{90}Strontium (with a half-life of 28 years), ^{132}Tellurium (with a half-life of 78 hours), ^{106}Ruthenium (a half-life of about a year and 8 days), Plutonium 239 (^{239}Pu) exhibits a half-life of 24,100 years.

Along with Strontium 90 (^{90}Sr) and a few Plutonium isotopes, ^{137}Cs comprises the principle radioactive component of the contamination from a nuclear accidents. Of these radionuclides, ^{90}Sr and ^{137}Cs are the two isotopes with medium-term half-lives from nuclear bomb tests and nuclear accidents. It is conventional to use ^{137}Cs as a standard by which to assess the overall radioactive fallout. With it's 30.17 year half-life, the source-term radioactivity from the other radioisotopes can be computed from the measurements of the ^{137}Cs benchmark. A map of the deposition of this Cs isotope in the Ukraine is shown in Figure 2, (15).

Whether people reside or work downwind of the nuclear plume helps determine the extent to which people were exposed. Whether the rain precipitated these nuclides from the air also was a risk factor. Iodine 131, Strontium 90, and Cesium 137 are deposited on the ground, in the grass and weeds, and leech into the water. They make their way into cows' milk as well and find their way into mushrooms. What people

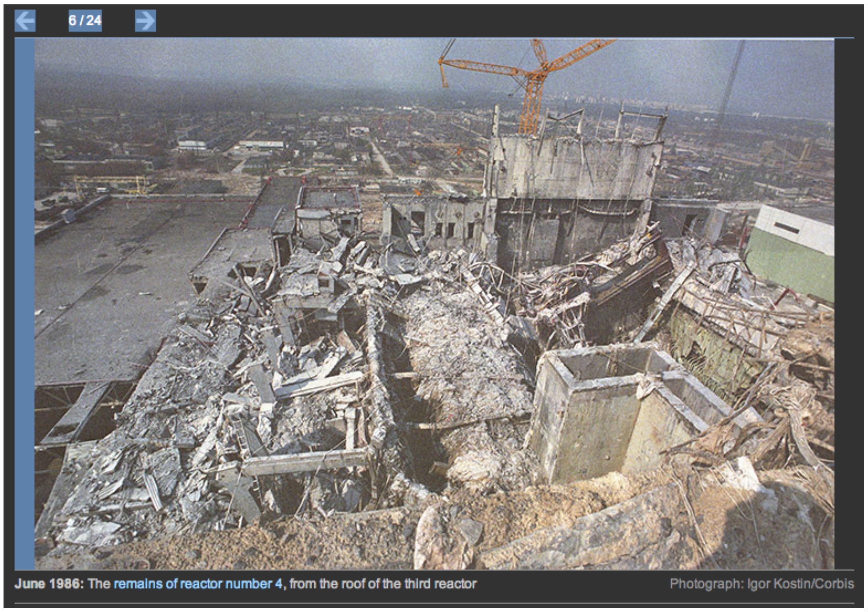

Figure 1: *Devastated reactor four almost a year after the accident*

ate and where they ate it contributed to the internal dosage. Where people resided and worked (outside or inside) helped determine the external dose to which a person is exposed.

1.3 Emergency containment operations

Clean-up workers, called liquidators, were brought in to try to help contain the damage and keep the situation under control. These were the people who suffered the most exposure, although temporal limits were imposed on the time they could participate in the work. The more immediate effects of acute radiation sickness (ARS) followed (3, 215). Many of the early studies focused on the liquidators.

According to the World Health Organization, "A nested case-control study of thyroid cancer has been carried out among Chernobyl liquidators of Belarus, Russia, and the Baltic countries, coordinated by the International Agency for Research on Cancer (IARC) (Kesminiene et al., 2002). The study population consists of approximately 10,000 Baltic countries liquidators, 40,000 Belarus liquidators and 51,000 liquidators from five large regions of Russia), who worked in the 30 km exclusionary zone in the period 26 April 1986 to 31 December 1987, and who were included in the Chernobyl registry of these countries. Overall, 115 cases of thyroid cancer and their respective controls have been interviewed (81, 37)."

In general, the early ecological and case-control studies focused on leukemia and thyroid cancer. The thyroids of children, less than four years old, intake more atmospheric iodine than they do as they age. Because the atmosphere contained radioactive (^{131}I), thyroid cancers were more prevalent among those who were more exposed at a young age. These cancers are surgically remediable. "A recent descriptive study has confirmed the age trend, finding the highest incidence among those exposed at ages 0-4, who also had the highest doses. In future follow-up studies, the highest risk subgroup will be expressing thyroid cancer during young adulthood, and consequently this age group should be studied preferentially in the next few

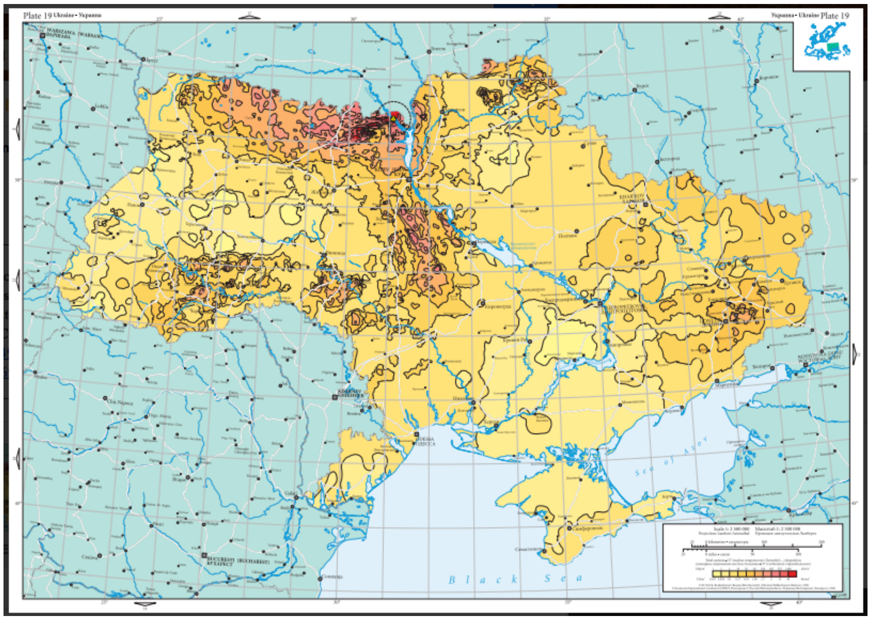

Figure 2: *^{137}Cs contamination measured in Ukraine*

years (81, 30)."

1.4 ^{137}Cs contamination (in Ukraine)

Although the exclusionary zone around Chornobyl extended for 30 km, and encompassed an area of 1,000 square miles or 26,000 square km, radioactivity from the accident was carried by wind currents and deposited with precipitation far beyond the spatial limits of the zone. Given these conditions, in some places, higher altitudes received more radioactive fallout than lower ones. In Ukraine alone, the post-Chornobyl ^{137}Cs contamination deposition is displayed in Figure 2.

1.5 Regional ^{137}Cs contamination

Contamination spread across Russia, Europe, and Scandinavia. It was reported that the Swedish scientists at Forsmark were among the first to detect the spikes in atmospheric radioactivity. After several days of initial denial, the Russians acknowledged that the source of the contamination was the Chornobyl power plant. In Figure 3, we can see the distribution of ^{137} Cesium contamination across Scandinavia, Europe and Russia.

1.6 β radiation contamination (in the U.S.)

Eventually, the air currents extended the radioactive contamination. Consequently, nuclear safety and security became a matter of international concern. Mankind has a common interest in protecting the Earth's habitat from nuclear contamination and degradation if we want to continue to enjoy the quality of life on this planet.

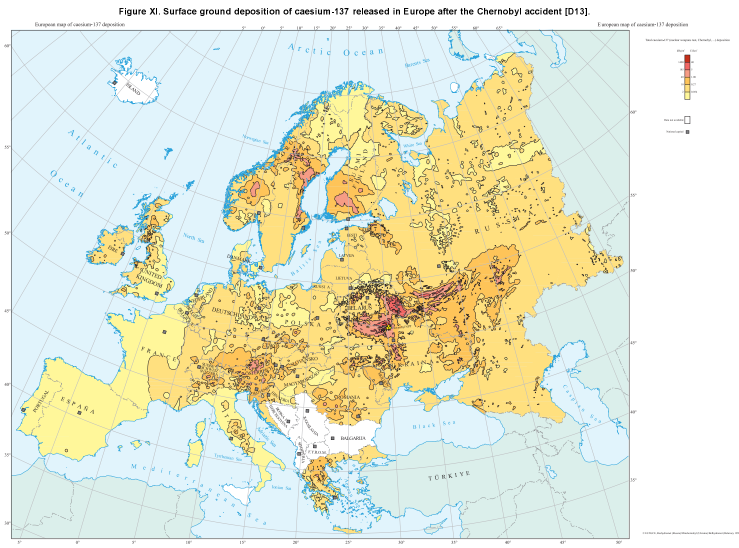

Figure 3: *^{137}Cs surface contamination in Europe and Western Russia*

If we use ^{137}Cs as a benchmark for general assessment, we acknowledge that this isotope emits both gamma and beta radiation. Evidence of contamination can be observed in the rise and fall of the β radiation, measured in picoCuries per cubic meter, in the U.S. atmosphere. Figure 4 reveals the sequence of monthly measures of β radiation levels in the United States from March through July of 1986 (62, 15).

Table 1 lists measurements of surface air concentrations of radionuclides in the U.S. after the Chernobyl nuclear accident taken from the New York Academy of Sciences. Cited sources for these listings included Larsen and Juzdan (1986) (39), Larsen et al. (1986) (40), US EPA (1986) (85), Toppan (1986) (75), Feely et al. (1988) (21), Gebbie and Paris (1986) (24), and Vermont (1986).

Given the wide diffusion of the radionuclides, the question of whether this contamination posed a biological threat to the public health arises. In this study, we focus on those closest to the source-term in Ukraine. Our sample, unlike many previous studies, does not focus specifically on cleanup workers, evacuees from the exclusionary zone surrounding Chornobyl nuclear power plant, or young children whose thyroid uptake of ^{131}Iodine may have led to excessive radioactive iodine absorption.

Our sample focused on the general public in Ukraine within the two oblasts most immediately exposed. The Chornobyl nuclear accident released approximately 10 times the radiation released from the March 11, 2011 Fukishima Daiichi accident, as estimated approximately 3 years afterward. As we can see from the evidence of global diffusion, this contamination is a matter of international concern. It has been estimated that approximately 1017 Bq of ^{137}Cs was released. For comparison, this fallout is 10% of that released from all atmospheric nuclear weapons tests and about 10 times that of Fukushima (17).The pubic health issues raised are of common interest to people from all nation-states and merit universal international cooperation to prevent, contain, and mitigate the danger posed by such an accident or incident. In many cases, one nation-state usually does not have the resources necessary to manage all of these urgent problems alone.

Table 1: *Domestic U.S. radioactivity measurements from the May 1986 Annals of the New York Academy of Sciences*

Radionuclide	**city**	**activity**	**unit of measurement**
^{131}I	New York, NY	$20,720$	$\mu Bq/m^3$
	Rexburg, ID	11,390	$\mu Bq/m^3$
	Barrow, AL	218.7	fCi/m^3
	Portland, ME	2.9	pCi/m^3
	Mauna Loa, HI	28.5	fCi/m^3
^{137}Cs	New York, NY	$9,720$	$\mu Bq/m^3$
	Barrow, AL	27.6	fCi/m^3
	Mauna Loa, HI	22.9	fCi/m^3
Metrics			
m^3	cubic	1^{3D}	m^3
μ	micro	0.000,001	10^{-6}
n	nano	0.000,000,001	10^{-9}
p	pico	0.000,000,000,001	10^{-12}
f	femto	0.000,000,000,000,001	10^{-15}
Legend			
Symbol	*Measure*	of *Radioactivity*	
Bq	Becquerel	$= 2.7x10^{-11}Ci$	$= 10^6 disintegrations/sec$
Ci	Curie	$= 3.7x10^{10}Bq$	
	Isotopes		
^{131}I	^{131} Iodine		
^{137}Cs	^{137} Cesium		

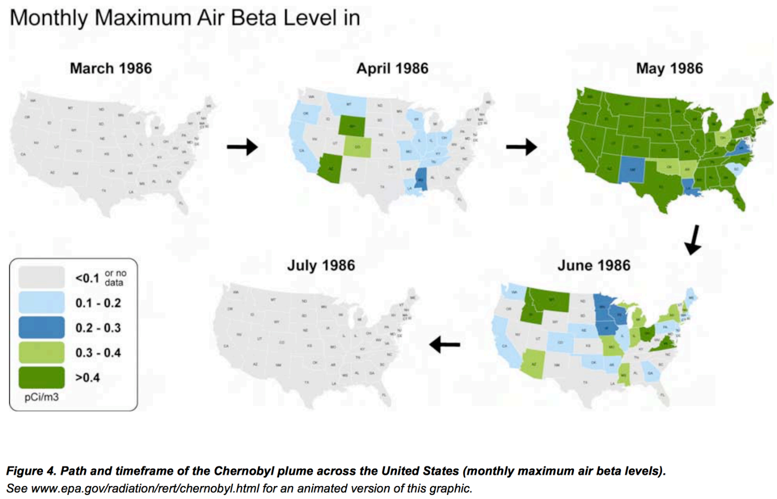

Figure 4: *March through July 1986 maximum atmospheric β levels in U.S.(U.S. EPA rad-net) (62, 15)*

These events may require people with the specialized education, training, capabilities, and skill sets from several countries to cooperate to make sure that such an important problem is addressed and resolved as safely, efficiently, effectively, and as completely as possible. This is a matter in which political leaders and atomic scientists of countries should be willing to cooperate to keep the environment as safe and secure as possible from any threat posed by a nuclear accident, incident, or devastation. A nuclear accident or war is something from which any or all may be indiscriminately faced with a devastatingly destructive and/or disruptive radioactive threat. For human survival, it is imperative that we work constructively and cooperatively on the national, transnational, and international levels to mitigate to risks of nuclear conflict.

1.7 Organization

The organization of this article includes a brief review of the accident and the radioactivity released into the atmosphere. We briefly review the general nature of earlier studies and point out some of their drawbacks. Some of the early studies were ecological, in that they compared groups exposed to radiation under different circumstances, to discover similarities. Most of the early studies were case-control group studies that focused on the highly exposed and unexposed control groups. We discuss these drawbacks and show how our approach attempts to control for their disadvantages.

We concur with the scientists and epidemiologists, studying the effects of Chornobyl after 20 years over the general population, who maintain that the most important effects were mental health consequences. Most early studies focused on the highly exposed groups of individuals, especially those of the clean-up workers and young children whose thyroid uptake of iodine from the air was relative large. However, radioactive ^{131} Iodine was prevalent among the isotopes released in the Chornobyl accident.

We focus our attention on the nature of their psychosocial and post-traumatic distress reported by the general population after the accident. To do so effectively, we must address a contention of Bromet, Havenaar, and Guey (2011), who argued that the collapse of the U.S.S.R. was so devastating in its effects, that those effects are almost impossible to disentangle from prominent psychological effects. We apply linear and non-linear time series techniques to empirically test their "inextricable entanglement hypothesis."

We empirically test this hypothesis with three different statistical methods. The first method is one developed by David Hendry and Jurgen Doornik of Oxford University. With OxMetrics's AutoMetrics, they saturate the data with outliers and/or level-shifts and saturate the data with indicators define the contours of structural change. The algorithm systematically removes all of the indicators that are not statistically significant. Our testing the equations with a Geweke test, indicates that the models exhibit significant simultaneity. The second method, therefore, applies these indicators to dynamic simultaneous equation systems, with three stage least squares to minimize simultaneity bias. The third method uses expectation maximization in Markov-switching regime change models to test whether the collapse of the U.S.S.R. in 1991 delineates a regime change in a non-linear time series model.

Graphs of trajectories of the psychosocial distress (depression and anxiety) and the post-traumatic distress in gender-specific models reveal surges in magnitude of these effects after the occurrence of Chornobyl. If an analysis of these psychosocial effects is to avoid confounding by the impact of intervening crises, we have to manage to circumvent their impact (depicted in Figures 6 and 7). There was little or no effort in earlier studies to control for these potentially confounding impacts. We will briefly review these impacts and demonstrate how we circumvent their confounding with structural time series modeling and forecasting.

We analyze the empirical data with a multivariate state space common local level model, after showing why this procedure should outperform all other contenders with scenario forecasts of what would have followed, had the intervening impacts of the Russian gas cut-offs in 2006 and 2009, along with the other impacts of the Great Recession not taken place. We present the trimmed version of the model, its parameter estimates, and components for women and men separately. We briefly discuss misspecification testing to demonstrate model congruency with statistical theory. We illustrate these forecasts with a forecast profile plot and evaluate *ex post* and *ex ante* forecasts for male and female models separately to provide predictive validation for our approach.

In our discussion, we discuss what we did that was new and different. We review how we minimized bias with our methods. Although we concur that among the most important effects were psychological, we use several methods for controlling for the collapse of the U.S.S.R., thereby avoiding confounding effects of impacts of external events. In so doing, we propound an alternative method for retrospectively analyzing post-disaster sequelae. Replication of this approach may facilitate long-term planning for emergency preparations for natural or accidental disasters. Thus, we show how an analysis of these factors should not be artificially isolated by ignoring the external impacts that affect the psychosocial security and well-being of the people, regardless of whether they derive from deprivations of essential resources.

2 Fndings of early epidemiological studies

2.1 Mental health issues were the most serious public health problems

According to the World Health Organization (henceforth WHO) (2006),

> The mental health impact of Chernobyl is the largest public health problem caused by the accident to date. The magnitude and scope of the disaster, the size of the affected population, and the long-term consequences make it, by far, the worst industrial disaster on record. Chernobyl unleashed a complex web of events and long-term difficulties, such as massive reloca-

tion, loss of economic stability, and long-term threats to health in current and, possibly, future generations, that resulted in an increased sense of anomie and diminished sense of physical and emotional balance. It may never be possible to disentangle the multiple Chernobyl stressors from those following in its wake, including the dissolution of the Soviet Union. However, the high levels of anxiety and medically unexplained physical symptoms continue to this day. The studies also reveal the importance of understanding the role of perceived threat to health in epidemiological studies of health effects (81, 95-96).

2.2 The collapse of the U.S.S.R. as a confounder

There is a claim that that is echoed in the observational studies to the present day. J. M. Havenaar et al. (1997) argued that "most psychological effects in the general population did not rise above subclinical levels", but observed effects were driven by the belief that the respondent had been exposed (28), (81, 93-94). Bromet, E., Havenaar, J.M., and Guey, L.T. (2011), (henceforth, BHG), in the 20th Anniversary Chernobyl Forum Report of the Chernobyl nuclear power plant disaster, concluded that mental health effects were the most significant public health consequence of the accident (5). Furthermore, these authors suggest that "the Chornobyl disaster encompassed a vast array of physical and psychosocial exposures *that are all but impossible to disentangle* from the general turmoil that followed the collapse of the Soviet Union in 1991 (5, 298)." Bromet, (2012), (henceforth, EB), in Mental Health Consequences of the Chernobyl disaster held that "The most common mental health consequences are depression, anxiety, post-traumatic stress disorder, medically unexplained somatic symptoms, and stigma" and that... "the epidemiological evidence suggests that neither radiation exposure nor the stress of growing up in the shadow of the accident was associated with emotional disorders, cognitive dysfunction, or impaired academic performance (6)." The United Nations Scientific Committee to study effects of Atomic Radiation (henceforth UNSCEAR)'s Sources and Effects of Ionizing Radiation scientific annexes suggests that there were forms of psychological stress, moderated by bad health habits of smoking, alcohol consumption, diet, and other lifestyle factors coupled with sex and age that had health effects. What these were and their impact was not clear (71, 57).

3 Methodological problems with observational epidemiological studies

3.1 Salient sources of observational bias

The World Heath Organization (WHO) acknowledged the problems with observational studies: "Because of the uncertainty of epidemiological model parameters, predictions of future mortality or morbidity based on the recent post-Chernobyl studies should be made with special caution (81, 107)." In particular, WHO cautions against predicting on the basis of the observational epidemiological studies, insofar as epidemiological studies are studies in which selection, information, and confounding bias are commonplace. We should clarify what we mean by these biases along with the relative advantages and disadvantages of ecological, case-control, and cohort studies.

Selection bias systematically introduces differences into case and control groups that distort the nature of association between exposure or disease, on the one hand, and outcome or response, on the other. Sources of this bias include differential group recruitment, group assignment, participant retention, or group attrition. Unless proper adjustments are made to control for this bias, distortion of the association between exposure and outcome remains.

Information bias stems from inaccurate measurement, misclassification, and linkages of such measurement and/or classification to the exposure or outcome. Information bias includes recall bias, misdiagnosis, missing data, nonresponse, any inclination to supply "the socially desired answer (34)." Although we can diagnose and assess misclassification bias with false discovery rate analysis, revealing the sensitivity and specificity of a screening system, it does not automatically remedy the situation (72).

Confounding effects are also commonplace in observational studies. A confounding effect can be an common antecedent or an intervening variable (depending upon whether the analysis is longitudinal or cross-sectional), without which the relationship of interest would be significantly different. If the relationship of interest is between exposure and response, a confounding bias may be characterized by complete or partial dependence on a confounder. If the confounder is related to both the exposure and the response, there is complete dependence. If the confounder is related to either the exposure or the response, but not to both, there is partial dependence (72). Ignoring control of confounder(s) can plague bivariate cross-tabulations with Simpson's paradox, in which the sign and/or magnitude of the relationship changes upon aggregation of subsamples. This is likely where a conditional relationship is assessed as unconditional, rather than conditional. Simpson's paradox can be considered a form of aggregation bias coupled with treating a conditional relationship as an unconditional relationship.

To avoid selection bias in epidemiological studies, matching is often used. Matching may be accomplished by standardization, inverse weighting, or propensity scores, but matching fails insofar as it overlooks potential confounders in the matching process. Moreover, it is not considered as effective as random selection and assignment, because matching is limited by the scope of the variables explicitly matched in the dataset, whereas random selection and assignment is not. With sufficiently large samples, Heckman two step-selection models or pattern-mixture models may be used to assess and control for selection bias in double-blind randomized control-group experimental designs where blocking of effects with sufficient sample sizes may be obtained (63, 1-5), (77, 275,295).

When the relationship of interest is customarily one of probability between exposure and disease, we generally condition on potentially confounding variables as age, gender, and access to medical services. Any variable that is related to the relationship under investigation after adjustments are made for all other influences can introduce confounding bias. Therefore, proper adjustment for all related influences– including age and gender– should be included and calibrated to nullify potential confounding in epidemiological studies. To minimize or eliminate specification bias resulting from overlooking the effects of potential confounder variables, we prefer multivariate models with general-to-specific (GETS) modeling and variable selection to bivariate χ^2 tests for our analysis, wherever linearity and statistical power conditions permit. Given these general definitions, we now address the relative advantages and disadvantages of ecological studies, case-control, and cohort studies.

3.1.1 Ecological studies

Ecological studies compare the consequences of Chernobyl with those of other disasters by comparing groups to one another. They are correlational studies that compare a population before and after an intervening event. Yet they have potential problems. These studies suffer from aggregation bias, within-group selection bias, and confounding. Group effects are analyzed for differences between groups but lack within-group measures. Confounding effects stem from variables that interpose themselves between the risk-factor and the disease outcome, between the exposure and the effect (response), or between the hypothesized cause and its associated effect. Greenland and Morganstern (1989) held that ecological bias can be generated by group confounders or groups acting as effect modifiers (27, 269). Two examples of confounding are depicted in Figure 5. Other effect modifiers include *interactions*, defined as joint effects over and above their

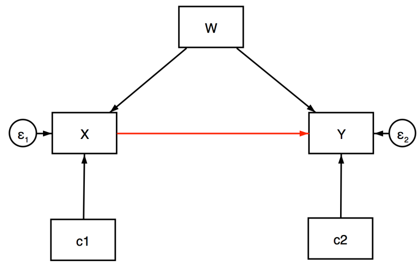

Figure 5: *A confounding variable (W) can precede an hypothesized (colored red) relationship between cause (X) and effect(Y), creating a spurious effect, in a time lapse within a time series; in a cross-sectional setting, W could effect both X and Y in one snapshot in time; Alternatively, a set of confounders (with elements c1 and c2) could impact the hypothesized cause, effect, or both cause and effect , altering the relationship under consideration.*

main effects, between variables might be overlooked. Interactions with group effect modifiers can introduce profound confounding effects (27, 269). Even differential distributions between the exposure or the control group may introduce ecological bias where there is a weak confounding and no group effect modification. Indeed, WHO acknowledged that ecological studies suffered from lack of control groups, adequate controls for confounders, tor sufficient number of dose measurements in their assessment of the health impacts of the Chernobyl accident (81, 6,42), (35, 93-119), (55, 134-143).

3.1.2 Case-control studies

J.E. Lane-Claypon in 1926 first used a case-control study to study possible causes of breast cancer (38, 15-27). Given the ethical prohibition of inflicting pathogens on people, when causality is simple, direct, and strong, this retrospective comparison of exposure frequencies to control group frequencies may be a practical, economical, and useful means of studying disease and its causes. When the etiology of an illness exhibits interim latency or lag time before its syndromal manifestation, the case-control study may not be so effective a method. Case-control studies can be conducted rapidly and inexpensively especially for rare diseases, for which reasons they are often employed.

Early Chornobyl studies were case-control studies that compared highly exposed cases to unexposed control groups. Examples included Chornobyl studies of damage control/clean-up workers called, *liquidators*, and infants. These were observational studies in which investigators sampled by disease and inferred cause from effect. Because their investigators collected data after the disease afflicted the cases, case-control studies are called retrospective. The WHO report on Chornobyl effects indicated that case-control studies needed

> ... a clear case definition, an appropriate selection of controls, a high response rate among both cases and controls, control for surveillance biases, and a valid retrospective ascertainment of dose that is not influenced by case-control status (81, 5)

They assume that the cases and controls are the same in every respect other than whether or not they have the disease. However, case-control studies are susceptible to selection bias, which can affect the construction of groups with differences that can be mistakenly inferred as following from phenomenon of interest (whether it be disease or exposure to the disease) (38). This bias can follow from differential recruitment or assignment to groups. O.S. Miettinen reported indicated that susceptibility bias needs to be controlled in case-control studies. If the level of control group exposure is not properly defined, such that different group levels of exposure are not prevented, this bias could undermine inference. It may also follow from differential attrition from the groups. Inferences are drawn from the proportion of cases that were exposed to those that were unexposed between the case and control group. Confounding may alternatively be controlled with the proper inclusion and exclusion criteria formulated for the study to remove potential confounding or missing data. These studies generally use matching to assign individuals who did not have the disease to control groups. Although the purpose of the matching is to match groups on a potentially confounding variable in order to neutralize that confounding effect. Nonetheless, cases and controls generally remain unmatched for all variables on which they were not deliberately matched. To the extent that these groups are unmatched, they are probably not generalizable beyond the sample. Thus, these studies are subject to selection bias and confounding from incomplete matching (70), (66), and (34).

Cohort studies are prospective analyses that suffer less from recall bias or even differential recall than case-control studies. However, they also have problems if rare diseases or those with very long latency periods are the subjects of interest. They require large samples, are more expensive, and take longer to complete, than case-control studies. They sample by exposure rather than by disease, and their researchers infer effect from cause. They can suffer from selection bias if there is varying attrition between the case and/or control groups. They can also suffer from selection bias if there is informative censoring that is not properly controlled. They often require uniformity of protocols over a long period of time and therefore may be susceptible to differential retention or attrition among groups, generating selection bias and confounding (81, 5-6)

Professor David Madigan of Columbia University, investigated the precision of p-values in medical observational studies utilizing an ensemble of databases in which drug test data have been stored. He found that observational studies are based on "theoretical null distributions based on unbiased estimators," an assumption that rarely holds in practice. He also found that 95% confidence intervals that are supposed "...to cover the true effect size 95% of the time, may be misleading." in the context of observational studies. "Coverage probability is much lower across all methods and all outcomes (47, 56, 62)."

3.2 Controlling for potentially confounding events

Major strategic political, economic, financial, and environmental events have had substantial impacts on social and psychological risk factors that were generally ignored in previous studies, rendering them potentially vulnerable to bias emanating from confounding and specification error, the effects of which are more deleterious than those of collinearity. We have to model their impacts by dummy variable modeling if we do not have all of their constituent variables in order to control for them. Evidence of their impact can be gleaned from inspection of unusual or unexpected patterns in time series plots of their trajectories or pathways–such as, blips (spikes or dips), outlier patches, level-shifts, changes in seasonality, surges, or broken long-term trends in Figures 6 and 7.

The endogenous series reported by female respondents revealed pronounced increases in depression and anxiety among women responding to events in 2006 and 2009. The spikes in psychosocial distress among women by 2009 rose to a level higher than as those at the time of Chornobyl (Figure 6). By 2006, male psychosocial distress had grown considerably higher than it appeared to be in 1995 (Figure 7). Without

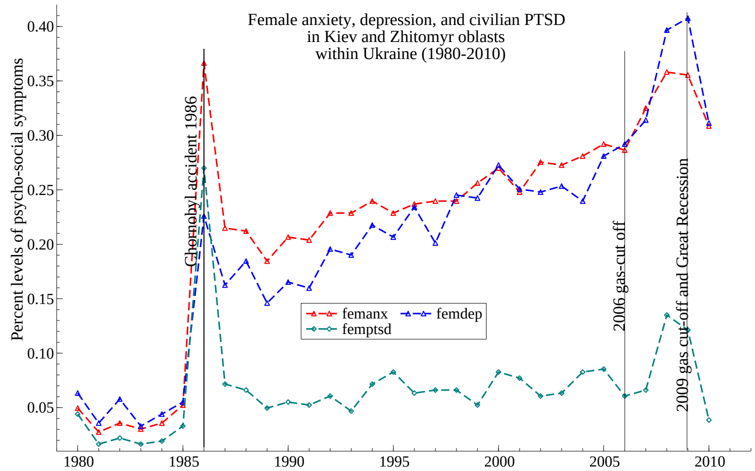

Figure 6: *Psychosocial anxiety, depression, and civilian PTSD reported by Ukrainian women*

an explanation and or control for these resurgences, we risk confounding our analysis. Yet earlier studies generally overlooked these impacts. Political, economic, financial events, or environmental events may be excluded from the analysis by over-compartmentalizing the analysis. Trying to access controversial material may create issues or problems for researchers, even though the data are supposed to be publicly available in the former U.S.S.R.. The WHO report on Chornobyl health effects acknowledged "Soviet censorship and constraints related to historical data acquisition forced Ukrainian researchers to develop novel and cost-effective approaches to conducting epidemiological assessments of Chernobyl (74). For example, we encountered difficulty in getting one researcher to share public data on internal dose in his custody in Kiev in 2008 without paying an exorbitant sum of money (42). Inconvenient interdisciplinary investigation may have gotten soft-peddled and even suppressed in the literature as a result (26, 21-22). We found occasional and somewhat vague references to the difficulty in obtaining accurate social science data in countries of the former Soviet Union (81).

Nonetheless, our time series graphs reveal that some phenomena had substantial psychosocial impact and cannot responsibly be ignored because later increases in psychosocial distress and subsequent spikes peak as high as that of Chornobyl in Figure 6 and 7. The most concerning of these patterns arises at the end of the series, inasmuch as end-effects can seriously bias forecasts, we need to be careful when dealing with them. The first change in direction and/or rate of increase of female anxiety symptom levels appears to have begun in 2006. We observe an increase in the male levels of depression at that time as well. The increase in these reported levels of anxiety and depression symptoms among women appears to have begun in 2006.

BHG (2011) suggested that the disruption of the fall of the USSR and the collapse of its social safety net confounded this problem and made the subject almost impossible to investigate (5). We observe no controls for political-economic event impacts on psychosocial conditions in earlier studies. It is possible that glasnost had already attained its peak before our arrival in 2008.

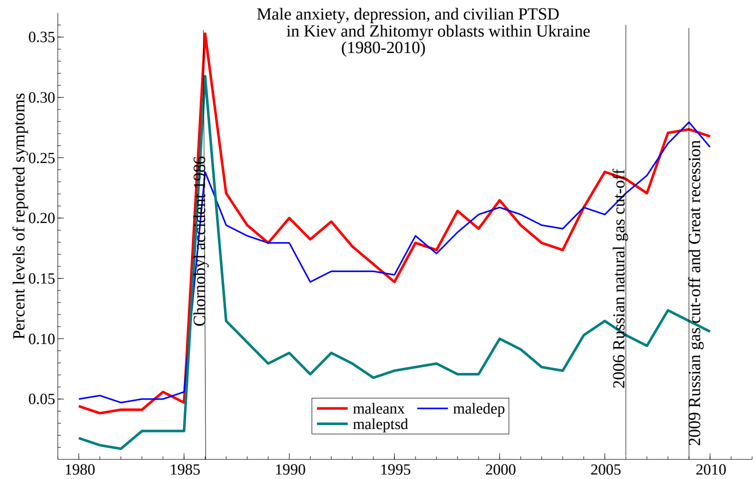

Figure 7: *Psychosocial anxiety, depression, and civilian PTSD reported by Ukrainian men*

3.3 The regional political and economic milieu of 2006

During the Putin era, Russia began to consolidate its state control over its energy (oil and gas) resources, as the operations of Gazprom, the Russian state gas monopoly, became integrated with Kremlin state control. Before the 1991 collapse of the U.S.S.R., the Council for Mutual Economic Assistance (COMECON), generously provided its Soviet Bloc allies with oil and gas subsidies as economic assistance as long as they remained politically and ideologically cooperative, whereas more independent member states–for example, Romania– had to pay higher energy fees (55, 135). This pattern enhanced dependence on Russian gas and energy, and Ukrainian dependence on it was no exception in the years prior to 2006 (55, 135-136). At the collapse of the U.S.S.R. in 1991, Russia 's economy was shrinking. Between 1991 and 1998, privatization allowed oligarchs to gain enormous wealth and power. By 1998, Russia was unable to pay its domestic expenses or its foreign debt, so it devalued its currency.

Under Putin the privatization was greatly curtailed. The Kremlin sought to reconsolidate the energy sector. In 1996, there were six oligarchs in control of Russian gas and oil industries. In 2000, Dimitry Medvedev became Vladimir Putin's campaign manager. In November 2005, Medvedev was appointed First Deputy Prime Minister, and he was in charge of overseeing national priority projects and in so doing he served as Chairman of the Board of Gazprom (79). Between 2003 and 2004, the Russian government worked to consolidate control over their energy sector. The government gained control over Yukos by arresting Mikhail Khodorovsky, the owner of Yukos, and possibly the wealthiest man in Russia at the time. Khodorovsky had become an advocate of "democracy, international cooperation, and reform in Russia." In 2005, Gazprom purchased Sibneft, owned by Roman Abromowitz, for $13.1 billion (55, 137). By 2006, only two oligarchs were left in the Russian energy sector (4). By September 2006, the company was broken up and taken over by the government, allegedly for unpaid taxes. To pressure Shell in 2006 to sell its control over the Sakhalin II joint venture, Shell was threatened with environmental pollution claims until the sale was agreed to, at which time the environmental pollution claims disappeared.

To protect its growth of control over the energy sector, Russia took steps to control transit routes to

Europe. If a client state became too independent, Russia would threaten to build other pipelines and thereby threaten the loss of transit fees that Russia paid to the State controlling the territory transited by its pipelines to Europe. For example, the threat to build a Nordstream pipeline was mentioned and finally concluded with Germany in 2006. The Western world, especially the E.U. became acutely aware of this authoritarian development and energy consolidation by the time of the 2006 Russian gas cut-off to the Ukraine (55).

The European "color" revolutions provided the political instability ripe for Russian meddling in 2003 and 2004. While Ukrainian President Leonid Kuchma was a friend of Russia (from 1994 to 2004), Russia charged favorable oil and gas prices to reward the cooperative country. After the *Orange Revolution* from November 2004 to January 2005, and the election of Victor Yuschenko, Ukraine began contemplating membership of NATO. The petro-carrots rapidly turned into petro-sticks, and in late 2005, Russia demanded that Ukraine pay its accumulated debt at about 4 times the price thitherto. Compliance would have bankrupted Ukraine (55, 140). Ukraine was not the only increasingly independent former member of the U.S.S.R. to whom this happened.

In 2005, the *Tulip Revolution* broke out in Turkmenistan. In December of that year Turkmenistan interrupted natural gas flows to Ukraine and Russia, calling for a price increase. In return for a transit fee, a consideration to Ukraine was made involving the gas price (69, 3). After the *Rose Revolution* in 2003, Georgia found itself burdened with Russian trade sanctions and gas price increases to induce them to follow the Kremlin political line. This dispute was settled with a doubling of gas prices as part of the settlement in December 2006. Moldova also experienced Russian gas price hikes in 2006. In 2006, Russia tried to increase its gas prices even among its allies (Belarus and Armenia) but attempted to raise gas prices to more resentful states, such as Ukraine, Georgia, and Moldova, to much greater heights (55, 139).

Throughout the Western world, chills were felt across Europe as newspaper articles were reporting on these events. In Europe, there was widespread apprehension to what was perceived as the potential for abuse of Russian petro-power. On January 4 of 2006, the BBC news wrote, "Austria, France, Germany, Hungary, Italy, Poland and Slovakia all reported drops of around 30% to their gas supplies (2)." In the United States by March 2006, a Council of Foreign Relations Task Force Report on Russia, indicated that the Kremlin "has used energy exports as a foreign policy weapon: intervening in Ukraine's politics, putting pressure on its foreign policy choices, and curtailing supplies to the rest of Europe (10)." Mert Bilgin (2011) wrote that Russia pursued a *realpolitik* foreign policy coupled with a state-centric approach to its gas-supplies designed to support peripheral compliance, whereas the EU followed a more liberal foreign market-based pricing strategy (4, 119). NATO maintained that "EU member states' reliance on and exposure to Russia on energy supplies has critical national security implications. The renewed disputes over gas pricing and transit recalled the specter of the 2006 and 2009 Russo-Ukrainian gas crises, yet again showcasing Russia as an unreliable supplier and as a state that is ready and willing to use energy as a weapon (51)." Ottrung and Overland (2011) discern evidence of strategic drivers of Russian foreign policy at work, immediately following the *Orange Revolution* (56). In later years, Stephen M. Dayspring, who wrote his masters' thesis on Russian hybrid warfare, considers this strategic dynamic change being masked as the status quo as a phase of hybrid warfare (12, 69-72). Richard Haass recently wrote,"Vladimir Putin's Russia is a one-dimensional power. Its influence is tied to its ability to dominate others through the use of force, be it military, cyber, or related to Russian oil and gas exports (46)."

3.4 Winter 2006 natural gas cut-off

Gazprom in January 2006 cut off the flow of natural gas to and transiting through Ukraine after an attempt to raise the price was rejected. Ukraine complained that the Russian price conflict stemmed from political factors, such as the Ukrainian *Orange Revolution* (Nov 2004-Jan 2005) and discussion of Ukrainian interest

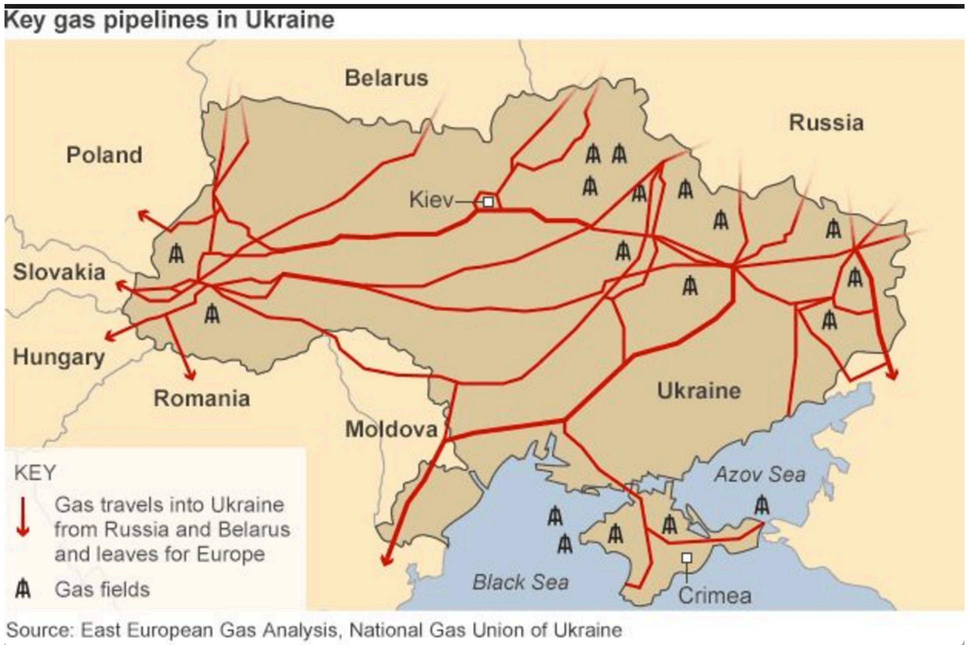

Figure 8: *Natural gas pipelines transiting Ukraine*

in joining NATO. Gazprom argued that they were trying to move countries of the former Soviet Union to market prices. The cut-off sent shockwaves through Western Europe about European energy security because 80% of European gas came through Ukraine; a web of pipelines transited Ukraine (56, 75), (69, 8), (16).

Although Jonathan Stern (2006) wrote that Putin tried to quadruple the price of natural gas, Stern characterizes this move to an economic attempt to drop gas subsidies to former USSR member states. There was a general recognition that "Russian gas enters Ukraine through more than 100 smaller pipes (16)." "The impact of Gazprom action on European countries was immediate... The fall in volumes delivered to European Union countries caused an outcry all over Europe (69, 8)." Through these pipelines, Gazprom supplied almost half of the energy to the EU. In 2006, Germany and Hungary were immediately affected (58). The Economist reported that it also cut by more than 40% the gas it pipes onwards to Serbia and Bosnia, Germany, Italy, Slovakia, Austria, Poland, Croatia and Romania (14). Peter Finn in the Washington Post wrote that "Under new pricing accords, Armenia, Georgia and the Baltic states pay $110 per 35,300 cubic feet. And Belarus, an increasingly authoritarian country closely aligned with Russia, pays $ 47. Gazprom officials say Belarus has provided the company with a stake in the pipeline that crosses the country, allowing the company to continue to provide subsidized gas(22)." For these reasons, Ukraine complained that Russia's demands that they pay so much more than these others must be a political response to their consideration of joining NATO after the *Orange Revolution*.

According to the NY Times's Andrew Kramer, likened the event to OPEC's 1973 action (16)." Kim Murphy of the Las Angeles Times wrote "The gas cutoff unleashed a political crisis in Ukraine and threatened to turn into a major misstep by Russian President Vladimir V. Putin, who was expected to shoulder much of the international blame if energy supplies to Europe were interrupted this winter over his nation's price dispute with Ukraine (49)." Recognition that there was developing a potentially unmanageable backlash prompted a rapid Russian settlement of the dispute.The dispute was settled after a four day cut-off of natural gas flow (69, 8). But there was no rolling back the outcome: Energy insecurity was now a major concern for Europe (69).

3.5 The regional political and economic milieu of 2009

Under Putin, Gazprom has been supporting political objectives. Putin's three week gas cut-off in Jan 2009 was coincident with the closing of approximately 80% of Ukrainian factories (56), (69). Is it possible that these broad-spectrum attacks were part of the hybrid warfare being directed at former states of the U.S.S.R. that contemplated joining NATO? Although the doctrine of non-linear warfare was not promulgated until 2013, it may be a formulation from a template that was used in the years prior to this point from Russian active measures since 2000.

In a February 2013 issue of the *Military-Industrial Kurier*, General Valery Gerasimov, Chief of the Russian General Staff, propounded a doctrine of nonlinear– that is, hybrid– warfare that blurred the line between peace and war and that increasingly seemed to have been a template for Russian activities in the "near-abroad" since 2003. In arguing for a multi-modal full-spectrum battle space, Gerasimov's doctrine reshaped the political, economic, and social topology of the target-state. The doctrine formulates six stages in a full-cycle of conflict. In the first stage, there is a hidden and disguised preparation, including multi-pronged penetration of key positions in the political and military organizations as well as in the critical infrastructure of the target country. Agents of influence are co-opted along the prospective strategic fault lines of political dissent, interests, polarization, and protest. Often co-optation is accomplished via corrupt or illegal back-room financial, economic, or political arrangements that would not survive the glare of exposure. Cyber-penetration of the target county's political organizations opposed to Russia appear to take place. In the second phase, there is enhancement political fault lines and economic warfare to promote pro-Russian alignment along with a generation of a pre-text for intervention. Where there is an Russian-speaking minority, alleged abuses against them have been raised to generate such a pretext, as they were in the Donbass section of Eastern Ukraine. There is also a pre-positioning military regiments for snap exercises. In the third phase, crisis generation is the modus operandi with infiltration of the military and security services, insertion of *maskirovka* (special forces disguised as indigenous militias or gangs) to take over police stations, airports, railroads, TV stations, radio stations, power stations, water-works, bridges, and roads with check points. Agitation of unrest, contracting elements of criminal networks for trouble-making became targets, take place. In the fourth phase, conquest of the adversary government included isolation of key governmental positions, capture of terrain, capturing control of critical infrastructure, destroying the military and political infrastructure of the adversary state. The fifth phase of consolidation entailed denial of involvement coupled information warfare with *disinformatzia* to confuse adversary allies about how to respond. In the sixth and final stage, there is de-escalation and installment of a puppet or pro-Russian government (8), (48), (50, 1-11). This pattern describes the snap military exercises on the Ukraine border, coupled with the movement of masked irregular troops into the Donbass (Eastern Ukraine) and the annexation of Crimea in 2014 immediately after the ouster of Victor Yanukovich from power in Ukraine. In retrospect, this template appears to have characterized Russian activities in Eastern Ukraine since the *Orange Revolution*, and may provide a checklist of red flags for which to watch in countries contiguous to Russia in the near future.

Whether these actions were purely Russian natural gas diplomacy, an application of the widened horizon of covert operations with computerized enhancement of information warfare, cyberattacks on government websites (Estonia in 2007, Lithuania in June 2008, Georgia in July and August of 2008, Kyrgystan in January and April of 2009), cyberattacks on democratic elections (Ukraine in May of 2014, U.S. in 2015 and

2016, France in 2016, Germany in 2016), on power grids (Ukraine in December 2015 and 2016), agitation propaganda (United States in 2016), aggravation of political polarization, disinformatzia, maskorovska (furtive insertion of disguised special forces, pseudo-indigenous secessionist agitation of peripheral countries (Eastern Ukraine (Donbass) and Crimea), the "Gerasimov doctrine of nonlinear warfare," appeared to be protocol of hybrid warfare taken to a more technologically sophisticated new level. The template for Russian hybrid warfare seems to have emerged out of the war against Ukraine and the information warfare against the U.S.: Targeting critical democratic elections with cyber-theft, agents of influence intervention, social media manipulation via botnets, disinformatzia, market manipulation with advertising amplification with activation of computer botnets, observed earlier in Russian cyberattacks on Estonia and Georgia, along with the great recession, we leave to others to investigate and decide (78). We merely note that these active measures seem to be occurring with increasing frequency against former USSR European countries, threatening neighborly relations with mounting insecurity. However, our objective is merely to identify potentially confounding problems and if possible, to demonstrate our circumvention of them in our endeavor to analyze and understand the psychological and social impact of the Chornobyl nuclear disaster. Perhaps mention of the impact of these potential events will be of use to researchers who need to control for them.

3.6 The Russian winter gas cut-off in 2009 amidst the Great Recessions and the implications

From the map shown in Figure 8, we can observe thee natural gas/oil deposits in Crimea and in Eastern Ukraine, partly in the Donbass. Before Russia's annexation of Crimea in 2014, Ukraine used to receive a discount on their natural gas supply from Russia in return for a lease for Russia's only warm-water naval base at Sevastopol, Crimea. After Russia's military incursion into Donbass and its annexation of Crimea, Russia increased control over more natural gas deposits and relieved itself of the burden of having to pay Ukraine for a lease of their only strategic warm-water naval base at Sevastopol. Hence, Russia extended its control over more energy resource deposits and a strategic access to its only warm-water naval port.

4 Research objectives and hypotheses

As a pre-requisite for accomplishing our objectives, we test the BHG (2011) claim that the impact of the psychological symptoms are so entwined with the fall of the U.S.S.R. in 1991 that they are almost impossible to disentangle. We test this hypothesis with techniques for testing structural change and seek to demonstrate that the inextricable entanglement hypothesis is not consistent with our findings.

We explore and model the temporal pathways of these salient psychosocial symptoms, to empirically identify them as honestly and completely as possible, with a view toward forecasting their continuation over the near term. In the process, we will examine potentially confounding impacts of external events on the trajectories and demonstrate how we circumvent their potentially confounding results. To do so, we had to try to identify these phenomena and and the sources of these impacts, even though many scholars would be averse to addressing such phenomena.

We will demonstrate predictive validation of our model using scenario forecasting. In support of this contention, we will evaluate ex post and ex ante forecasts using a multivariate state space model.

5 Research methods

5.1 Representative sample of general population

We obtained a representative sample by randomized telephone sampling of 702 respondents, consisting of 363 (51.7%) women and 339 (48.3%) men in Kiev and Zhitomyr oblasts in Ukraine. Random sampling neutralized selection bias and provided an equiprobability of telephonic number selection. To minimize non-response in the event of no-answer, four callbacks at different times of day were made to minimize non-response bias. An independent auditing group confirmed the propriety of each interview before we uploaded data. We stripped all personal identifying information prior to ultimate statistical analysis. We employ an interview format with multiple levels and ranges of periodization to facilitate mnemonic recall to reduce recall bias. We control for gender by stratification, making all models gender specific. We avoid bivariate tests and give preference to GETS or AutoMetrics models where possible (31). A detailed summary of the sample characteristics may be found in Appendix A.

5.2 Endogenous scale construction

5.2.1 Depression/anxiety becomes principal endogenous scale

Because respondents would not be able to recall the details of the psychosocial symptom for each year separately unless they kept a personal log, respondents were asked respondents to assess their level of anxiety, depression, and PTSD on a percent scale of zero to 100 only when that symptom under consideration significantly changed from one level to another, along with the year in which change took place. Standardized tests asked too many very particular questions about a panoply of aspects of feelings at one current time to be applicable to a span of time extending over more than 25 years. By limiting the recall to the year of significant change from one level to a different level, we could obtain a reasonable self-report for a change in anxiety, depression, and PTSD from one percentage level to another. Standardized tests were found to be inapplicable extend spans of time, leaving us with this approach.

To facilitate response recall, we asked questions in a variety of time periods, so that respondents could more easily link their responses to prominent events in Ukrainian history. We asked some questions according to average responses within three study periods or waves. We linked the wave periodization in which these questions were embedded with significant national events to facilitate recall while asking about the long-term historical symptomatology. For time series, we asked respondents when they recalled significant changes in symptoms, and what they changed from and to on a percentage basis. We dropped the lowest five percent for depression to distinguish the depression from a mildly sad mood. A computer program generated the time series from these responses for each person. The mean value for men and women separately were computed when those time series were collapsed by year, yielding an annual time series for men and women for each of these series.

After an examination of the dynamic factor analysis of these time series, we reformulated the psychosocial symptomatology in accordance with the eigenvalues for the symptoms. Table 2 reveals, by collapsing the temporal dimension, that anxiety and depression were most highly correlated with one another for both men and women. However, there were far fewer PTSD cases among the men and the women. Civilian PTSD was also highly correlated with anxiety and depression but not as much as anxiety and depression were intercorrelated. After graphical inspection of Figures 6 and 7, and a review of the correlation coefficients, the anxiety and depression symptoms, the most highly correlated scores, were combined into one psychosocial distress indicator. Because these series load highly on the same factor, we construct a psychosocial distress scale consisting of the average of standardized depression and anxiety: `fdepanx2` = (zfemdep +

Table 2: *Time series correlations (lower triangle) and alpha reliabilities for scales computed from row and column items*

α **reliabilities** **correlations**	**female anxiety**	**female depression**	**male anxiety**	**male depression**
female anxiety	1.000	0.969		
fem depression	0.949	1.000		
female PTSD	0.690	0.502		
male anxiety			1.000	0.975
male depression			0.943	1.000
male PTSD			0.880	0.720

zfemanx)/2 with Cronbach's α = 0.969. `mdepanx2` = (zmaledep+ zmaleanx)/2 with Cronbach's α = 0.975. As we shall see soon, this bivariate reconfiguration affords a more manageable dynamic factor structure than the tripartite psychosocial factor structure.

5.3 Exogenous measures and indices

We divided or study into waves for the purpose of performing panel data analysis and for facilitating memory of personal states of health. The first study period was from the date of the Chornobyl accident to the end of 1986. The wave extended from 1987 through 1996, whereas the third wave extended from 1997 to the end of 2009 for the extent of the dose reconstruction. It was extended to the time of the interview (2009 through 2011) in order to capture recent significant personal events.

The average cumulative external radiation dose was computed separately for the men and women in the sample by Thomas Borak and Remi Frazier. Their computations included the effects of dose from external penetrating gamma rays (variables: `mavgcumdose` for males, and `favgcumdose`, for females) to determine the exposure to radiation from the radioactivity released during the Chornobyl accident. The unit of measurement of reconstructed external dose is the milliSievert (mSv). The reported results from dose reconstruction exclude contributions from natural background radioactivity or cosmic rays. A process was developed to reconstruct the dose from penetrating gamma rays emitted by radioactivity deposited on the ground to each individual in the survey as a function of time. The radiation source term was obtained from the Comprehensive Atlas of Caesium Deposition on Europe after the Chernobyl Accident (1998) (17). This document includes maps showing ^{137}Cs concentration across Europe, presented in equal- area Lambert oblique azimuthal projections.

The electronic version of this Atlas includes each map plate stored in a vector graphics format with multiple layers of information. One of these layers shows isolines representing intervals of equal ^{137}Cs deposition at the time of the accident; an overlaid layer provides a labeled grid corresponding to intersections of latitude and longitude (this is properly referred to as the conjugate graticule). Software was developed to recover the contour color that specifies the ^{137}Cs concentration at a specified latitude and longitude. This was accomplished by using the intersections of the conjugate graticule as a guide to define a transformation from the original Lambert projection into an equi-rectangular projection. This transformation was then

Table 3: Cronbach's α reliabilities for perceived risk of Chornobyl-related radiation

Study Period	Time span of wave	female α	male α
Wave1	Apr. 26, 1986- Dec. 31, 1986	0.822	0.761
Wave2	Jan. 1, 1987- Dec. 31, 1996	0.835	0.796
Wave3	Jan 1, 1997- Dec 31, 2009	0.841	0.818

applied to the map layer which showed ^{137}Cs concentration, which allowed the ^{137}Cs concentration maps to be loaded into a geo-statistical database. Conversion tables between published isoline colors and indicated ^{137}Cs concentration were produced. Latitude and longitude coordinates could then be submitted to the geo-statistical database in order to recover the ^{137}Cs concentration at an arbitrary location. Where map plates published in the Atlas overlapped, the ^{137}Cs concentration was taken from the map with the most spatial detail; if a location was submitted to the geo-statistical database which had no corresponding map data, the closest available ^{137}Cs concentration was used.

A model was created to determine the dose rate at an arbitrary time t for any individual in the study. This model is based on the following sequence of factors: 1] ^{137}Cs concentration at a location (Lat. Long.) at the time of the accident, $C(t_0)$ (17), 2] ^{137}Cs concentration, at time, t, based on decay, soil mixing and weathering, C(t) (43), 3] Kerma rate to air, K(t), from penetrating gamma rays emitted by all radioisotopes, normalized to the Cesium concentration C(t) (42), 4] Conversion from kerma in air-to-dose in person, as a function of age, at time t(17) (42), (43), (65), [28], [29]; 5] Modifying factors for time spent outdoors based on occupation and age citepLikt0; and 6] Shielding factors based on residency indoors and typical construction (42). The data are integrated and presented as the annual dose rate received by each individual in units of mSv/year. Figure 9 shows the results of the dose reconstruction for males and females in terms of annual dose rate, milliSieverts per year, (mSv/y) and time integrated cumulative dose (mSv), and Table 4 lists the descriptive statistics for the cumulative dose.

Another pair of indices studied were indices of perceived risk of Chornobyl-related radiation exposure for women and men. These indices were averages of three variables: 1) How much in percent the respondent believed Chornobyl accident affected his or her health, 2) How much in percent respondent believed that Chornobyl accident affected his or her family's health, and 3) the percent of belief in the statement that in Kiev/Zhitomyr oblasts, most human cancer cases are known to be caused by radiation. Each of these items exhibited a total scale reliability exceeding the recommended Cronbach's α reliability of 0.70 for scale inclusion,(Table 3) (54, 226). Thus, our averaged index of perceived Chornobyl accident health risk spans the self, family, and community levels. The Cronbach's α reliability measures for the female and male indices, respectively designated `frpre2` and `mrpre2`, are listed in Table 3. These items were measures of the average number of annual illness experienced during different study periods, divided into waves.

6 Statistical methods

We first use Hendry and Doornik's AutoMetrics IIS-SIS modeling to remove all non-significant outliers and level-shifts representing this 1991 collapse (19, 220-234). We then test the U.S.S.R. collapse outlier and level-shifts in dynamic simultaneous equation models for the positive impact of the collapse of the USSR and fine none. Finally, we applied Markov-switching regime change models to test for persistent changes of principal forms of psychosocial distress stemming from the collapse of the USSR.

6.1 Nonlinear and multivariate time series analysis

We employ some several time series analytic approaches to analyzing these data. We use linear and nonlinear time series analysis to address these hypotheses. We test for the impact of the USSR collapse with 3 different statistical techniques. We used General-to-specific (GETS) modeling with outlier and step-shift indicator (IIS-SIS) saturation followed by the trimming of all non-significant indicators unnecessary for proper model specification with each of two endogenous time series models. The technique resulted in identification of all significant outliers and level-shifts. To accommodate the multivariate simultaneity in our models, we employed dynamic simultaneous estimation models to test the significance of such indicators while they minimize the correlation of equation errors. Thirdly, we used non-linear Markov-switching regime change models test whether the blip and level-shift variables inaugurate regime shifts (18, 38-52). The first approach selects potential structural change indicators and automatically removes them. The final approach defines and classifies the regime shifts in the psychosocial distress and post-traumatic stress time series.

6.2 State space forecasting models

We applied multivariate state space with common local levels for the task of forecasting for several reasons. We had multi-frequency data. Our measures were taken at different frequencies. State space models have been can be used with multi-frequency data. We needed to be able to smooth a short-time series and we had to be able to handle missing data properly (29), (13). They permit smoothing and replacement of missing data without difficulty, because they estimate and forecast underlying latent variables (29). Previous research indicates that these methods generate excellent forecasts (82). We perform a modified scenario forecast psychosocial trajectories applying multivariate state space models. We evaluate our ex post and ex ante forecasts with a variety of criteria which indicate that we have a means of forecasting emergency medical needs for the affected population.

7 Findings

7.1 External dose in Ukraine

Borak and Frazier found that the cumulative average dose to which the general population was exposed was for the most part below the threshold of biochemical reactivity (BEIR 7 assessed this has being approximately 100 mSv per year). Figure 9 reveals the extent of the external dose to men and women in the two oblasts affected most within Ukraine, whereas a summary tabulation of the external dose to the general population may be found in Table 4.

These external doses are below the levels generally considered sufficient to initiate bio-chemical reactions. As we shall soon see in the findings of our statistical models, the average cumulative external dose is not found to be statistically significant as an explanatory variable in either the male or the female models. Nor is a statistically significant predictor in either of our forecasting models.

7.2 The BHG entanglement hypothesis test results

We first test the Bromet, Havanaar, and Guey (2011) entanglement hypothesis in three ways. At first, we tested for the retention of a significant positive blip outlier, a level-shift effect, or a combination of those

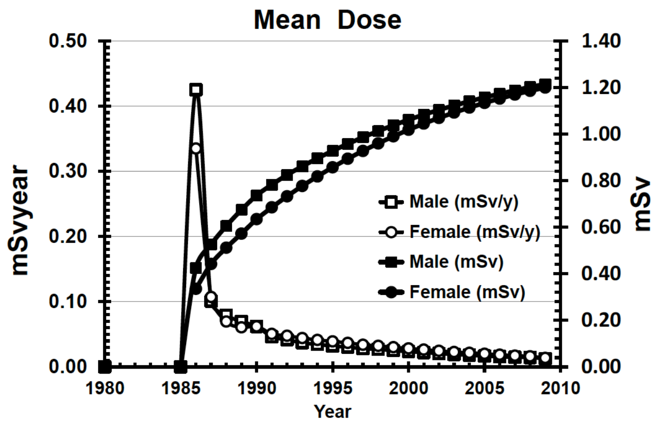

Figure 9: *External dose to general population in Kiev and Zhitomyr oblasts*

External Dose Summary Measure	**12/31/1986**	**12/31/1996**	**12/31/2009**
Lowest value of External Dose received by an individual	0.0074	0.036	0.047
Largest value of External Dose received by an individual	28.0	30.0	31.0
95th % Quantile of External Dose received by the sample	[0.037 – 1.4]	[0.14 – 3.4]	[0.19 – 4.4]
Average value of External Dose received by the sample	0.38	0.93	1.2
Standard Deviation of External Dose received by the sample	1.2	2.0	2.2
Median value of External Dose received by the sample	0.28	0.69	0.91
Estimated Average value of External Dose from Natural Background	0.33	5.3	12.0

Table 4: *External dose to general population in Kiev and Zhitomyr oblasts*

effects in a univariate AutoMetrics saturated with impulses and step-shift indicators (in an IIS-SIS) model. Even if an effect is subclinical, an empirical test requires that the effect be syndromal; it should not be empirically sub-syndromal and undetectable. For this reason, in a time series model, a significant positive outlier or level-shift would reveal the impact of the 1991 U.S.S.R. collapse.

7.2.1 OxMetrics AutoMetrics IIS-SIS tests for 1991 blip or level-shifts

If we are to empirically control for a measurable effect, a 1991 outlier, level-shift, or combination effect, should be detectable and testable with AutoMetrics, using the impulse-indicator - step-indicator saturation (IIS-SIS) option. This algorithm will flood the model with blip and level-shifts wherever they are needed to define the model structure, after which they are systematically removed if they remain statistically non-significant. According to the BHG (2011) "inextricable entanglement hypothesis," the U.S.S.R. collapse had a significant impact on the salient psychosocial sequelae under consideration, a positive outlier or level-shift would be retained by AutoMetrics at the recommended nominal significance level settings.

To test for this kind of effect, we set for impulse indicator and step indicator saturation (IIS-SIS) with each of the two dependent variables in the model. We begin with our psychosocial distress variable (combining reported depression and anxiety) for women. To avoid external impacts from the 2006 and 2009 Russian natural gas cut-offs, we restrict our estimation sample to the time span of 1980 through 2005. We first set the significance level to 0.01 as recommended by David Hendry and Jurgen Doornik (2011) (30, 153-158). We conserve our statistical power by incorporating only level-shifts or outliers generated by the IIS-SIS setting for our model. Following the first model for female psychosocial distress, averaging depression and anxiety, with a significance level of 0.01, we run another model with that level relaxed to equal 0.05. We perform the same two analyses for women with the civilian PTSD variable. However, we first difference these endogenous variables to assure covariance stationarity. We repeat this for the males, and formulate the eight equations below to summarize our data. In the subsequent equations, the odd numbered equations are tests at the 0.01 critical level, whereas the even-numbered equations are tested at the 0.05 value. The coefficient standard errors are contained in parentheses below the regression parameter estimates in the OxMetrics equation output below.

Female models

$$\text{dfdepanx2} = -\underset{(0.00824)}{0.07993}\ \text{S1:1985}_t + \underset{(0.0106)}{0.1277}\ \text{S1:1986}_t - \underset{(0.00752)}{0.04784}\ \text{S1:1987}_t \tag{1}$$

$$\text{dfdepanx2} = -\underset{(0.0109)}{0.1277}\ \text{I:1987}_t - \underset{(0.00859)}{0.07941}\ \text{S1:1985}_t + \underset{(0.00768)}{0.07988}\ \text{S1:1987}_t \tag{2}$$

$$\text{dfemptsdmc} = -\underset{(0.0157)}{0.2391}\ \text{S1:1985}_t + \underset{(0.0202)}{0.4353}\ \text{S1:1986}_t - \underset{(0.0143)}{0.1983}\ \text{S1:1987}_t \tag{3}$$

$$\begin{aligned}\text{dfemptsdmc} = &-\underset{(0.0119)}{0.03168}\ \text{I:1981}_t + \underset{(0.0107)}{0.02479}\ \text{I:1994}_t + \underset{(0.0107)}{0.0303}\ \text{I:2000}_t \\ &-\underset{(0.0119)}{0.2328}\ \text{S1:1985}_t + \underset{(0.0151)}{0.4353}\ \text{S1:1986}_t - \underset{(0.0107)}{0.1983}\ \text{S1:1987}_t\end{aligned} \tag{4}$$

The level-shift retention resulting from the first pass at the 0.01 level is uniformly consistent, regardless of gender or endogenous variable. Step shift indicators at the times of 1985, 1986, and 1987 are retained in both male and female models explaining psychosocial and post-traumatic distress. None of the female model tests retain a positive 1991 level-shift or blip outlier, necessary for an inference that the significant increases of psychosocial symptoms are linked to the collapse of the U.S.S.R..

We obtain similar results for the male psychosocial distress models. However, when we test for effects in the male civilian PTSD models, we find an unexpected result. An exception to this rule occurs in the model for male civilian PTSD. In Equation 8, a significant step level-shift at 1991 is generated, but the parameter estimate is a negative one: $-0.0352SI : 1991_t$. This result implies that we were able to identify and disentangle a significant decline in the general level of male civilian PTSD beginning in 1991. This is not an uptick in level. It represents a decline in the average of level male PTSD. It appears that the general psychosocial health among males significantly improved as a result of the collapse of the U.S.S.R.. We were testing for the ability to identify and distinguish symptomatic effects, so this finding appears is not inconsistent with our ability to identify enhanced symptomatic effects. There are plenty of positive (especially, 1986) and negative (for example, 1985 and 1987) symptomatic effects identified and distinguished at other times. However, for males we find a significant improvement in PTSD at the time of the collapse of the Soviet Union. For this reason, our AutoMetrics tests generated results are generally inconsistent with the entanglement hypothesis.

Male models

$$\text{dmdepanx2} = -\underset{(0.00586)}{0.08137}\ \text{S1:1985}_t + \underset{(0.00756)}{0.1227}\ \text{S1:1986}_t - \underset{(0.00535)}{0.04126}\ \text{S1:1987}_t \tag{5}$$

$$\begin{aligned}\text{dmdepanx2} = &-\underset{(0.00563)}{0.1227}\ \text{I:1987}_t + \underset{(0.00398)}{0.009152}\ \text{I:1998}_t + \underset{(0.00398)}{0.01043}\ \text{I:2004}_t \\ &-\underset{(0.00445)}{0.0813}\ \text{S1:1985}_t + \underset{(0.00422)}{0.08399}\ \text{S1:1987}_t - \underset{(0.00422)}{0.01329}\ \text{S1:1995}_t \\ &+\underset{(0.00398)}{0.01075}\ \text{S1:1996}_t\end{aligned} \tag{6}$$

$$\text{dmaleptsdmc} = -\underset{(0.0149)}{0.2929}\ \text{S1:1985}_t + \underset{(0.0193)}{0.4971}\ \text{S1:1986}_t - \underset{(0.0136)}{0.2029}\ \text{S1:1987}_t \tag{7}$$

$$\begin{aligned}\text{dmaleptsdmc} = {} & \underset{(0.00806)}{0.02941}\ \text{I:2000}_t + \underset{(0.00806)}{0.02941}\ \text{I:2004}_t - \underset{(0.00883)}{0.2929}\ \text{S1:1985}_t \\ & + \underset{(0.0114)}{0.4971}\ \text{S1:1986}_t - \underset{(0.00987)}{0.1853}\ \text{S1:1987}_t - \underset{(0.00987)}{0.02647}\ \text{S1:1989}_t \\ & + \underset{(0.0114)}{0.02647}\ \text{S1:1990}_t - \underset{(0.0114)}{0.03529}\ \text{S1:1991}_t + \underset{(0.00806)}{0.01765}\ \text{S1:1992}_t \end{aligned} \tag{8}$$

7.2.2 Dynamic simultaneous model tests using PcGive 14.3

Our models contain two highly correlated equations. The correlation among the structural residuals was strong to moderate. Between male psychosocial distress and male PTSD, the correlation among structural residuals was approximately 0.644; among females, this correlation was about 0.355. We need to use a form of estimation in multiple time series models to minimize simultaneity bias or specification error, stemming from lack of exogeneity or correlated errors. If we had enough proxy or instrumental variables, we could apply a form of instrumental variables estimation to avoid the correlated error problem. In these equations, we use full-information maximum likelihood (FIML) and three stage least squares (3sls) estimation. Both method are used because they yield slightly different results at the cusp of our threshold of statistical significance. To test the BHG entanglement hypothesis, we use indicators of structural breaks: blip outliers and level shift indicators at the time of 1991, when the U.S.S.R. collapsed. We add outliers and level-shifts beginning in 1991 to test for impact of the collapse of the U.S.S.R.. Our null hypothesis is that none of these indicators is statistically significant. That is, if we find that none of these indicators is statistically significant, we would have no evidence to support the BHG entanglement hypothesis. If we discover, however, that any of those indicator variables retains its statistical significance with a positive sign, we will have discovered evidence of the significant uptake in the endogenooveus psychosocial distress or post-traumatic distress possibly engendered by the USSR collapse.

The first tests are performed in dynamic simultaneous equations for women. Table **??** displays the results with the parentheses containing the t-values rather than the standard errors. In the upper panel of Table 5, we display the results of the female equation using differenced psychosocial distress, designated `dfdepanx2`, as the endogenous variable, and in the lower panel we provide the results from the equation using the differenced female civilian PTSD, named `dfemptsdmc`, as the endogenous variable. There are three columns in the Table. Column one presents the tests of the model in which a 1991 blip dummy indicator, designated `ussrfall`, is tested. Column two lists the results where the 1991 level-shift indicator, designated `ussrlev`, is tested, and column three presents the results from the model where both the 1991 outlier and the 1991 level-shift indicators are tested together.

These models are identified. Our models contain two endogenous variables, for which reason we need at least two separate exogenous variables for exact identification. In our female models, we test for a significant positive effect of USSR collapse on our two principal measures of psychosocial and post-traumatic distress (see Table 5). We transform these endogenous variables with first-differencing to render them covariance stationary, thereby avoiding spurious regression. To control for the impact of the Chornobyl nuclear disaster, we include a 1986 blip-dummy, called `chornblip`. In the female models, the test for a significant positive outlier at 1991, revealing a spike in female psychosocial distress, fails to yield such an effect. However, in the test for a significant level shift in female psychosocial distress, does generate a positive significant level shift in such distress, and in the test for both the significant positive outlier and the significant positive level shift at 1991, a quasi-significant positive level shift or significant level shift, is generated. Whether the level shift is just below or slightly above the threshold of significance at the 0.05 level depends on the technique used for estimation. The level shift is at the borderline of statistical significance. FIML tends to yield significant results, while 3SLS tends to yield quasi-significant level shifts. Therefore, the null hypothesis may be rejected here. We indicate p-values between 0.10 and 0.05 with a hash symbol. We have at least partial support for the BHG entanglement hypothesis, among the females, with respect to psychosocial distress. We do not find such support among the females with respect to civilian PTSD.

Table 6 displays the male simultaneous equation model test results with differenced male psychosocial distress, `dmdepanx2`, and differenced male civilian PTSD, `dmaleptsdmc`, being used as the endogenous variables. With respect to male psychosocial distress, we find that the blip outlier at 1992 exhibits quasi-significance (indicated with the hash symbol). This is evident in the model exhibiting the blip outlier, regardless of whether the left shift indicator is employed. However, we find no indication of statistical significance of that outlier at the 0.05 level. When the 1991 level-shift indicator was tested by itself, the 1991 level-shift did not exhibit evidence of statistical significance. For these reasons, we have partial support for the BHG entanglement hypothesis with both males and females regarding psychosocial distress (anxiety/depression). We have found this in our earlier analysis of the psychosocial depression and anxiety on the part of the males and females with univariate state space models (83), (84).

7.2.3 Markov-switching dynamic regression model tests for regime-change

We also tested for regime change in the psychosocial symptomatology at the fall of the U.S.S.R. using to use Markov-switching regime change models in OxMetrics. In these cases, we test if either a blip or level-shift in 1991 would generate a regime-change in a dynamic regression model with multiple states. We allow the the Chornobyl nuclear accident to split the study into two regimes. Then we allow for another split at the time of the collapse of the U.S.S.R. permitting a total of three states. We apply Markov-switching dynamic regression models with differenced psychosocial distress as the dependent variable and the fixed variance to test for 3 states to see whether another regime can be formed at 1991, either by a blip-outlier or a step level-shift variable. Both of those are included in the general unrestricted model, along with a number of others. All such regime indicators are removed except those retained in Equation 9. The Markov-switching dynamic regression models, listed below, exhibit the parameter estimates, below which are the standard errors in parentheses.

$$\text{dfdepanx2} = -\underset{(0.0109)}{0.1277}\ \text{I:1987}_t - \underset{(0.00859)}{0.07941}\ \text{S1:1985}_t + \underset{(0.00768)}{0.07988}\ \text{S1:1987}_t \tag{9}$$

When we test for a different regime at 1991 the while using differenced version of the mean-centered female PTSD as the dependent variable, dfemptsdmc, we obtain the Equation 10. Both outlier and step indicators at 1991 are again removed because they do not distinguish one state from another.

$$\begin{aligned} \text{dfemptsdmc} = & -\underset{(0.00973)}{0.03168}\ \text{I:1981}_t + \underset{(0.0094)}{0.03903}\ \text{I:2000}_t + \underset{(0.00871)}{0.01928}\ \text{I:2004}_t \\ & -\underset{(0.00973)}{0.2328}\ \text{S1:1985}_t + \underset{(0.0123)}{0.4353}\ \text{S1:1986}_t - \underset{(0.0094)}{0.1942}\ \text{S1:1987}_t \\ & -\underset{(0.00711)}{0.02204}\ \text{S1:1993}_t + \underset{(0.00711)}{0.02663}\ \text{S1:1995}_t - \underset{(0.00355)}{0.008724}\ \text{S1:2002}_t \end{aligned} \tag{10}$$

Table 5: *Dynamic simultaneous female model tests for USSR Collapse blip and USSR level-shift*

Variables	blip FIML	blip 3sls	level FIML	level 3sls	both FIML	both 3sls
endog var= dfdepanx2$_t$	**female**	**psycho-**	**social**	**distress**		
dfdepanx2$_{t-1}$	-2.40	-0.238#	-0.351**	-0.343**	-0.345*	-0.342*
	(-1.95)	(-1.93)	(-2.91)	(-2.85)	(-2.79)	(-2.75)
chornblip$_t$	0.0791***	0.047**	0.083***	0.065**	0.065**	0.065***
	(9.56)	(3.19)	(11.6)	(4.16)	(4.07)	(4.04)
dchornblip$_t$	-0.031***	0.031*	0.0171	0.017	0.017	0.018
	(-2.49)	(2.51)	(1.35)	(1.36)	(1.35)	(1.37)
ussrfall$_t$	-0.002	-0.002	-0.003		-0.003	-0.003
	(-0.269)	(-0.272)	(-0.622)		(-0.502)	(-0.505)
ussrlev$_t$			0.007*	0.007#	(0.007)*	0.007#
			(2.11)	(2.07)	(2.11)	(2.10)
_cons	0.002	0.001	-0.003	-0.002	-0.003	-0.002
	(1.37)	(0.453)	(-0.211)	(-0.102)	(0.336)	(-0.981)
σ	0.007	0.007	-0.007	0.006	0.007	0.007
endog var= dfemptsdmc$_t$	**female**	**civilian**	**PTSD**			
dfemptsdmc$_{t-1}$	-0.017	-0.015	-0.050	-0.032	-0.034	-0.030
	(-0.257)	(-1.37)	(0.820)	(-0.438)	(-0.448)	(-0.405)
chornblip$_t$	0.236***	0.040	0.291***	0.041	0.238****	0.048
	(16.3)	(1.43)	(6.89)	(1.48)	(15.1)	(1.45)
dchornblip$_t$	-0.195	0.196	-1.89***	0.190***	-0.189***	0.190***
	(-8.87)	(8.91)	(-7.82)	(7.62)	(-7.40)	(7.45)
ussrfall$_t$	- 0.004	-0.004			-0.005	-0.005
	(-0.282)	(-0.285)			(-0.336)	(-0.338)
ussrlev$_t$			0.003	0.003	0.004	0.003
			(0.479)	(0.462)	(0.500)	(0.485)
_cons	-0.001	-0.001	-0.012	-0.001	-0.001	-0.001
	(-0.444)	(-0.453)	(-0.98)	(-0.191)	(-0.195)	(-.177)
σ	0.014	0.014	0.014	0.014	0.014	0.014
SC	17.684	17.684	-17.893	17.892	17.643	-19.665
corr (y1,y2)	0.334	0.332	0.363	0.359	0.355	0.352
n	24	24	24	24	24	24
legend endog var= endog variable * p<0.05,	t stats are in parenthesis ** p<0.01,	*** p<0.001	# p< 0.10	corr(y1,y2) = correlation among residuals		

Table 6: *Dynamic Simultaneous Male Models testing USSR collapse as a blip and level-shift*

Variables	blip FIML	blip 3sls	level FIML	level 3sls	both FIML	both 3sls
endog var= `dmdepanx2` =	**male**	**psycho-**	**social**	**distress**		
dmdepanx2$_{t-1}$	0.042	0.058	-0.013	-0.005	0.016	0.023
	(0.490)	(0.541)	(-0.109)	(-0.038)	(0.142)	(0.197)
chornblip$_t$	0.034*	0.034*	0.043*	0.0424*	0.040**	0.039*
	(2.87)	(2.83)	(2.39)	(2.87)	(2.90)	(2.86)
dchornblip$_t$	0.046**	0.047**	0.039**	0.041**	0.042**	0.042**
	(4.46)	(4.51)	(3.17)	(3.23)	(3.58)	(3.63)
ussrfall$_t$	-0.020	-0.010#			-0.011#	-0.011#
	(-1.44)	(-1.89)			(-1.94)	(-1.95)
ussrlev$_t$			-0.002	0.002	0.002	0.002
			(-0.661)	(0.640)	(0.885)	(0.870)
_cons	0.002	0.001**	-0.001	-0.001	-0.001	-0.001
	(0.716)	(0.732)	(-0.430)	(0.405)	(-0.361)	(-0.341)
σ	0.005	0.005	0.006	0.006	0.005	0.005
endog var= `dmaleptsdmc` =	**male**	**civilian**	**PTSD**			
dmaleptsdmc$_{t-1}$	0.047	0.051	0.019	0.025	0.033	0.037
	(0.755)	(0.820)	(.277)	(0.363)	(0.482)	(0.550)
chornblip$_t$	0.074*	0.072*	0.088*	0.086*	0.084*	0.082*
	(2.63)	(2.60)	(2.61)	(2.57)	(2.53)	(2.50)
dchornblip$_t$	0.218*	0.220**	0.207***	-0.209***	0.212***	0.213***
	(9.31)	(9.42)	(7.58)	(-7.71)	(7.92)	(8.03)
ussrfall$_t$	-0.019	-0.020			-0.021	-0.021
	(-1.37)	(-1.46)			(-1.47)	(-1.49)
ussrlev$_t$			0.003	0.003	0.004	0.004
			(0.458)	(0.435)	(0.607)	(0.591)
_cons	- 0.002	-0.002	-0.001	-0.001	-0.001**	-0.001
	(-0.627)	(-0.647)	(-0.249)	(-0.219)	(-0.178)	(-0.154)
σ	0.013	0.013	0.014	0.014	0.014	0.014
SC	-13.045	-13.044	-12.8948	-12.895	-12.8236	-12.8234
corr(y1,y2)	0.606	0.603	0.629	0.667	0.610	0.610
n	24	24	24	24	24	24
legend endog = endogenous var = variable * p<0.05,	t statistics are in parenthesis ** p<0.01,	*** p<0.001	# p < 0.10	corr(y1,y2)= corr. among residuals		

For neither equation 9 nor for equation 10 do we obtain an indicator that sets up a separate state for females at 1991.

We next perform the same tests for the males with differenced psychosocial distress as the dependent variable, testing both outliers and level-shifts to determine whether 1991 designates the beginning of a third state state. Both 1991 outliers and 1991step-level-shifts are removed not exhibiting any significant impact on psychosocial distress among men as can be seen in Equation 11.

$$\begin{aligned} \text{dmdepanx2} = & - \underset{(0.00563)}{0.1227} \text{ I:1987}_t + \underset{(0.00398)}{0.009152} \text{ I:1998}_t + \underset{(0.00398)}{0.01043} \text{ I:2004}_t \\ & - \underset{(0.00445)}{0.0813} \text{ S1:1985}_t + \underset{(0.00422)}{0.08399} \text{ S1:1987}_t - \underset{(0.00422)}{0.01329} \text{ S1:1995}_t \\ & + \underset{(0.00398)}{0.01075} \text{ S1:1996}_t \end{aligned} \tag{11}$$

We repeat the process using differenced male civilian PTSD as the dependent variable and obtain Equation 12. However, this time, we obtain a significant step level-shift indicator at 1991. We might be inclined to say that this indicates a significant regime change for male PTSD. To our surprise the parameter estimate for this level-shift is a negative one, $-0.0353 * SI : 1991_t$, indicating that the general level psychosocial male civilian PTSD significantly improves at the collapse of the U.S.S.R..

$$\begin{aligned} \text{dmaleptsdmc} = & \underset{(0.00806)}{0.02941} \text{ I:2000}_t + \underset{(0.00806)}{0.02941} \text{ I:2004}_t - \underset{(0.00883)}{0.2929} \text{ S1:1985}_t \\ & + \underset{(0.0114)}{0.4971} \text{ S1:1986}_t - \underset{(0.00987)}{0.1853} \text{ S1:1987}_t - \underset{(0.00987)}{0.02647} \text{ S1:1989}_t \\ & + \underset{(0.0114)}{0.02647} \text{ S1:1990}_t - \underset{(0.0114)}{0.03529} \text{ S1:1991}_t + \underset{(0.00806)}{0.01765} \text{ S1:1992}_t \end{aligned} \tag{12}$$

To recapitulate. we find that we are able to empirically model impacts on psychosocial distress and post-traumatic stress and that this enables us to empirically decompose most, if not all, of the driving phenomena of these trajectories over time. Our dynamic simultaneous equation models yield partial support for the BHG hypothesis. We have found quasi-significant increase in the 1991 level shift indicators explaining psycho-social distress in our dynamic simultaneous equation models for both Ukrainian men and women if we use 3sls. If we use FIML, these effects are slightly more significant. Our AutoMetrics impulse indicator saturation and step-indicator saturation reveals a significant improvement in male PTSD at the collapse of the U.S.S.R. in both of those models. Our use of dummy variable blip and level-shift indicators allows us to empirically identify and model impacts that are not clumped to closely together to mask one another, provided that we have enough statistical power. In general, these results are partly inconsistent with the BHG entanglement hypothesis. Moreover, We have been demonstrated that the psychosocial male PTSD significantly drops coincident with the collapse of the U.S.S.R.. rather than confounds the situation. In this respect, we have found something completely unanticipated.

8 Forecasting with a multivariate state space common local level model

When I presented an earlier univariate state space analysis of the separate gender specific reported anxiety, depression, and civilian PTSD symptoms recalled by respondents, I thank Professors Neil Ericsson (George

Washington University and the U.S. Federal Reserve Board) and Siem Jan Koopman (Vrije Universiteit of Amsterdam, CREATES, and the Tinbergen Institute) along with Sir David Hendry later for recommending a cointegrated model, on which basis that two types of distress and post-traumatic stress be modeled with a multivariate state space common local level model. From the graphs of the symptoms shown in Figures 6 and 7, we can observe the dovetailing of the gender-specific anxiety and depression trajectories. They are so highly correlated that it is likely that these models will have variance matrices that are not of full-rank. The multivariate state space model will permit us to model this particular pattern. However, given the very high correlations between anxiety and depression, we constructed a composite component from anxiety and depression and called it psychosocial distress, the variable names for which are `fdepanx2` for women and `mdepanx2` for men. Therefore, the gender-specific models each consisted of two endogenous variables, psychosocial distress and post-traumatic distress and a set of predictors and indicators where appropriate The models fit well and provided a reasonable forecast for both men and women. For the multivariate common local level model, the measurement and transition equations are, respectively: Koopman, Harvey, Doornik, and Shephard (2009) formulate the multivariate common level model as

$$\begin{aligned} \mathbf{y_t} &= \boldsymbol{\Theta}\mu_{\mathbf{t}} + \mu_\theta + \epsilon_{\mathbf{t}} \quad \epsilon_{\mathbf{t}} \sim \mathbf{NID}(\mathbf{0}, \textstyle\sum_\epsilon) \\ \mu_{\mathbf{t}} &= \mu_{\mathbf{t-1}} + \eta_{\mathbf{t}} \qquad \eta_{\mathbf{t}} \sim \mathbf{NID}(\mathbf{0}, \mathbf{D}_\eta) \end{aligned} \tag{13}$$

where ϵ_t and η are mutually uncorrelated at all time periods. η_t is a k x 1 vector, D_η is a diagonal matrix, Θ is a N x K standardized factor loading matrix with ones in the diagonal position, $\Theta = (\Theta_1', \Theta_2')'$, such that the first K rows comprise Θ_1, μ_θ is a N - K vector with the first N-K elements being zeros and the remaining elements are contained within $\bar{\mu}_t = -\Theta_2\Theta_1^{-1}\mu_{1t} + \mu_{2t}$ with $t = 1 \cdots T$. When reparameterized as a seemingly unrelated time series, not only does $\bar{\mu}_t = -\Theta_2\Theta_1^{-1}\mu_{1t} + \mu_{2t}$ with $t = 1 \cdots T$, but $\sum_\eta = \Theta D_\theta \Theta'$, which happens to be singular with rank K (36, 172).

Estimation is performed by the augmented Kalman filter, minimizing the predictive error variance, to achieve convergence to a steady state (29), (13). The Kalman filter recursive equations are set forth nicely in (36, 179). The estimation was terminated in 2005 to avoid the impacts of the Russian gas cut-offs in 2006 and 2009. The world wide backlash at the attempt to quadruple the gas price in 2006 raised concerns all across Europe, and led the U.S. to recommend a more gradual adjustment to market prices. The commotion and backlash apparently led to a quick four-day resolution of the 2006 price dispute, with the rapid resupply of gas to Ukraine and Europe. We terminate our estimation early to avert confounding our data with the impact from that gas cut-off as well as the impact of the Great Recession in 2009, and the three week gas cut-off from Russia that on January 1st, 2009, both of which led to increases in psychosocial stress for both men and women in Ukraine.

Having reduced the depression and anxiety scales to a single factor of psycho-social distress, owing to the very high correlation of their individual indicators, and a separate factor for post-traumatic distress, we are in a position to analyze the models as multivariate state space models. Given the substantial correlation between PTSD and the psychosocial distress, and the rank of the level covariance matrix equaling unity, we allow for a common level to be used for the separate male and female analysis.

8.1 Female multivariate common local level model

According to our omnibus measures of model fit, the female model fit well It was a multivariate common local level model. To measure goodness of fit, we use R^2 and Andrew Harvey's R_d^2, which is an R-square normalized for time series differencing.

Table 7: Equation fdepanx2: regression effects in final state at time 2005

Y_1 =	**Level**	**Explanatory + variables**	**+Interventions**	**+ Irregular components**
Omnibus fit	- 2 Log Lik = - 412.079 BIC = -9.087 **Level = rank(1)**		R^2 = 0.907 R_d^2 = 0.844 **Irreg=rank(2)**	level error variance= 100.0 % Irregular error variance = 76.87 %
State vector	**analysis**	**at period**	**2005**	
Equation	fdepanx2 **Value**			**Prob**
Level	0.062			0.000
Variable	**Coefficient**	**RMSE**	**t-value**	**Prob**
Level break @1998	0.252	0.015	4.244	0.000
chornblip	0.063	0.007	8.608	0.000
legend				
chornblip =	1986 outlier			
Level break @ 1998 =	1998 level-shift			
Estimates are	rounded off	to the thousandths	place	except for %

$$R_d^2 = 1 - \sum_{t=1}^{T} \frac{SSE}{(\Delta y_t - \Delta \bar{y})^2} (14)$$

where SSE= sum of squared errors, in addition to which we provide the BIC, the deviance (-2LL), and mention of the percentage of error variance for the level and irregular components.

The optimal component structure was found to be a common local level model, allowing convergence of the model to a steady state.

Estimation of both models with the Kalman filter runs through 2005 but terminates before 2006. The reason for proceeding this way was to circumvent any impact of the natural gas cut-off by Russia in 2006. The cut-off to Ukraine of the natural gas had been preceded by gas cut-offs in Georgia and Moldova. The female civilian PTSD element was highly correlated with the psychosocial distress; Together, these two elements comprised a common local level component in the model that explained 100% of the total level variance. As for the total error variance, 89.21% came from psychosocial distress and 10.89% stemmed from female civilian PTSD. The residuals were not statistically significantly different from normal. All significant outliers and level-shifts were modeled. The female components and regression effects models are contained in Tables 7 and 8. By dropping out the non-significant parameters in the models presented on the 20th of April, we obtain a better fit, for which reason we present the better models here.

Auxiliary residuals were analyzed to facilitate modeling outliers and level-shifts as needed while the residuals were reviewed for acceptable normality and homoskedasticity before forecasting was undertaken.

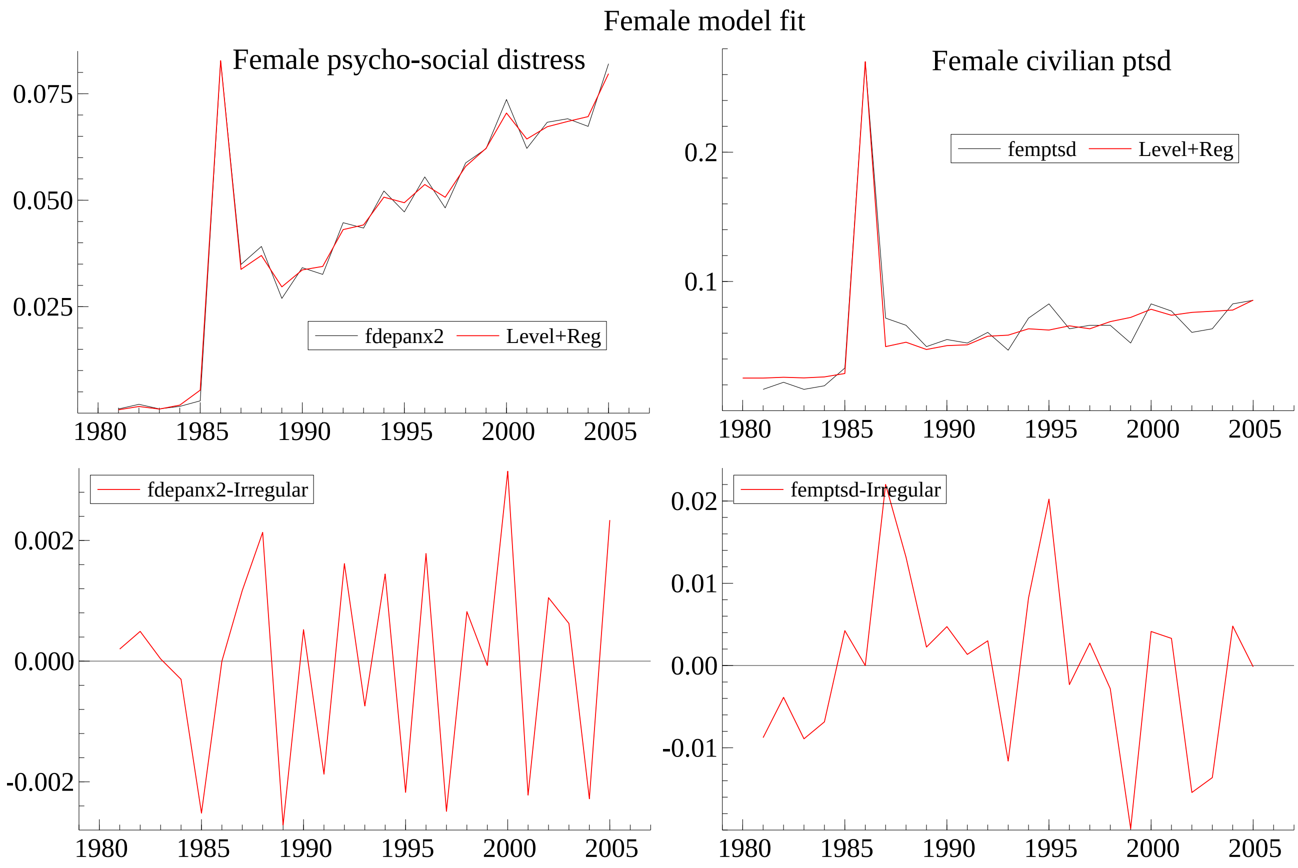

Figure 10: *Female multivariate common local level fit for psychosocial and post-traumatic distress*

Table 8: Equation femptsd: regression effects in final state at time 2005

Y_2 =	**Level**	**Explanatory + variables**	**+Irregular**	**components**
Omnibus fit	- 2 Log Lik = - 412.079 BIC = -8.6 **Level = rank(1)**		R^2 = 0.955 R_d^2 = 0.975 **Irreg=rank(2)**	level error variance = 2.513e-05 % Irregular error variance = 23.13 %
State vector	**at**	**period**	**2005**	
Equation	femptsd **Value**			**Prob**
Level	0.081			0.000
Variable	**Coefficient**	**RMSE**	**t-value**	**Prob**
chornblip	0.231	0.011	21.196	0.000
Dchornblip	-0.020	0.008	-2.307	0.031
legend				
chornblip	= 1986 outlier			
Dchornblip	= 1st differenced	1986 outlier		

8.2 Male multivariate common local level model

The male state space model was also a multivariate common local level model. It also fit well through 2005. The component structure was optimized by estimating a common local level, removing the slope component. But by 2006, it experiences issues with the end effects of the 2006 gas cut-off, which sent shivers throughout Europe when people began to become concerned about the security of their energy sources. The male models are contained in Tables 9 and 11.

Auxiliary residuals were analyzed to facilitate modeling outliers and level-shifts as needed while the residuals were reviewed for acceptable normality and homoskedasticity before forecasting was undertaken.

8.3 Misspecification tests

Each model was analyzed for misspecification to be sure that the statistical assumptions assumptions were fulfilled. When the assumptions are fulfilled, the mathematical models become congruent with statistical theory, validating their results. We can then apply those results to generate inferences. The null hypotheses of these tests indicates a fulfillment of the assumption. An "ns" is used to designate a non-statistically significant test result that is consistent with fulfillment of the statistical assumption tested. The results of these diagnostic tests, contained in Table 11 indicate that our models are congruent with the fulfillment of the statistical assumptions required for their validation.

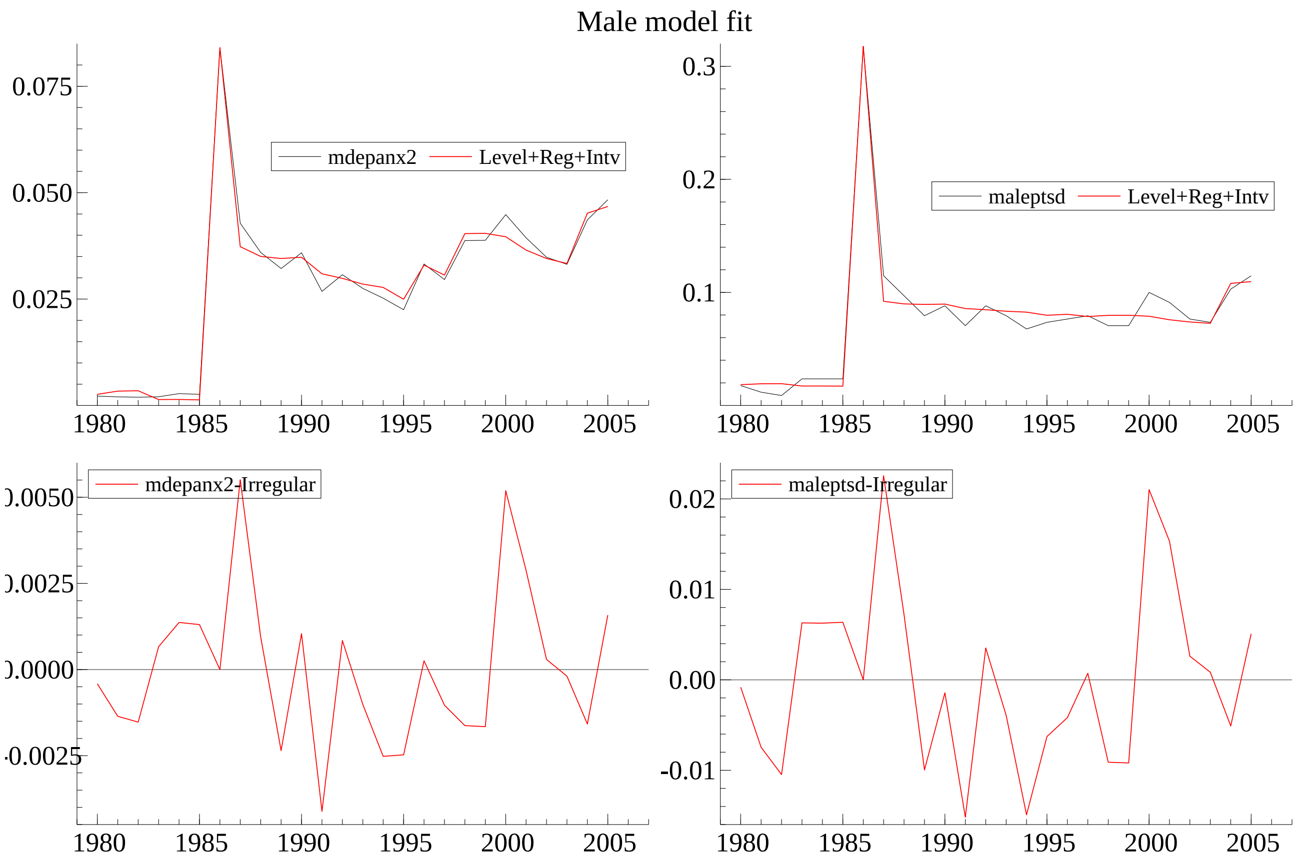

Figure 11: *Male multivariate common local level fit for psychosocial and post-traumatic distress*

Table 9: Equation mdepanx2: regression effects in final state at time 2005

Y_1 =	Level	Explanatory + variables	+Irregular	components
Omnibus fit	-2 Log Lik = -427.687 BIC = -10.484 **Level = rank(1)**		R^2 = 0.978 R_d^2 = 0.978 **Irreg=rank(2)**	Level error variance= 100% Irregular error variance = 99.61 %
Variable	**Coefficient**	**RMSE**	**t-value**	**Prob**
Outlier 1997(1)	-0.005	0.002	-2.549	[0.020]
Level break 1996(1)	0.009	0.002	4.688	[0.000]
Level break 1998(1)	0.005	0.003	2.175	[0.043]
Level break 2004(1)	0.011	0.003	3.555	[0.002]
chornblip	0.049	0.004	13.585	[0.000]
mrpre2	0.029	0.003	9.429	[0.000]
legend				
mrpre2 chornblip	= male = 1986	perceived chornobyl	risk of outlier	exposure

Table 10: Equation maleptsd: regression effects in final state at time 2005

Y_2 =	Level	Explanatory + variables	+Irregular	components
Omnibus fit	-2 Log Lik = -427.687 BIC = - 8.665 **Level = rank(1)**		R^2 = 0.976 R_d^2 = 0.985 **Irreg=rank(2)**	level error variance= 1.420e-14 % Irregular error variance = 0.391 %
Variable	**Coefficient**	**RMSE**	**t-value**	**Prob**
Level break 2004(1)	0.034	0.008	4.022	[0.001]
chornblip	0.230	0.011	20.638	[0.000]
mrpre2	0.059	0.005	11.804	[0.000]
legend				
mrpre2 chornblip	= male = 1986	perceived chornobyl	risk of outlier	exposure

Table 11: *Residual diagnostics*

Misspeci-fication assumption	**test type**	**female distress test p-value**	**female ptsd test p-value**	**male distress test p-value**	**male ptsd test p-value**
residual autocorr	ACF lag1	ns	ns	ns	ns
residual autocorr	ACF lag2	ns	ns	ns	ns
residual autocorr	ACF lag3	ns	ns	ns	ns
residual normality	Bowman-Shenton	ns	ns	ns	ns
resid. homo-	cusum	ns	ns	ns	ns
geneity	resids	ns	ns	ns	ns
irregular normality	Bowman-Shenton	ns	ns	ns	ns
irregular skewness		ns	ns	ns	ns
irregular kurtosis		ns	ns	ns	ns
level normality	Bowman-Shenton	ns	ns	ns	ns
level skewness		ns	ns	ns	ns
level kurtosis		ns	ns	ns	ns
Legend					
sig = p < 0.05	ns = p => 0.05				

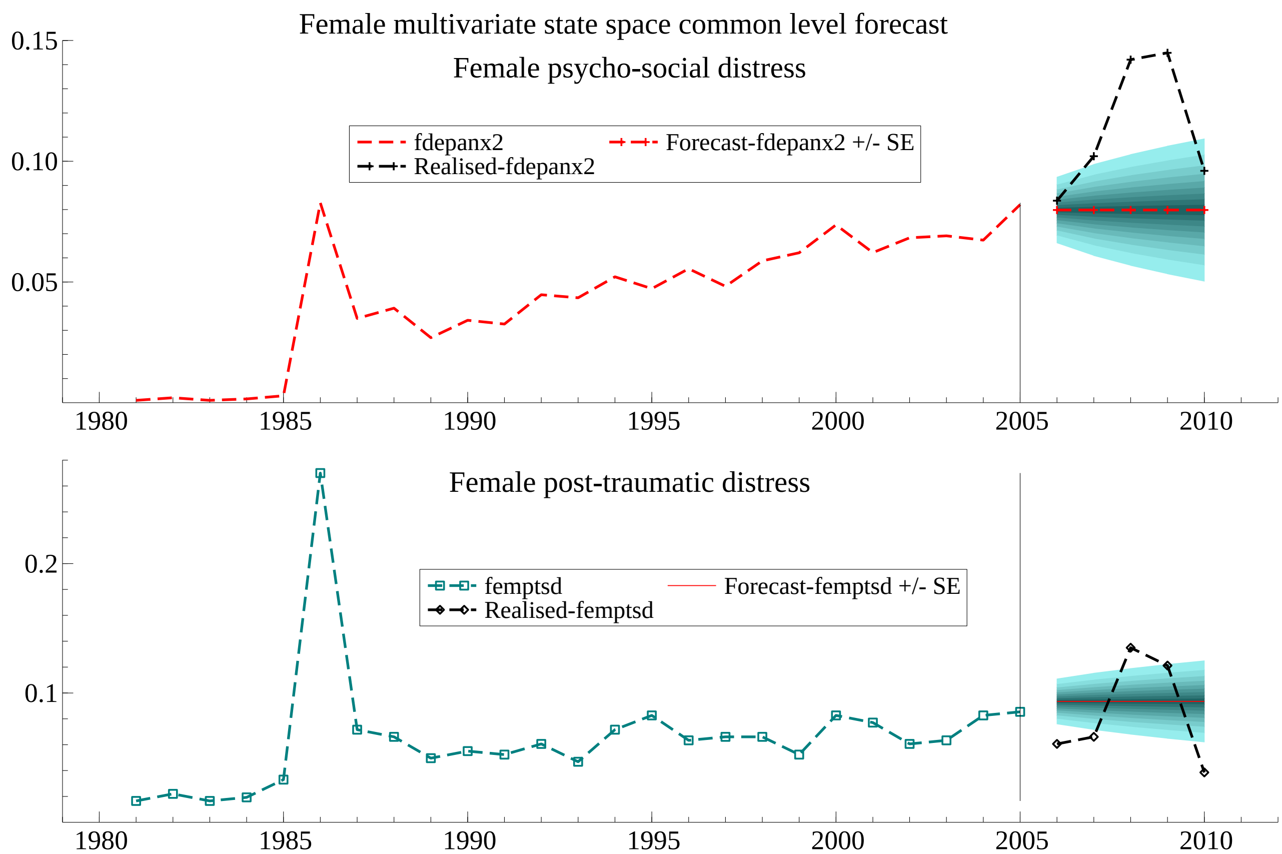

Figure 12: *Female multivariate common local level fit for psychosocial and post-traumatic distress forecasts*

8.4 Forecasting

When we examine the forecast plots for the female and male models, we observe that the end effects are circumvented by early termination of estimation at 2005. From 2006 on, we forecast to reveal what would have happened had all things remained the same. There is a one-lag adjustment in the Kalman filter so that we observe things beginning to break through the brackets of the upper 95% prediction intervals by 2007 for female anxiety/depression distress. By 2008, the great recession was erupting in Europe and in the United States. Coupled with the 2009 Russian gas cut-off for three weeks, which led to a closing of about 80% of the factories in the Ukrainian industrial sector, this Great Recession also contributed to a rise in the psychosocial distress. We observe a similar pattern among the female civilian post-traumatic stress after 2006, peaking in 2008 and 2009.

The male model forecasts exhibit a very similar pattern. The males were not as broadly sensitive as the women. But they assuredly responded between 2007 and 2008 to the emergence of the Great Recession.

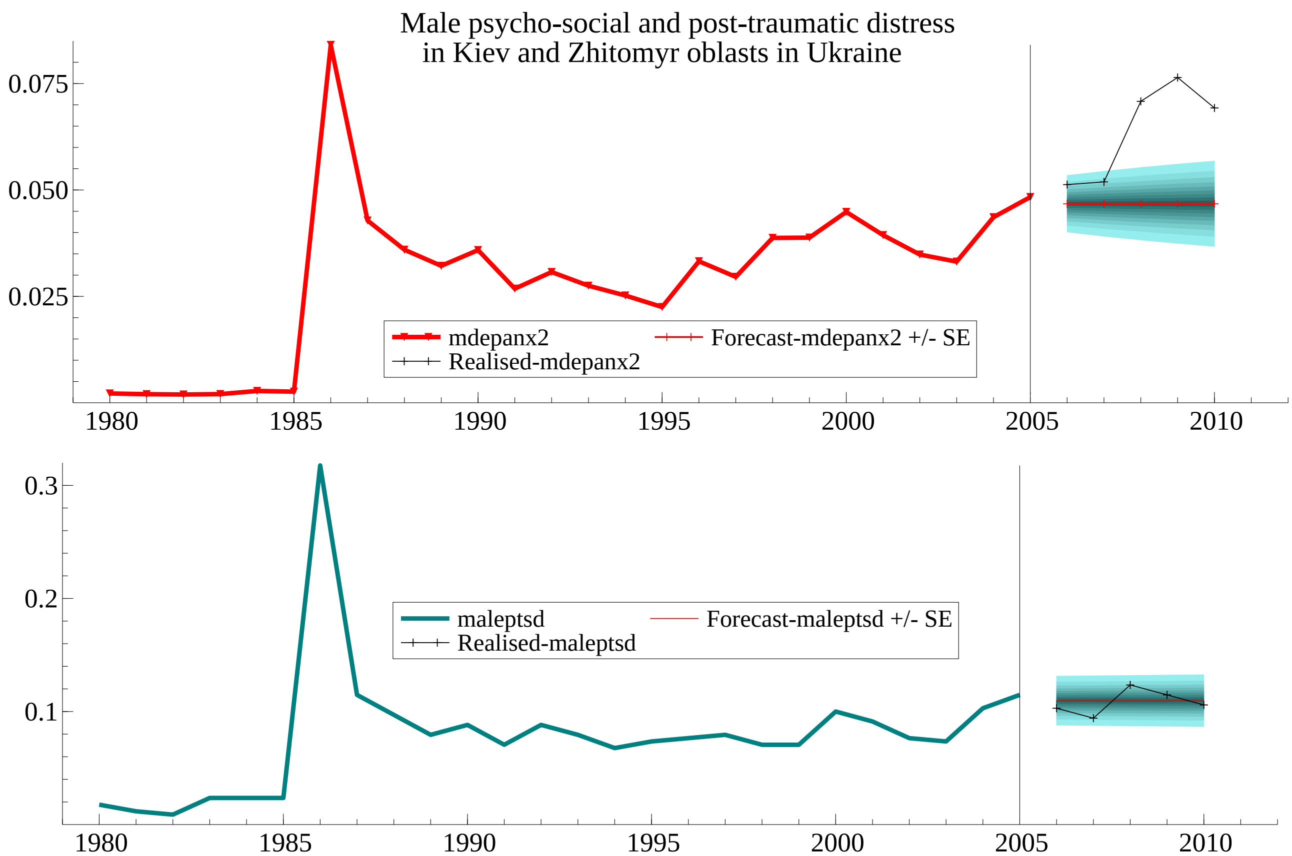

Figure 13: *Male multivariate common local level fit for psychosocial and post-traumatic distress forecasts*

9 Discussion

9.1 What we did that was new

Our empirical finding that external dose was not a significant factor in generating the psychosocial effects following Chornobyl, based on our dynamic simultaneous equation results, is supported in report 7 from the U.S. National Academies of Sciences: Biological Effects of Ionizing Radiation (BEIR VII), which summarizes the latest findings of epidemiological and experimental research on low levels of ionizing radiation. At doses less than 100 mSv (.1 Sv), it becomes difficult to evaluate risk to humans. People in the United States are exposed to annual background radiation of 3 mSv. A chest X-ray exposure is about 0.1 mSv, whereas The lifetime-attributable-risk (LAR) for developing cancer in a population receiving 100mSv would be about 1% for males and 1.4% for females. This is about 40 times lower than the incidence of cancer expected in the population from other causes (3).

We concur with the findings in the literature that the pre-eminent problem following this nuclear disaster was a problem public mental health. We also concur that the principle risk factor behind underlying these symptoms is evidence the presence of the male and female perceived exposure to Chornobyl related radiation, rather than actual external exposure. This explanatory variable was shown to be pre-eminent among the significant predictors of depression and anxiety in earlier models (83), (84).

After conducting a pilot study of 100 respondents to check responses to key questions, we conducted a randomly sampled telephone survey of 702 residents of the Kiev and Zhitomyr Oblasts in Ukraine. This population survey used four call-backs at different times of day to minimize non-response bias. The interviewing quality was monitored and screened by an independent auditing group before the data were uploaded to the Vovici company which input the data for us. We converted the datafile to Stata for data management and performed the analysis with Stata and OxMetrics.

In performing this analysis, we did several novel things in this area of research. We employed a linear and nonlinear time series analysis to test the Bromet, Havenaar, and Guey (2011) entanglement hypothesis, and we found partial support for their hypothesis with respect to psycho-social distress among both Ukrainian men and women. We find that we are able to isolate some of these symptoms, but we suspect that we would have to design an instrument dedicated to the disentanglement of the collapse of the U.S.S.R. from particular forms of symptoms. This may not be practicable while the conflict between Ukraine and Russia remains unresolved.

We also used structural time series analysis to deal with the problems we encountered on our journey to discover what happened. We did not expect to encounter these potentially confounding events when we set out. However, when we subjected our data to a longitudinal analysis we observed end-effects in our time series that we were forced to address. These events took place apparently in 2006 and 2009. After some historical analysis, it appears that the observed impacts may have stemmed from psycho-social reverberations from gas cut-offs and/or the Great Recession. It is possible that they were driven by political considerations involving the exertion of Russian petro-power over independently oriented countries that were former members of the U.S.S.R..

We found that particular political, economic, and military events have had impacts on the psychosocial variables of interest to us. We took steps to model or control for such impacts, whereas most earlier studies do not endeavor to do so. We did the historical research to discover what was behind these new surges in distress and civilian PTSD and discovered geopolitical and strategic conflicts that we had to either circumvent or model.

Because our objective was to focus on the psychosocial stress and PTSD and to avoid the detail of those political conflicts, our decision was to terminate our estimation prior to the incidence of these political impacts. In so doing, our estimation would not be confounded by the surges at the end of our endogenous time series. Those impacts exhibit prominent increases in our stress variable in 2006 and again in 2009. The statistical technique we used allowed us to control the range of estimation and circumvent the confounding influences that could otherwise undermine the isolation that protects the internal validity of our analysis.

However, our ability to analyze these effects as a time series depends on our ability to disprove the claim of Bromet, Havenaar, and Guey in 2011 that the mental health effects could not be disentangled from the disruptive effects of the collapse of the U.S.S.R. in 1991. We were able to empirically disentangle anxiety, depression, and PTSD from the collapse using dummy indicator variables. Using AutoMetrics with IIS-SIS, dynamic simultaneous equation models, and Markov regime switching models, we were able to show that the Soviet Union's collapse is associated with a reduction in self-reported male Ukrainian PTSD. Otherwise, it did not appear to compromise our measures of depression, anxiety, and PTSD.

Is it possible that part of the Ukrainian general unconscious that elements of the shock and horror of exposure to the radioactivity from the meltdown at Chornobyl reside at a sub-conscious level that we have not been able to empirically measure or test, after the fashion of a suppressed lock on part of the respondent, from which the person will not be freed until he or she can intellectually dredge up the traumatizing event and intellectually come to grips with how it shapes the contour of his or her behavior? If this is part of that to which BHG were referring, this may not be amenable to empirical analysis until each person undergoes such analysis. We have to limit the focus of our attention on what we can empirically analyze and test.

9.2 Bias control

One criticism of our methodology is that we used a retrospective analysis, and that could be subject to recall bias. Retrospective studies necessarily depend on the recall of their respondents. If we are endeavoring to reconstruct trauma and extreme distress, these things are recalled better than most. We asked respondents to tell us in what year the anxiety, depression, and PTSD significantly changed and from what level as well as to what level on percentage scale. Questions were posed with answers pertaining to different periods of time, punctuated by the occurrence of well-known national events. Respondents could answer with reference to our three-wave periodization and use that as a memnonic aid for more precisely recall in what year their feelings of anxiety, depression, or PTSD significant changed from one level to another.

In the research planning for our analysis, we performed a statistical power analysis to assure that we had enough statistical power for each of the planned statistical analysis to be conducted with a 90% power, given a small-to-medium effect size, to avoid finite sample bias. With data collection, we randomized selection of respondents' telephone numbers to neutralize selection bias (72, 77), and we did four callbacks at different times of day to minimize non-response bias. To preclude information bias, we used back-translation to prevent incorrect interpretation of questions. We use mixed-frequency sampling of response to to minimize recall bias. By linking answers to prominent proximate historical events with different temporal periodization, we designed questions to optimize the elicitation of information about the psychological and social history of the respondents. In this respect, our applied mnemonic device to facilitate recall of events and salient psychosocial symptoms.

To be sure that the questionnaire was professionally administered and that all responses were voluntary, and devoid of improper guidance or direction, we had an independent auditing group check with each respondent to confirm that there was no improper interaction effect with the interview before that respondent's dataset was uploaded to our general database.

In our dynamic simultaneous equation models, we also created time series with potential confounders – including smoking, wine and beer drinking, vodka drinking–to control for these effects where practicable. Owing to spatial constraints, these analyses will have to await a later article.

To avoid bias generating end-effects, sometimes referred to as multiple interference of external impacts, with our time series, we performed our analysis with time series data, the estimation of which, we terminated prior to the impact from potentially confounding gas cut-offs. In this way, our estimation was not corrupted by end-effects. The downside of this approach is that it reduced the number of observations in our time series by five.

We generated multivariate state space models for the purpose of forecasting, which permitted our use of multi-frequency sampling data in the analysis and which was particularly adept at modeling and forecasting short time series owing to the capabilities of the Kalman smoother with the augmented Kalman filter. This augmented Kalman filter is exceptional at forecasting with missing data, and is recommended as an optimal method of handling missing data in time series (44, 162,165-168).

We perform general-to-specific modeling when we build models to minimize specification error and to avoid traps like Simpson's paradox. We proceed from a full model to a trimmed model to conserve and optimize statistical power. We test misspecification tests to assure model congruency with statistical theory. In our analysis, we performed all of our analyses as gender-specific to circumvent confounding by gender.

9.3 Anonymity and confidentiality

In keeping with the Health Information Privacy Act of 1996, the data were maintained in and backed up on several computers, locally networked together, but unconnected in any manner to a cloud until the data were collected and uploaded.

9.4 Internal validity

Internal validity is demonstrated with refined multivariate state space common local level models that fulfilled all of the statistical model assumptions listed in Table 11. Congruency with the assumptions of the statistical models is tested with a variety of residual diagnostics. The residual autocorrelations of the first three lags tested by the Box-Ljung tests for each of the first three lags are all non-significant. The level and irregular residual normality and homogeneity, tested respectively by the Bowman-Shenton tests and the the cusum t-tests were also found to be statistically non-significant. These model *ex post* forecasts not appear to be statistically significantly in error. Predictive validity was thereby tested and as shall be soon observed, found to hold for the validation segment of the sample.

9.5 External validity

The external validity was assured by our random sampling of telephone numbers. This permitted us to generalize beyond the sample to the target population. We have demonstrated that we have *ex post* forecast accuracy, and this form of predictive validation suggests that we may be able to perform scenario forecasting of ceteris paribus projections over a short term of five years. The random selection minimizes selection bias and any interaction with external events. By ceasing our estimation early, we were able to avoid the impacts of potentially confounding events.

9.6 Statistical conclusion validity

The telephone random sampling of the population provided the optimal method of neutralizing potentially confounding variables and generalizing from our sample to the target population. At the time of our study, Census data were not available. We found that our approach was the best method for obtaining a representative sample of the general population.

9.7 Limitations

We performed a power analysis for each of the planned statistical tests to assure ourselves of a power of .90 or higher for a small-to-medium effect size for each of those tests. We did not expect to perform a time series analysis of our psychological symptomatology. Nevertheless, it might be helpful to undertake a time series analysis that would exhibit the time-dependent patterns of those trajectories. What we found was surprising. We discovered potentially confounding events that, ignored or downplayed, could undermine the internal validity of our findings.

We endeavor to empirically disentangle the USSR collapse from our reported psychosocial sequelae. Yet the authors of the entanglement hypothesis claim that the driving forces of perceived risk are "sub-clinical." We show that their entanglement hypothesis is generally not consistent with our findings. We have shown in earlier papers that their claims of sub-clinical did not mean sub-syndromal and unmeasurable in that we were able to show that perceived risk rather than actual external exposure appeared to be associated with psychosocial depression and anxiety (83), (84).

We found increases and spikes in our trajectories that reflected unexpected impacts of political-economic events outside the locus of our focused concern. With that discovery, we realized we had to find a way of controlling for the impacts from those political and economic events. By terminating our estimation early we avoided confounding our variables and our analysis with the impacts of these external events

We had to form a time series that extended from 1980 to 2010 by taking the gender-specific average of the self-reported changes in anxiety, depression, and civilian PTSD. The estimation over the 31 years of average measures of these symptoms had to be limited only to the years prior to the Russian gas cut-offs, in 2006 and 2009. Fortunately, state space models can be used for such analysis with remarkable precision.

Upon historical research, we learned that the events that could have generated these increases or spikes psychosocial anxiety/depression distress along with similar patterns in civilian PTSD were related to the exercise of Russian "petro-power" as an instrument of their foreign policy with respect to countries in the "near-abroad", or geographically inhabiting part of the former peripheral sphere of influence of the U.S.S.R.. Another catalyzing phenomenon involved was the emergence of the global Great recession affecting all concerned countries and what happened between them as a result of this situation.

9.8 Forecast evaluation

Forecast evaluation provides for predictive validation of our model. If George Box was correct in saying that "All models are wrong; but some may be useful," we find that their utility may be derived by their added predictive value. We show how time series analysis may be applied for retroactive disaster analysis.

Because the smaller the value of the forecast, the larger the mean absolute percentage error is due to the scale dependency bias inherent in the MAPE, We compute a type 3 symmetric mean absolute percentage error, sMape, which attempts to correct for such bias. When the computation of the sMAPE is performed, we do it for the ex ante forecast horizon of 5 years.

9.8.1 Ex post forecast evaluations : female and male models

An ax post forecast evaluation covering the last 7 observations and estimations up through 2005. Our evaluation of the validation sample covers those last 7 observations of the estimation sample. It is split into two parts, the first of which generates numbers that should be minimized. In those first two rows of Table 12, we provide the sum of the absolute prediction errors and the sum of the squared prediction errors over the last 7 observations within that estimation sample. Ideally, these measures should be as small as possible for the model to be good.

The second part of the *ex post* forecast evaluation generates two numbers which essentially generate chi-square tests which ideally will be non-significant. In the last two rows of these tables, we exhibit the results from chi-square test of significance of the prediction errors and the Brown, Durbin, and Evans (1975) Cusum t test, indicating lack of significant differences between the actual and fitted values. These results should be non-significant for the model to exhibit predictive validity.

This prediction validation extends from 1999 through 2005 for women from and over the last six observations from 2000 through 2005 for men. For both women and men, we do not find a significant difference between the actual and forecast values over this *ex post* horizon, as indicated by the χ^2 and the Cusum t tests results in Tables 12 and Table 13. This is evidence of the predictive validity of our models.

Table 12: *Female model ex post-sample tests*

Component	**Test**	**chi-square**	**p- value**
fdepanx2			
	$\sum_i^7 \lvert pred.error \rvert$	=	0.042
	$\sum_1^7 (pred.error)^2$	=	0.000
	Failure $\chi^2(7)$	5.391	0.402
	Cusum t(7) test	1.177	0.278
femptsd			
	$\sum_i^7 \lvert pred.error \rvert$	=	0.083
	$\sum_1^7 (pred.error)^2$	=	0.001
	Failure $\chi^2(7)$	8.428	0.296
	Cusum t(7)	0.592	0.573

9.9 Ex ante forecast evaluation

Tables 14 and 15 display the ex ante forecasts and their standard errors. For each of these *ex ante* forecast horizons we provide the RMSE, the RMSPE, the MAE, and the MAPE. Another measure called the symmetric or sMAPE has been developed to adjust for scale dependency. The smaller the value of the forecast, the easier it is for the percentage error to be large, and therefore, for the MAPE to be large. If there is an error of 1, then a 2 forecast could provide for a 100% MAPE. In an attempt to adjust for scale-dependency bias, we use a modified version of the symmetric MAPE (sMAPE), the formula for which underwent several variations since Armstrong propounded it in 1985, another version used by Spyros Makridakis in 1993. The general formula for the version used can be found in Wikipedia (73). A modification of sMAPE restricts its application to the forecast horizon, H, because it is used for forecast evaluation , rather than estimation evaluation.

Table 13: *Male model ex post-sample tests*

Component	Test	chi-square	p- value
mdepanx2			
	$\sum_i^6 \lvert pred.error \rvert$	=	0.015
	$\sum_1^6 (pred.error)^2$	=	5.34e-05
	Failure $\chi^2(6)$	3.442	0.752
	Cusum t(6)	0.428	0.684
maleptsd			
	$\sum_i^6 \lvert pred.error \rvert$	=	0.056
	$\sum_1^6 (pred.error)^2$	=	0.001
	Failure $\chi^2(6)$	6.546	0.390
	Cusum t(6)	1.379	0.217

Table 14: *Female ex ante forecasts and forecast standard errors*

year	Level fdepanx2 Forecast	standard error
2006	0.06192	0.00758
2007	0.06192	0.00935
2008	0.06192	0.01084
2009	0.06192	0.01215
2010	0.06192	0.01333
	level femptsd	**standard**
year	**Forecast**	**error**
2006	0.08081	0.00730
2007	0.08081	0.00913
2008	0.08081	0.01065
2009	0.08081	0.01198
2010	0.08081	0.01317

Table 15: Male ex ante Level equation forecasts and forecast standard errors

year	mdepanx2 Forecast	standard error
2006	0.047	0.004
2007	0.047	0.005
2008	0.047	0.005
2009	0.047	0.006
2010	0.047	0.006
year	**maleptsd Forecast**	**standard error**
2006	0.110	0.013
2007	0.110	0.013
2008	0.110	0.014
2009	0.110	0.014
2010	0.110	0.014

$$sMAPE = \frac{100}{H} \sum_{h=1}^{H} \frac{abs(F_t - A_t)}{(abs(F_t) + abs(A_t))/2} \tag{15}$$

where A_t = the actual value, F_t = the forecast value, and H = the length of the forecast horizon.

9.9.1 Ex ante forecast evaluation: female model

To overcome the scale dependency bias, we compute the female psychosocial distress sMape for the five year *ex ante* forecast horizon as 34.281%. If this percentage seems large, we have to recall that during this five year period of time, the forecast error is tiny and the forecast values are also tiny, so it is easy to obtain large percentages, notwithstanding the attempted adjustments by the symmetric MAPEs. Moreover, this was the validation sample within which the Great Recession occurred affecting Europe and the Ukraine greatly, as early as 2008. It was also the time during which the external impacts of the Russian gas cut-offs occurred generating relatively large differences between the actual value and its forecast. The Gazprom cut-off the flow of natural gas to Ukraine on January first, 2009 and prevented the flow from continuing for approximately three weeks. By 2007, the actual female mean level of psychosocial distress broke through the upper 95% confidence level, as shown in Figure 12. These large discrepancies were anticipated as end-effects which would and did bias the forecast accuracy, for which reason we terminated estimation before they could occur.

The sMape for female civilian PTSD over the five year *ex ante* forecast horizon as 42.851%. Although these values are inflated by the impacts of the gas cut-offs in 2006 and 2009, the latter is also inflated partly as a result of the Great Recession of 2008 to 2010 shown in Figure 12.

Table 16: Equation fdepanx2: forecast accuracy measures from period 2005 forwards:

Year	Error	RMSE	RMSPE	MAE	MAPE
2006	-0.0066	0.0066	0.7919	0.0066	0.7919
2007	-0.0251	0.0183	1.8233	0.01584	16.2288
2008	-0.0650	0.0404	3.0332	0.0322	26.0774
2009	-0.0679	0.0488	3.5190	0.04114	31.2658
2010	-0.0190	0.0444	3.2696	0.0367	28.9712

Table 17: Equation femptsd: forecast accuracy measures from period 2005 forwards:

Year	Error	RMSE	RMSPE	MAE	MAPE
2006	0.0202	0.0202	3.3333	0.0202	33.3326
2007	0.0147	0.0177	2.8327	0.0175	27.7771
2008	-0.0542	0.0344	3.2740	0.0297	31.8968
2009	-0.0404	0.0360	3.2890	0.0324	32.2561
2010	0.0422	0.0374	5.7135	0.0343	47.7094

9.9.2 Ex ante forecast evaluation: male model

Both male sMAPEs are really very good, considering their tiny forecast errors. The sMAPE for the male psychosocial distress is 14.054% over the five year *ex ante* forecast horizon.

As for the maleptsd forecast, the sMape is 9.046 %, which is approximately the same size as the penultimate MAPE for this *ex ante* forecast. Moreover, the 95% confidence interval fan for the men does bracket the actual male civilian PTSD over the *ex ante* forecast horizon.

9.10 Recapitulation

We have applied time series to the analysis of the psychological sequelae following the Chernobyl nuclear accident. We found that mental health effects were pre-eminent over the general population, and these were

Table 18: Equation mdepanx2: forecast accuracy measures from period 2005 forwards:

Year	Error	RMSE	RMSPE	MAE	MAPE
2006	-0.00430	0.00430	0.83803	0.00430	8.38032
2007	-0.00494	0.00463	0.89712	0.00462	8.95294
2008	-0.02387	0.01429	2.07910	0.01104	17.20268
2009	-0.02947	0.01924	2.63793	0.01564	22.54133
2010	-0.02231	0.01989	2.76444	0.01698	24.47545

Table 19: *Equation maleptsd: forecast accuracy measures from period 2005 forwards :*

Year	Error	RMSE	RMSPE	MAE	MAPE
2006	0.00686	0.00686	0.66678	0.00686	6.66778
2007	0.01569	0.01211	1.26940	0.01128	11.66784
2008	-0.01372	0.01267	1.21890	0.01209	11.48195
2009	-0.00490	0.01124	1.07700	0.01029	9.67959
2010	0.00392	0.01021	0.97744	0.00902	8.48463

generated, not by actual external exposure, but by the perceived self, family and community exposure to Chornobyl-related radiation (83), (84).

By graphing the trajectories of these self-reported effects, we discovered several potential confounders, the effects of which we were able to identify and circumvent. Yet these impacts were not controlled for by almost all earlier studies.

We have demonstrated that the BHG entanglement hypothesis is partly consistent with our statistical results. This demonstrates that further analysis of the psychological sequelae of the Chornobyl accident is possible, if one uses the appropriate statistical methods and controls for the impacts of potentially confounding effects, as we have managed to do, even if we identified the problems and terminated our estimation before they could impact the estimation. We show how time series analysis may be applied for retroactive disaster analysis.

We have also used a multivariate state space model with common levels for both men and women to generate forecasts that exhibit *ex post* predictive validity (see Figures 12 and 13). Moreover, because our *ex ante* forecast errors were so tiny, even the sMape evaluations of them were not large.

The female psychosocial distress sMAPE for the five year *ex ante* forecast horizon as 34.281%. Given the tiny forecast errors, this sMAPE is respectable. The sMape for female civilian PTSD over the five year *ex ante* forecast horizon as 42.851%. Tiny forecast errors render this evaluation respectable as well. Both male sMAPEs are really very good, considering their tiny forecast errors. The sMAPE for the male psychosocial distress is 14.054% over the five year *ex ante* forecast horizon.

The overall forecast accuracy for the male models were tested and found to be quite good. The male sMAPE for psychosocial distress was 9,046%, This is not bad considering the size of the male forecast error, which happens to be miniscule. This suggests that our scenario forecasts over that five year *ex ante* horizon were not too bad, even if they were not as accurate as the *ex post* forecasts.

9.11 Potential future applications

We have devised a time series method that can be applied for retrospective analysis of natural, accidental, or incidental disasters. We demonstrate its utility with this example. With short time-series, he Kalman smoother provides a useful and accurate method of signal extraction, while the Kalman filter provides an efficient method of forecasting.

To tease out of this analysis, the impact of the USSR collapse from that of Chornobyl would probably require an intense interview that dedicated to distinguishing strategic political-military and economic factors from the psychosocial impacts stemming from Chornobyl-related risk of earlier exposure, which may have to wait for the resolving of the Russian-Ukrainian conflict.

In later research we can try to improve on the accuracy of the augmented Kalman filter by using an unscented Kalman filter, a modified unscented Kalman filter, or a particle filter. But the results of the analysis just provided are quite promising.

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11 Appendix A: Sample characteristics

11.1 Sample characteristics

The sample consisted of 702 respondents from the Kiev and Zhitomyr oblasts in Ukraine. By gender, the sample comprised 48.29 % (339) males and 51.71% (363) females. Most of the sample resided in Kiev oblast at the time of the survey (2009 through 2011) 85.9% (603) came from Kiev and 14.1% (99) from Zhitomyr oblasts. Approximately 32%(224) were 41 years old or younger. Approximately 31% (218) were 42 thru 54 years old, and about 37%(260) of the sample were 55 or more years old. At the time of the interview, most respondents (approximately 70%(488)) reported being married with 9% (64) reporting being single. About 7% (49) said that they were divorced and about 9% (61) reported being widowed. About 5%(32) indicated that they were cohabiting. The occupational status consisted of a plurality percentage as occupying a professional, executive, or administrative position at the time of the interview. Approximately 62% (434) indicated that they were employed full time with about 8.12% reporting part time employment.

Only 5.13% claimed that they were unemployed and about 25% described themselves as being retired. At the time of the interview about 26.92% (189) of the respondents indicated that they were professional, executive, or administrative positions. 26.63% (167) reported that they were homemakers or caregivers. 19.30% (121) described their positions as technical sales or administrative support. 11.96% (75) maintained that they were in a service occupation or protective services. Almost 7% (43) stated that they were working in a precision production or mechanical craft or construction. 3.67% reported being factor laborers, machinists, cleaners, or involved in transportation. 1.28% (8) indicated that they were involved in agriculture, forestry, fishing, trapping, or logging. One respondent reported being a student. The sample was in general well educated, with slightly more than 40% (281) indicating that they had finished a master?s or specialist?s degree. 34.33% (241) reported having a technical degree. 13.82% (92) indicated that they had graduated college with a bachelor?s degree. About 1% indicated that they held a PhD, Ph.sci, or MD. The drop-out or incomplete rate was minuscule in that only 5.27% (37) reported having only a high school or less education and only 5.41% had not finished college or had not earned a bachelor?s degree. In terms of education, this was a fairly well-accomplished sample. Income sufficiency indicated the financial stress on the sample. Approximately 15.78% (98) of the responses indicated that their income was not sufficient for basic necessities, whereas 47.67% (296) reported of the responses reported that their income was just sufficient for the basic necessities. About 1/3 (33.01%)of the responses (205) maintained that their income was sufficient for the basics plus a few extra purchases or savings now. Only 3.54%(22) of the responses admitted that they live comfortably and afford luxury items.

12 Appendix B: filename index

__Table 20:__ File names and locations:

model type	gender	computer	Eqnum	linenum	pathname / filename
AutoMetrics IIS-SIS .01 "	female dfdepanx2	mbp2 "	GUM1 "	110 "	current_reasearch/ffc/oxoutput.out/ Results.out
AutoMetrics IIS-SIS .01 "	female dfemptsdmc	mbp2 "	Eq4 "	427 "	current_reasearch/ffc/oxoutput.out/ results.out
AutoMetrics IIS-SIS .01 " "	male dmdepanx2 "	mbp2 " "	Eq2 " "	195 " "	current_reasearch/ffc/oxoutput.out/ ussrtests/AutoMetricsIIS-SIS .01/ results.out
AutoMetrics IIS-SIS .01 " "	male dmaleptsdmc "	mbp2 " "	Eq 8 " "	896 " "	current_reasearch/ffc/oxoutput.out/ ussrtests/AutoMetricsIIS-SIS .01/ results.out
AutoMetrics IIS-SIS .05 "	female dfdepanx2	mbp2	Eq39	5998	current_reasearch/ffc/oxoutput.out/ RegSwitch/RSmodels.out
AutoMetrics IIS-SIS .05 " " "	male dmdepanx2 " "	mbp2 " " mbp2	GUM(42) " " "	6589 " " "	current_reasearch/ffc/oxoutput.out/ ussrtests/AutoMetricsIIS-SIS .05/ AutoIIS-SIS_05.out RegSwitch/RSmodels.out
AutoMetrics IIS-SIS .05 " "	male dmaleptsdmc "	mbp2 " "	Eq5 " "	1229 " "	current_reasearch/ffc/oxoutput.out/ ussrtests/AutoMetricsIIS-SIS .05/ AutoIIS-SIS_05.out
DSEM	female dfdepanx2 dfemptsdmc	mbp2 " "	Eq 1 " "	7 " "	current_reasearch/ffc/oxoutput.out/ DSEM/DSEMf2.out DSEM/desmFIMLf3.out
DSEM	male dmdepanx2 dmaleptsdmc	mbp2 " "	Eq 1 " "	7 " "	current_reasearch/ffc/oxoutput.out/ DSEM/DSEMm2.out "
Regime Switching	female dfdepanx2 dfemptsdmc "	mbp2 " " "	Eq 1 " " "	7 " " "	current_reasearch/ffc/oxoutput.out/ RegSwitch/RSmodels/ RSmodels2/ RSmodels2.out RSmodels2
Regime Switching	male dmdepanx2 dmaleptsdmc	mbp2 " "	Eq 1 " "	7 " "	current_reasearch/ffc/oxoutput.out/ RegSwitch/RSmodels/ RSmodels2 RSmodels3
state space	female	mbp2	uc3	1707	current_research/ffc/oxoutput.out/ femalemodels/finalfemalemodels/ femfinalfc.out
state space	male	mbp2	uc2	110	current_research/ffc/oxoutput.out/ malemodels/finalmalemodels / maleRep2fc.out