Pathways of psychosocial anxiety, depression, and post-traumatic stress in Ukraine following the Chornobyl nuclear disaster

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based on work with RoseMarie Perez-Foster[2],
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4. Remi Frazier, M.S., assistant to Professor Borak for external dose radiation, reconstruction, and assessment. Remi Frazier devised a novel method of extraction of ^{137}Cesium deposit contours from the IAEA ^{137}Cesium Atlas to enable individual respondent external dose reconstruction for each respondent based on their residential history.
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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 Zhytomyr 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, their relation to perceived radiation exposure, pain and discomfort, addictive habits, medical utilization, and impacts on the lives of respondents.
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

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Keywords and phrases: nuclear incident, nuclear accident, psycho-social 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

This presentation represents the position and opinion of the corresponding author[1]. It is not necessarily that of any governmental department, agency, or administration. Nor does it necessarily represent the position and opinion of any of the other grant recipients.

1 Historical background

On April 26, 1986 the light water graphite-moderated nuclear reactor suffered a power surge that led to the destruction of reactor number four. The surge in steam pressure and subsequent hydrogen explosion killed several workers and released a large amount of radioactive by-products into the atmosphere. Two firefighters died at the time of the explosion. Within a four months, 28 workers died from radiation. About 106 of the 600 clean-up workers suffered from acute radiation sickness [30]. Some 200,000 clean-up workers were exposed to between 1 and 100 rem of radiation within.the next two years, whereas six rem is the annual dose to which a U.S. citizen is exposed. The Soviet Union after several days evacuated 115,000 people from the most heavily contaminated area around Chornobyl and another 225,000 in the next few years. The remains of reactor four after one year are displayed in Figure 1 above. The radioactivity is commonly measured scientifically in terms of deposits of ^{137}Cesium (^{137} Cs) tested and measured on the land. With an approximate half-life of 30 years, ^{137}CS contamination in Ukraine, Europe, and the USSR is displayed in those terms in the maps below. In the U.S. we display thematic. maps of the U.S. Environmental Protection Agency maps depicting the contamination from the beta radiation in atmospheric concentration over the United States in the months before and after the Chornobyl disaster. One of the questions that arose was how much was the populace psychologically traumatized and hassled.

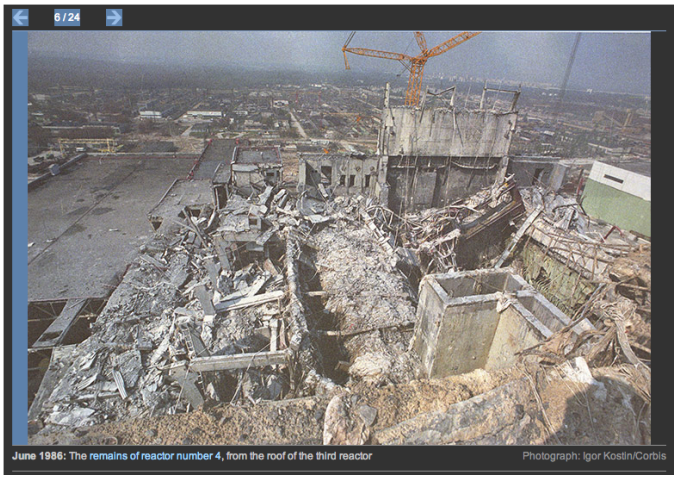


Figure 1: Explosion damage at Reactor Four

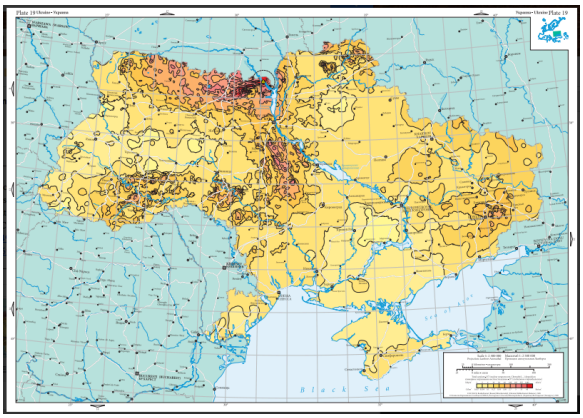


Figure 2: ^{137} Cesium contamination measured within Ukraine

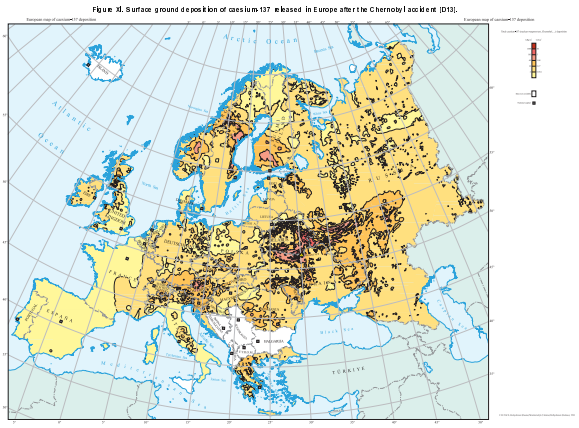
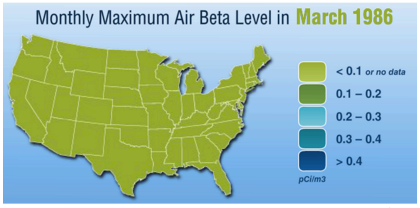
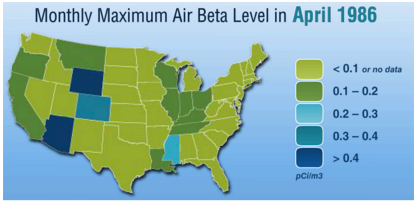


Figure 3: ^{137}Cs surface ground contamination in Europe and Western Russia

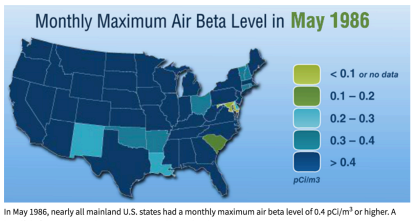


In March 1986, monthly maximum air beta levels across the contiguous U.S. were consistently 0.1 pCi/m^3 or lower.

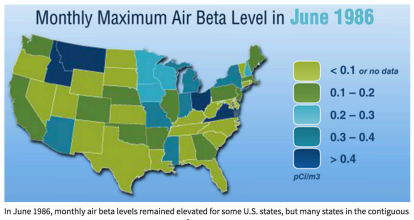


In April 1986, several midwestern, southwestern and west coast U.S. states' monthly maximum air beta levels reached 0.3 pCi/m^3 or higher.

Figure 4: March and April 1986 U.S. β air level in $picoCuries/m^3$ [41, 15]



In May 1986, nearly all mainland U.S. states had a monthly maximum air beta level of 0.4 pCi/m^3 or higher. A handful of states across the nation measured lower levels.



In June 1986, monthly air beta levels remained elevated for some U.S. states, but many states in the contiguous U.S. showed maximum air beta levels of 0.1 pCi/m^3 or lower.

Figure 5: US Atmospheric β contamination in May and June of 1986 in $picoCuries/m^3$ [41, 15]

1.1 Radioactive atmospheric β concentration in the U.S. is depicted in the monthly sequential graphs for the U.S. measured in pico curies per cubic meter

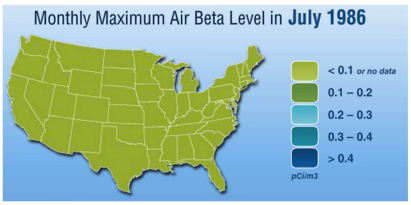


Figure 6: US Atmospheric contamination in July of 1986

2 Literature review

Pre-eminent in the structure of concern was the danger that radiation contamination posed to the public. This is the subject of our concern. We focus on the mental health consequences of this critical aspect to public well-being. We examine the major findings of the scholars who conducted studies to assess the real and imagined harm that this accident posed to the general populace. Public heath depended upon knowledge of the exposure and the radiation from the source term. We did not have access to the data on the amount ingested by the residents. Therefore, our analysis was based on the amount of radiation to which the individual was exposed by external sources only. Out literature review refers to the published studies, most of which were epidemiological in nature. These studies consisted mostly of case-control and a few cohort studies.

2.1 Health Consequences

J. M. Havenaar et al. (1997) maintained 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 [22], [49, 93-94]. According to the World Health Organization (WHO), the post-Chornobyl observational studies included ecological, case-control, and cohort-studies [48]. The vast majority were case-control studies. Bromet, E. Havenaar, JM, and Guey, LT (2011) (henceforth BHG) In the *20th Anniversary Chernobyl Forum Report of the Chernobyl nuclear power plant disaster*, the authors concluded that mental health effects were the most significant public health consequence of the accident [4]. BHG (2011) maintain 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 [4, 298]." Bromet, (2012) (henceforth EB) in Mental Health Consequences of the Chernobyl disaster argued 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* [5]." UNSCEAR's Sources and Effects of Ionizing Radiation scientific annexes suggests that there were forms of psycho-

logical 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 [43, 57]. The World Health Organization in 2006 echoed these claims in their 2006 report on Chernobyl [48, 1], [49]."

3 Methodological problems with past observational studies

Ecological studies, compared the consequences of Chernobyl with those of other disasters. These studies suffered from selection bias and confounding. The large majority of studies were case-control studies , comparing highly exposed cases to unexposed groups. These studies used matching to set up control groups, but they remained unmatched for all variables not applied in the specific propensity matching. Hence, these studies are still subject to selection bias and confounding [39], [34]. Cohort studies have problems with analysis of rare diseases or those with long latency periods. Almost none had randomized respondent selection. Major political, economic, and military events that had substantial impacts on social and psychological risk factors were generally ignored in previous studies, leaving them vulnerable to bias from confounding, omitted variable, and/or specification error. However, we do test for potential confounding factors to our psychological symptoms as well as interactions among them. Without that randomization in the respondent selection, the problem of generalizability and potential confounding with political intervention persists.

3.1 The emergence of GazProm in Russian foreign policy the context of the "color revolutions"

The World Health Organization 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 [38]. 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 [4]. But a series of "color revolutions" in the former Eastern European Soviet Republics shortly after the Soviet collapse in 1991 gave rise to strategic geopolitical concern in Moscow. As these former Soviet states began considering joining the NATO alliance, Moscow appeared to become more paranoid about this development. Among these uprisings against soviet subservience were the Rose revolution in Georgia in 2003, the 2005 Tulip Revolution in Kyrgystan, and the Orange revolution in Ukraine (2004-2005). At about the same time as the Orange Revolution in Ukraine, 2005 and 2006 protests in Belarus protests were in various parts given the name of the Blue Jeans or denim revolution. Russian foreign policy sought means to induce countries to remain within the Soviet sphere of influence. Clearly, natural gas prices regulated by GazProm were readily available. To countries who remained within the Soviet sphere, Putin provided discounted gas prices. To former Soviet Republics exhibiting more zest

for more autonomy, they found themselves subject to a variety of new pressures, generally including higher natural gas prices.

Ukraine was particularly important for the USSR because it provided the bedrock territory across which lay the nexus of gas transit lines between Russia and Europe, displayed in Figure 7. After Ukrainian consideration of joining NATO, Putin's gas cut-off in January 2006, after the Ukrainian Orange Revolution (Nov 2004-Jan 2005), sent shockwaves throughout Europe about European energy security. Approximately, 80% of European gas came through Ukraine; a web of pipelines transited Ukraine [31, 75], [37, 8], [24]. These strategic geopolitical factors of potential buffer zone fragmentation may have led to strategic concern for robustness of the Russian sphere of influence and loss of critical natural resources along with transiting infrastructure. For example, there were many natural gas pipelines carrying liquid energy to Europe through Ukraine, as shown in Figure 7 below. The resulting loss of valuable natural resources may also have played a role in Russian concerns. Ukraine had approximately eight major pipelines transiting its territory from Russia to Europe. Ukraine remained a potential strategic energy chokepoint, depending upon the relative market price of that energy and its transportation costs.

Although Jonathan Stern (2006) writes 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. Although Stern claims that this was merely an attempt to let the former Soviet states subject natural gas import and transit prices depend soley on the market, other factors reveal that there were geopolitical strategic issues had a compelling plausibility. "Russian gas enters Ukraine through more than 100 smaller pipes [24]." "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 [37, 8]." Through these pipelines, GazProm supplied almost half of the energy to the EU. In 2006, Germany and Hungary were immediately effected [33]. The Economist reported that it cut by more than 40% the gas it pipes onwards to Serbia and Bosnia. Germany, Italy, Slovakia, Austria, Poland, Croatia and Romania [17]. According to the NY Times' s Andrew Kramer, likened the event to OPEC's 1973 action [24]." 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 on the part of 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 [27]." Perhaps recognition that there could be an unmanageable backlash brought about a settlement of the dispute. The dispute was settled after a four day cut-off of natural gas flow [37, 8]. Although Stern maintains that this event did not significantly disrupt Europe's energy supply, it put all of Europe on alert: Energy security had become a major concern for Europe after this four day gas cut-off [37].

3.2 Did Russian responses to the color revolutions devolve into hybrid warfare?

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 line in 2006. 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 both cases, Russian

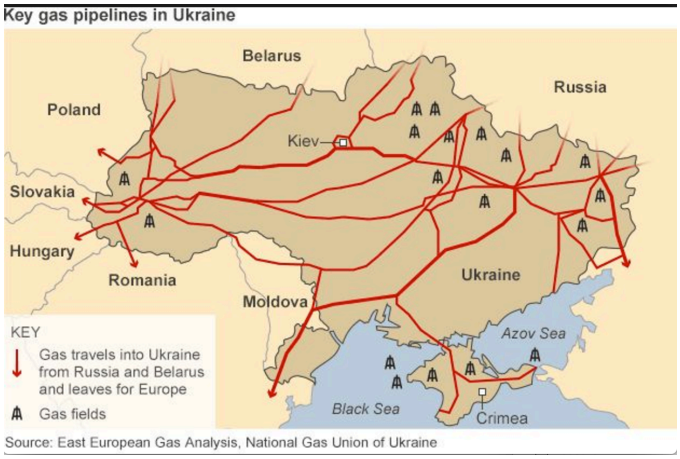


Figure 7: Natural gas pipelines in Ukraine

pressure against joining NATO lead to more European diversification and less dependence on Russia. According to a March 2006 *Council of Foreign Relations Task Force Report on Russia*, 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 [3]." "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 [28]" Ottrung and Overland (2011) discern evidence of strategic drivers of Russian foreign policy at work, immediately following the Orange revolution [31]. In later years, Stephen Dayspring might consider this strategic dynamic change being masked as the status quo as a preliminary 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 [20]."

3.3 Russian cyberattacks as part of Russian hybrid warfare

Hybrid warfare, according to General Varlerie Gerasimov, Chief of the general staff of the Russian Army, begins with a repertoire of covert actions. Gerasimov's *doctrine of nonlinear warfare* entails a variety of covert actions accompanied by a coordinated propaganda barrage designed to provide protection for covert actions with spetz-propaganda and to create a virtual reality amidst Russian denials of interference, coupled with attribution of emerging differences to polarization of indigenous interest groups or even threats to ethnic Russians. These differences are amplified and escalated to generate overt conflict. Overt conflict between the opposing parties includes protests, demonstrations, provocations, sab-

otage, paramilitary activities, and even murders of leaders. The objective is to create a crisis environment. Meanwhile, Russia begins to search for ways to resolve the crisis in the form of a regime change in their favor. This entails a change of political and military leadership to support this change, after which peace is restored [44, 19]

As long ago as 2007, Russia appears to have included cyberattacks as part of its repertoire of new-generation information warfare. Hybrid warfare appears to have been pursued by Russia in a response to the developments of the "color revolutions", according to Igor Panaran [44, 5]. Russian hackers launched three waves of distributed denial of service (DDOS) attacks directed at Estonia's governmental servers from April 27, 2007 through May 9, 2007, after a decision was made to relocate a Russian bronze soldier statue memorializing Russian WWII deaths. Also targeted were political parties, the three largest newspapers, and the largest commercial banks. When ethnic Russians protested, about 1200 were arrested, 100 were injured, and there was one fatality. According to the Ian Traynor of *"the Guardian"*, many attackers were identified by their Russian internet addresses [40]. In June of 2008, more than 300 Lithuanian government web sites were defaced with hammer and cycles, after the Lithuanian government outlawed display of Soviet and communist symbols. In July and August of 2008, the Georgian government was added to the list of targets while Russian military forces invaded. The Georgian internet was taken down. On January 18, 2009, Kyrgystan's web sites were hit with denial of service attacks from Russians, while Russia was pressuring Kyrgystan to shut down U.S. access to the airbase it was using as a logistic waypoint to U.S. forces in Afghanistan. In 2009, Russian hackers attacked Kyrgyzstan's internet and forced a U.S. military base to leave the country [1, 5-8,6-13]. In April of 2009, Russian hackers attacked Kazakhstan internet after it's President criticized Russia.

Some authors have begun to suspect that Ukraine was being used as an field test of Russian hybrid warfare- particularly, with the application of cyberattacks. Shortly after the end of our study horizon, Ukraine was bombarded with cyberattacks on December 2, 2013, as half-a million Ukrainians flooded the main square in Kiev to protest President Yanukovich's decision not to sign an agreement of political association with the E.U.. Although this may be part of the hybrid warfare strategy, it began to blossom into full bloom after our focus ends. In the governmental attempt to quash the protests, police tried to seize the cell phones of the dissidents. The Berkut police fired on the protesters, killing more than 100 of them. When the attempt to stifle the protest began to fail, a variety of cyber attacks were launched. A denial of service attack targeted the Presidential website. The lighting in city hall was turned off remotely by the internet. This oppression outranged the protesters. In Western Ukraine, the government tried to shut-down the opposition TV channel. When protesters entered the police departments, they disconnected their phones and internet connections. Pro-Russian hacker groups– including, CyberBerkut and Cyber-riot-Novorisia– initiated denial of service attacks and stolen email from Ukrainian officials. Cyberwarfare was used by the Russians in their support of the insurrection in Donbass. Their forces would learn the identity of their opposing commanders and geo-locate their positions when they used their cell-phones. With those new and accurate coordinates, they would provide the coordinates to their air force and heavy artillery personnel, with devastating results. By Feb 22 2014, President Yanukovych felt the need to escape to Russia to seek asylum [32, 61-62]. In May 2014, Russian hackers attacked the Ukrainian

election commission during the Russian seizure of Crimea. In December 2015, Russian hackers used spearfishing with malware reportedly called "Black energy" to seize control of a Ukrainian power station, leaving more than a quarter million Ukrainian homes without power [47], [18]. The following year the Ukrainian power grid was attacked again. Since that time, Russia has reportedly targeted Ukrainian infrastructure with many new cyber attacks [53]. It is possible that many of the attacks on the Ukraine have derived from testing this hybrid warfare military strategy. Readers interested in this subject should consult the cited sources cited in the references for more fascinating details.

3.4 The 2009 Russian natural gas cut-off

The Great Global Recession emerged in the fall of 2008 in the United States, after the collapse of Lehman Brothers. Early signs of it appeared in Britain with a run on the Northern Rock bank in the previous autumn. By 2009, Eastern European countries wrote President Obama a letter to the effect that Russia was engaged in covert and overt war against those former Soviet countries that exhibited indications of independence. The covert measures generally preceded the overt ones. They included "energy blockades, politically motivated investments for bribery and media manipulation in order to advance its interests..." (opposing the transAtlantic orientation of Central and Eastern Europe) [10, 1-3]. Russia had covertly cultivated an opaque network of corrupt influence through which they sought to pursue their objectives of disrupting the potential democratic tendencies of wayward regimes.

When Putin applied his pressure on Ukraine again amidst these trying times, the pressure had a more devastating impact and context. Putin's three week gas cut-off to Ukraine in January, 2009 led to a closing of approximately 80% of Ukrainian factories [31], [37]. Under Putin, GazProm has been supporting political objectives. These actions were seen by some as a form of Russian natural gas diplomacy, while others throught it emerged from as a form of *hybrid warfare* stemming from *the Gerasimov doctrine of nonlinear warfare*. It may have been a hybrid product of these sources. We merely note their occurrence, amidst several other applications of gas cut-offs to other former USSR European countries, threatening them with energy insecurity. Even if this action might appear to be the pouring of salt into the open wound, the objective is merely to identify potentially confounding problems, and if possible, to circumvent the problems posed for researchers trying to analyze and understand the psychological and social impact of the Chornobyl nuclear disaster in the future. A complete explanation of what happened should not overlook these potential bases of Russian actions.

3.5 The 2014 natural gas cut-off

Although our study ends in 2009, later actions by Victor Yanukovych, after he was elected as prime minister in 2010, shed light on Russian hybrid war strategy based on earlier activities. When he failed to sign a trade agreement with the European Union in November of 2014, he proceeded in December of that year to conclude an agreement with Russia to buy $\$15\ billion$ of Ukrainian debt and to reduce the cost of gas by one-third. This reversal was very unpopular in Ukraine, after the Orange Revolution.. This betrayal of the

Ukrainian preference for alliance with Western Europe led to mass protests erupting in January and February in Independence square (Maidan). The pro-Russian position of Victor Yanukovych, led to protests leading to his ouster from power, confirmed by a unanimous vote of the Parliament in February 2014. After arranging some minor compromises with his opponents, he fled to Russia where he was granted refuge by Vladimir Putin. In February of 2014, Russia once again used the natural gas weapon against the Ukraine. Captain (USAF) Seth B. Neville indicates that this application was part of Russia hybrid warfare in Ukraine. Russia had begun to hold "snap" military exercises near the border, from which special forces without insignia (pretending to be indigenous volunteers) spearheaded an insurrection in the Eastern sector of Ukraine known as Donbass. By the time the Russian irregulars were eventually identified, they had seized and annexed airports, ports, and TV stations in Crimea. Under the pretense of a "local referendum," the insurrectionists gained control of Crimea, which Russia proceeded to annex. To counter International protest, Russians mounted a propaganda campaign against the ouster of Yanukovych by branding it as an attempt of a fascist coup [29, 1-4, 65-67]. Moreover, the propaganda claimed that the Russians were merely moving in troops to protect the Russian-speaking enclave in Ukraine and Crimea [29, 70-71]. Immediately, thereafter, Russian gas companies began complaining about late gas payments by Ukraine and, as they had previously, threatened to cut off the gas supplies to Ukraine again. The coincidental timing of this emerging dispute was not lost on the observers and deemed part of the full-spectrum of conflict applied.

4 Hypotheses

4.1 Hypotheses and their operationalized tests

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. Our response variables in these tests are the annual averages of gender-specific, self-reported psycho-social symptoms of depression, anxiety, and PTSD. Standardized scales of established measures could not be used because respondents could not recall specific answers to constituent items included in those scales. Because psycho-social depression and anxiety are so highly correlated with one another, we standardized gender-specific score, added them together, divided by two, and called the combined scale psychosocial distress. This became the first response variable of our endogenous time series.

The second general response time series was that of self-reported recollection of civilian PTSD. Annual averages of this score for males and females separately were constructed using the same computer science program.

It should be noted that we could not use standardized tests or scales because they included detailed questions that respondents could not remember over long-periods of time. We had to use this more representative recall of previous significant changes in condition or risk having no data at all. Even if our data reflected previous public opinion, it was worthwhile to have a historical record, for we could control with such a series for confounding phenomena in ways cross-sectional data would not permit. The value of psycho-social data is that it can have historical validity that remains useful for pubic health assessment. We

organized our questions in ways to facilitate recall of major events and scaled the ranges of response in percentage format.

When we combine depression and anxiety and call it psycho-social distress, we can test whether there was a significant rise in the values of the variables between the pre-collapse time span and the post-collapse time span. In other words, we use a step-indicator system dummy variable to indicate the post-collapse period as our independent variable. The model we use include both univariate and multivariate models to minimize endogeneity or simultaneity bias.

1) First, we use Hendry and Doornik's OxMetrics AutoMetrtics software to perform the tests. More specifically, we apply AutoMetrics SIS modeling to remove all non-significant outliers and level shifts representing this 1991 collapse [15, 220-234]. If there is a significant regime change in level of the series, then AutoMetrics SIS should select a step-shift indicator at the year, 1991 for each response variable. If it does not, we infer that there is no significant confounding of the outcome variables since the Chornobyl accident.

2) Second, we apply a level shift at 1991 to each of our models to determine whether there is a significant. Increase in our multivariate models at that time. If not, we infer no confounding regime change exists.

3) We apply Markov-switching regime change models to test for persistent changes of principal forms of psycho-social distress stemming from the collapse of the USSR. Finally, we test USSR collapse outliers and level shifts in dynamic simultaneous equation models for the positive impact of the collapse of the USSR and fine none.

5 Research strategy and methods

5.1 Research strategy

Our emphasis on a random sample of the populations of Kiev and Zhytomyr oblasts assured us of a representative sample of the population on which we could perform a statistical analysis. To perform these interviews, we undertook a retrospective interview with a variety of aides to facilitate reliable recall. To conduct these interviews we focused on psychologically significant events that respondents are likely to recall.

We sought to link the personal histories of the respondents to prominent events in the national history. We could not employ standardized tests for depression, anxiety, and civilian PTSD because these questionnaires generally contained items that referred to details in the respondents's life– for example, their tastes for different foods at particular times. We found that these details were the ones most likely to be forgotten by the respondents. We therefore asked the respondents to think of these symptoms on a percentage scale and to tell us only when they experienced a significant shift or change in this percentage scale. When these significant improvements or exacerbations occurred, we asked them to tell us from what level they changed to what level. With a computer program, we supplied the connecting levels between these crises or ameliorating events. The result was two time series—one for males and the other for females, for depression, anxiety, and civilian PTSD. We applied this same technique to several other variables with which we planned to analyze our key endogenous variables. A list of exogenous variables may be found in Appendix A.

Some variables were more the type that people do not think about every year. We could ask questions relating to these variables in a panel, comprising four waves: 1) Pre-Chornobyl accident (1980-1986), which we used as a baseline. 2) 1986 following the Chornobyl accident and its emergency evacuation from the exclusionary zone (30km from Chornobyl). 3) 1987 through 1996. 4)1997 till the time of their interview during the period of 2009-2011. Measures of external radiation were uniformly terminated in 2009. Hence, some of our variables are constant over these waves or periods.

Recognizing that any psycho-social analysis could be confounded by the intervention of external events, we circumnavigate these events by ceasing estimation prior to them and showing that the collapse of the U.S.S.R. does not significantly change our analysis.

We circumvent Putin's gas cut-offs to preclude confounding by ceasing the estimation of our model prior to the events of Putin's gas cut-offs by ceasing all estimation of our models prior to 2006. In this way, we avoid corruption of the internal validity of our estimation that may have come from any emotional reaction to Putin's gas shut-down.

We endeavor to test for the impact of the Collapse of the USSR hypothesis of BHG (2011) with GETS (general to specific variable selection) supplemented by testing of impulse indicator and step shift indicators (IIS-SIS) tests to determine whether there was a significant increase in any of the psychological symptom indicators by which we measured psycho-social depression, anxiety, or PTSD. We use dynamic simultaneous equation models (DSEM) testing of such indicators. models of external exposure Markov- switching regime change models [14, 38-52].

Because Geweke tests reveal instantaneous simultaneity We explore vicious cycles w.r.t. civilian PTSD as one of our key endogenous variables.

We generate modified scenario forecast psychosocial trajectories applying multivariate state space models. We evaluate our ex post and ex ante forecasts.

6 Research methods

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 Zhytomyr oblasts in Ukraine. This type of sampling optimally neutralizes selection bias.To minimize non-response in the event of no-answer, we used four callbacks at different times of day to minimize non-response bias. We also used an independent audit of the propriety of each interview before uploading data. We stripped all personal identifying information prior to ultimate statistical analysis. All models are gender specific to control for gender bias.

6.1 Scale construction

6.1.1 Depression plus anxiety becomes principal endogenous scale

A review of the endogenous series for male anxiety and depression, on the one hand, and female anxiety and depression, on the other, reveals how these two sets of series dovetail one another over time. If we examine the collapsed correlation between the two sets, we can see how highly correlated the red are blue time series and why are often deemed to be

Table 1: Time series correlations and α reliabilities (in red)

α reliabilities correlations	female anxiety	female depression	male anxiety	male depression
female anxiety	1.000	0.969		
fem depression	0.949	1.000		
male anxiety			1.000	0.975
male depression			0.943	1.000

co-morbid (Figures 8 and 9). We use these stylized facts as a basis for combining them into a single scale of psycho-social distress.

Because these series load highly on the same factor, we construct a psychosocial distress scale consisting of the average of standardized depression and anxiety. $fdepanx2 = (zfemdep + zfemanx)/2$ with Cronbach's α = 0.969 and $mdepanx2 = (zmaledep + zmaleanx)/2$ with a Cronbach's α = 0.975. While we combine these measures for the purpose of our analysis, we make no claim that these are official symptoms listed in the DSM. Hence, along with our psycho-social distress component, we model PTSD as a separate component at the same time in a multivariate model of these responses because all of these factors are highly inter-related. As for the exogenous time series that are tested as potentially predictive of the exogenous series, we find that the following time series for women and men turn out to be useful. We also use a Chornobyl dummy variable, coded 1 in 1986 and 0 otherwise. A first difference of this variable is also employed. We merely suggest that such an analysis could be very useful for emergency or post-disaster socio-medical analysis needs.

7 Time series plots of the endogenous series

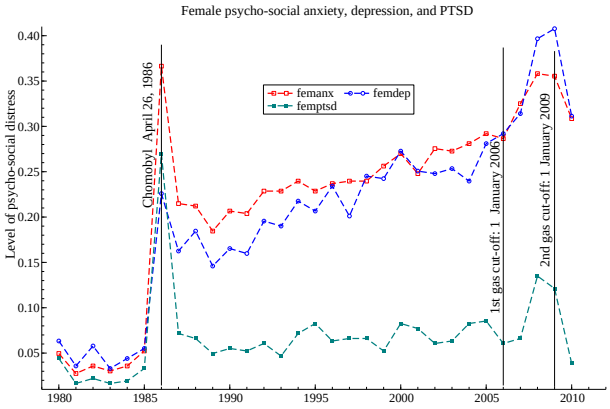


Figure 8: Female Endogenous series

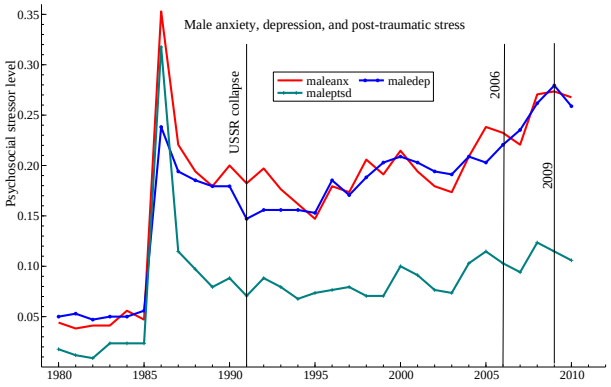


Figure 9: Male Endogenous series

8 Time series plots of transformed endogenous series

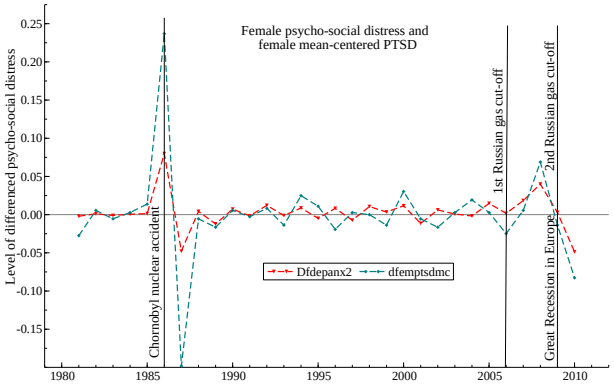


Figure 10: Transformed female Endogenous series

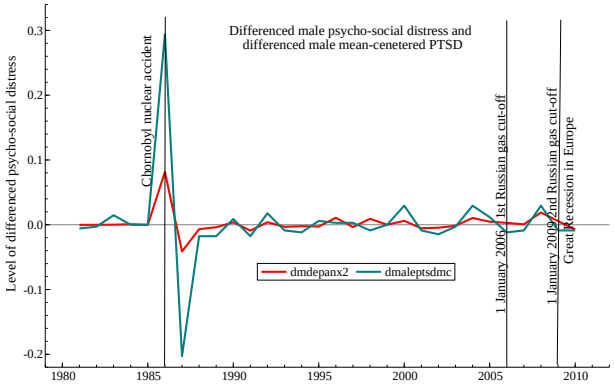


Figure 11: Transformed male endogenous series

9 Untransformed exogenous variables

- External exposure was reconstructed by Prof. Thomas B. Borak and Remi Frazier for each respondent depending upon a variety of factors relevant to the respondent's residential and work history. For details of their innovative procedure, see [51].
- Remi Frazier developed a method of replicating the ^{137}Cs from the Atlas of Cesium deposits developed by DeCort et al.

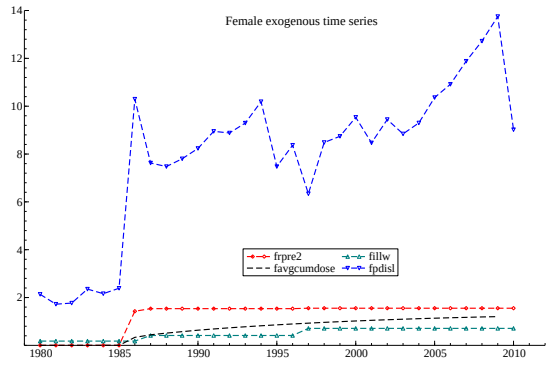


Figure 12: Female exogenous time series

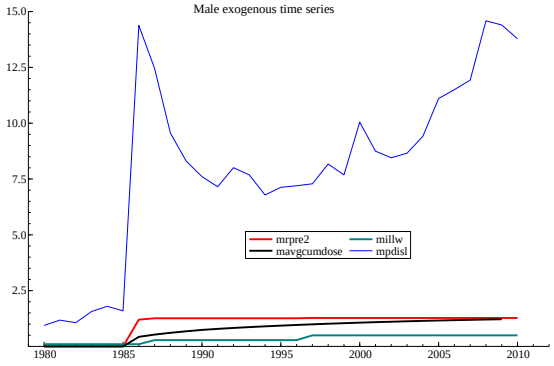


Figure 13: Male exogenous time series

- To render these time series covariance stationary, they were first differenced before being included in AutoMetrics time series regression models.

10 Statistical techniques

10.1 with Time series analysis

We test entanglement with several approaches to outlier analysis. We use AutoMetrics-SIS variable selection to test the selection of a USSR collapse dummy variable [23]. We use impulse indicator saturation to test whether there is an event in 1991 that needs fitting with regard to our symptoms. We use Markov-switching dynamic regression models to determine whether the collapse of USSR in 1991 generates a regime change [14].

$$Y_t = \nu(S_i) + \epsilon_t \;\; where\, S_i = state\, i,\; where\, i \;=\; 0, 1, 2, ... \tag{1}$$

11 Automatic selection of level shift in 1991 in AutoMetrics (SIS) models

Among the ways we test for a real regime change in 1991 is the use of the SIS selection option in AutoMetrics. AutoMetrics was used with the SIS option to identify any significant level shift, and the Step level shift variable was unrestricted so we could obtain precise parameter estimates of it in a univariate model. The general unrestricted model (GUM) for these test include a Chernobyl blip-dummy, its first difference, the first difference of perceived Chornobyl-related risk, a measure of the average number of physical illnesses per periods, as well as a measure of the first difference of the level of physical discomfort experienced.

Table 2 presents the AutoMetrics test results for the separate models tested. The test was conducted at the 0.01 target size level, based on the 1/k formula, where k refers to the number of variables applied by the model. The misspecification tests referred to the autocorrelation of the residual, the heteroscedasticity of the residuals, the heteroscedasticity of the residuals with interactions, the normality of the residuals, An ARCH test, and the Ramsey RESET test. Only if all tests were passed is the yes, entered Into the last column. In none of these cases does the model select the USSR collapse level shift as a necessary level shift indicator. Regardless of whether we set the target size at 0.05 or 0.01, we fail to require the inclusion of the USSR collapse level shift to fit the model.

Table 2: AutoMetrics Testing 1991 as a necessary level shift at a 0.05 target size

Outcome time series	ussr level shift b	std err	t-value	p-value	all misspec. tests ok
female depanxiety	0.003	0.002	1.75	0.09	AR 1-2 p=0.006**
female ptsd	0.006	0.006	1.12	0.275	AR 1-2 p=0.013*
male depanxiety	-0.0001	0.001	-0.106	0.917	yes
male ptsd	0.001	0.004	0.150	0.882	yes

The inference to be drawn is that in no case tested is the level shift at the time of the collapse of the USSR statistically significant. Above tests were performed with univariate time series as the single endogenous series. For each of the separate models for the two response series for each gender, there is no evidence of a significant decline in the BHG's (2011) hypothesis.

11.1 Geweke Tests indicate simultaneity between response and exogenous time series

We decide to test whether there is evidence of any simultaneity among our response and exogenous variables. We therefore employ Geweke tests to determine whether we have any evidence of simultaneity. in the output segments displayed in Figures 14 and 15, simultaneity is shown to exist between some of the variables used [16], [35, 1655-1675]. We also employ them because of the high intercorrelation among the endogenous variables and the equation errors.

Instantaneous feedback	Chi2	df	P-value
femptsd <-> dfrpre2	**63.7447**	**1**	**0.0000**
femptsd <-> ussrlev	**0.1858**	**1**	**0.6665**
femptsd <-> fillw	**0.1381**	**1**	**0.7102**
dfrpre2 <-> ussrlev	**0.3501**	**1**	**0.5541**
dfrpre2 <-> fillw	**0.1407**	**1**	**0.7076**
ussrlev <-> fillw	**0.0196**	**1**	**0.8887**

Figure 14: Geweke tests reveal simultaneity in female tests

Instantaneous feedback	Chi2	df	P-value
mdepanx2 <-> dmrpre2	**58.9609**	**1**	**0.0000**
mdepanx2 <-> ussrlev	**0.1657**	**1**	**0.6839**
mdepanx2 <-> millw	**0.0076**	**1**	**0.9306**
dmrpre2 <-> ussrlev	**0.0096**	**1**	**0.9219**
dmrpre2 <-> millw	**0.0213**	**1**	**0.8840**
ussrlev <-> millw	**0.9262**	**1**	**0.3359**

Figure 15: Geweke tests reveal simultaneity in male models

11.2 Tests in DSEM models reveal no regime shift at collapse of USSR

Because the above Geweke tests reveal reciprocal instantaneous correlation, we cannot be content with using Vector Autoregression. We employ dynamic simultaneous equation models (DSEM) to test a level shift in the response variables at 1991 to test the BHG entanglement hypothesis. The DSEM models allows us to deal with equations whose equation

Three-stage least-squares regression

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
dfdepanx2	**25**	**3**	**.2840236**	**0.7349**	**69.32**	**0.0000**
femptsd	**25**	**3**	**.0120172**	**0.9335**	**350.90**	**0.0000**

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
dfdepanx2						
dfrpre2	**1.709098**	**.212927**	**8.03**	**0.000**	**1.291769**	**2.126427**
ussrlev	**.3473368**	**.1786097**	**1.94**	**0.052**	**-.0027317**	**.6974053**
fillw	**-.4679804**	**.4268105**	**-1.10**	**0.273**	**-1.304514**	**.3685528**
_cons	**-.004805**	**.1538315**	**-0.03**	**0.975**	**-.3063093**	**.2966993**
femptsd						
dfrpre2	**.1682613**	**.0090091**	**18.68**	**0.000**	**.1506038**	**.1859187**
fillw	**.0590251**	**.0180586**	**3.27**	**0.001**	**.0236308**	**.0944193**
ussrlev	**.0124168**	**.0075571**	**1.64**	**0.100**	**-.0023948**	**.0272284**
_cons	**.0200416**	**.0065087**	**3.08**	**0.002**	**.0072848**	**.0327985**

Endogenous variables: dfdepanx2 femptsd
Exogenous variables: dfrpre2 ussrlev fillw

Figure 16: USSR collapse level shift tests reveal no regime change in 1991 in female models

errors may be correlated or whose multiple endogenous variables are correlated. To render these models covariance stationary, we first difference the depression/anxiety response variable in the simultaneous equation models [16], [35, 1655-1675]. For this reason, the response variable begins with a d indicating that the variable has been differenced. In Figures 16 and 17, the 1991 level shift dummy (testing regime change in level at the collapse of the USSR) is applied to both female and male models, respectively. Regardless of gender or the outcome variable, this 1991 level-shift indicator variable does not appear to be statistically significant. For this reason, we observe no empirical evidence of a average level of response variable is empirically linked to the psychosocial distress or civilian PTSD at the time of the collapse of the USSR. Hence, the evidence of inextricable entanglement is not consistent with our empirical findings.

Admittedly, BHG claimed that the entanglement may be subclinical. If this entanglement is not subsyndromal, it should be able to be detected by a statistically significant step-shift indicator variable, 'ussrlev.' The lack of statistical significance for this indicator is not sporadic or occasional. The lack of statistical significance of "ussrlev," is generally found to hold, regardless of the gender being tested.

```
. reg3(dmdepanx2 l.dmdepanx2 dmrpre2 ussrlev millw) ///
>     (dmaleptsd dmrpre2 millw ussrlev) if year < 2006   // ussrlev ns

Three-stage least-squares regression
```

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
dmdepanx2	24	4	.2268417	0.9063	245.98	0.0000
dmaleptsd	24	3	.0426456	0.6676	48.20	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
dmdepanx2						
dmdepanx2						
L1.	-.2254306	.0565423	-3.99	0.000	-.3362514	-.1146097
dmrpre2	2.857377	.1948408	14.67	0.000	2.475496	3.239258
ussrlev	.2062111	.1394079	1.48	0.139	-.0670234	.4794455
millw	-.1764415	.4532593	-0.39	0.697	-1.064813	.7119303
_cons	-.1017837	.11506	-0.88	0.376	-.3272972	.1237299
dmaleptsd						
dmrpre2	.2541406	.0384095	6.62	0.000	.1788594	.3294218
millw	-.0850915	.0882568	-0.96	0.335	-.2580717	.0878887
ussrlev	.0482735	.0270011	1.79	0.074	-.0046478	.1011947
_cons	-.0117384	.0226815	-0.52	0.605	-.0561933	.0327165

```
Endogenous variables:  dmdepanx2 dmaleptsd
Exogenous variables:   L.dmdepanx2 dmrpre2 ussrlev millw
```

Figure 17: USSR collapse level shift tests reveal no regime change in 1991 in male models

12 Markov-switching dynamic regression rejects USSR collapse as switching variable

We triangulate our findings with a Markov-Switching regime change models. These models contain a specified number of states. There are two natural states—-one before Chornobyl and one afterward. Our models with two states naturally converge. However, if we add two states, before and after the USSR collapse in 1991, they may not converge if the 1991 U.S.S.R. collapse does not define a structural break. If the model for three or four states does not converge, we do not consider the model valid. We use a dummy variable to test for a level switch at 1991. If the model does not converge with three or four states and if this dummy variable is not statistically significant, we infer that the model does not support the BHG hypothesis.

We use different structural change algorithms to look for a change in level, variance, or autoregressive conditional heteroscedasticity as a function of the collapse of the USSR in 1991. Finally, we examine structural change in the magnitude of the autoregressive parameters. Regardless of the criterion we use, we find no evidence in support of a 1991 structural increase in the psycho-social distress of the respondents. We proceed to test a model with three and four states— pre and post-Chornobyl as well as pre-and post-1991. We find that the models that test a structural change in 1991 with three or four states generally do not converge. We obtain the following results when testing the model with four states. In the Markov switching model tables below we use a "none" to indicate prob > 0.05 for the test of the 1991 level shift dummy.

Table 3: Testing 3 regime states in 1991 with fixed variance

Time series	model type	switching condition	number of states	ussr 1991 level shift sig	model convergence
female anxiety	dynamic regression	fixed variance	3	none	none
female depression	dynamic regression	fixed variance	3	none	none
female ptsd	dynamic regression	fixed variance	3	none	none
fdepanx2	dynamic regression	fixed variance	3	none	none
male anxiety	dynamic regression	fixed variance	3	none	none
male depression	dynamic regression	fixed variance	3	none	none
male ptsd	dynamic regression	fixed variance	3	none	none
mdepanx2	dynamic regression	fixed variance	3	none	none

12.1 Markov-switching dynamic regression rejects USSR collapse as switching variable with 4 states

As we attempt to find a model that converges to four states with a fixed variance, we find no retention of the 1991 level shift. Nor do we find that any of these dynamic regression models with four states converge.

Table 4: Testing regime change in 1991 with fixed variance

Time series	model type	switching condition	number of states	ussr 1991 level shift sig	model convergence
female anxiety	dynamic regression	fixed variance	4	none	none
female depression	dynamic regression	fixed variance	4	none	none
female ptsd	dynamic regression	fixed variance	4	none	none
fdepanx2	dynamic regression	fixed variance	4	none	none
male anxiety	dynamic regression	fixed variance	4	none	none
male depression	dynamic regression	fixed variance	4	none	none
male ptsd	dynamic regression	fixed variance	4	none	none
mdepanx2	dynamic regression	fixed variance	4	none	none

Although some of the models with a switching variance converge, we find no evidence of support for a significant 1991 level shift when the U.S.S.R. collapsed even when the models converge. Without both the significant 1991 level shift and convergence, there is no conclusive evidence consistent with the BHG hypothesis.

12.2 Markov-switching dynamic regression rejects USSR collapse as switching variable with 3 states

Table 5: Testing regime change in 1991 with switching variance

Time series	model type	switching condition	number of states	ussr 1991 level shift sig	model convergence
female anxiety	dynamic regression	switching variance	3	none	converged
female depression	dynamic regression	switching variance	3	none	none
female ptsd	dynamic regression	switching variance	3	none	none
fdepanx2	dynamic regression	switching variance	3	none	none
male anxiety	dynamic regression	switching variance	3	none	converged
male depression	dynamic regression	switching variance	3	none	none
male ptsd	dynamic regression	switching variance	3	none	none
mdepanx2	dynamic regression	switching variance	3	none	none

12.3 Markov-switching dynamic regression rejects USSR collapse as switching variable with 4 states

Table 6: Testing regime change in 1991 with switching variance with four possible states

Time series	model type	switching condition	number of states	ussr 1991 level shift sig	model convergence
female anxiety	dynamic regression	switching variance	4	none	converged
female depression	dynamic regression	switching variance	4	. none	converged
female ptsd	dynamic regression	switching variance	4	none	converged
fdepanx2	dynamic regression	switching variance	4	none	converged
male anxiety	dynamic regression	switching variance	4	none	converged
male depression	dynamic regression	switching variance	4	none	converged
male ptsdmc	dynamic regression	switching variance	4	none	none
mdepanx2	dynamic regression	switching variance	4	none	none

A similar situation prevails in the case of switching GARCH models: Whether there are three or four states in the model, we find no evidence to support a significant level shift at 1991 when the U.S.S.R. collapsed.

12.4 Markov-switching dynamic regression rejects USSR collapse as switching variable with 3 states

Table 7: Testing regime change in 1991 with switching generalized conditional autoregressive heteroscedasticity (GARCH)

Time series	model type	switching condition	number of states	ussr 1991 level shift sig	model convergence
female anxiety	dynamic regression	switching GARCH	3	none	none
female depression	dynamic regression	switching GARCH	3	none	none
female ptsd	dynamic regression	switching GARCH	3	none	none
fdepanx2	dynamic regression	switching GARCH	3	none	none
male anxiety	dynamic regression	switching GARCH	3	none	none
male depression	dynamic regression	switching GARCH	3	none	none
maleptsdmc	dynamic regression	switching GARCH	3	none	none
mdepanx2	dynamic regression	switching GARCH	3	none	none

12.5 Markov-switching dynamic regression rejects USSR collapse as switching variable with 4 states

Table 8: Testing regime change in 1991 with switching generalized conditional autoregressive heteroscedasticity (GARCH)

Time series	model type	switching condition	number of states	ussr 1991 level shift sig	model convergence
female anxiety	dynamic regression	switching GARCH	4	none	none
female depression	dynamic regression	switching GARCH	4	none	none
female ptsd	dynamic regression	switching GARCH	4	none	none
fdepanx2	dynamic regression	switching GARCH	4	none	none
male anxiety	dynamic regression	switching GARCH	4	none	none
male depression	dynamic regression	switching GARCH	4	none	none
maleptsdmc	dynamic regression	switching GARCH	4	none	none
mdepanx2	dynamic regression	switching GARCH	4	none	none

12.6 Markov-switching ARMA model rejects USSR collapse as switching variable with 3 states

Table 9: Testing regime change in 1991 with switching AR coefficients with 3 states and fixed variance

Time series	model type	switching condition	number of states	ussr 1991 level shift sig	model convergence
female anxiety	switching ARMA	AR coef	3	none	none
female depression	switching ARMA	AR coef	3	none	none
female ptsd	switching ARMA	AR coef	3	none	none
fdepanx2	switching ARMA	AR coef	3	none	none
male anxiety	switching ARMA	AR coef	3	none	none
male depression	switching ARMA	AR coef	3	none	none
maleptsdmc	switching ARMA	AR coef	3	none	none
mdepanx2	switching ARMA	AR coef	3	none	none

12.7 Markov-switching ARMA model rejects USSR collapse as switching variable with 4 states

Table 10: Testing regime change in 1991 with switching AR coefficients with 4 states and fixed variance

Time series	model type	switching condition	number of states	ussr 1991 level shift sig	model convergence
female anxiety	switching ARMA	AR coef	4	none	none
female depression	switching ARMA	AR coef	4	none	none
female ptsd	switching ARMA	AR coef	4	none	none
fdepanx2	switching ARMA	AR coef	4	none	none
male anxiety	switching ARMA	AR coef	4	none	none
male depression	switching ARMA	AR coef	4	none	none
maleptsdmc	switching ARMA	AR coef	4	none	none
mdepanx2	Switching ARMA	AR coef	4	none	none

The Markov-Switching regime change models were all executed with random starting values to optimize the probability of the model converging. Above tests were performed with time series that can be jointly modeled with a multivariate state space model. Nevertheless, the findings are not consistent with the BHG entanglement hypothesis. Our multi-metthod tests do not provide empirically evidence for the BHG hypothesis. The implication is that our findings are consistent with the lack of a confounding of our response

variables from a significantly positive regime shift at 1991 when the U.S.S.R. collapsed Zhytomyr in the level, variance, or magnitude of the our psycho-social distress or post-traumatic distress syndrome time series.

13 Forecasting

13.1 Multivariate state space common local level model

13.2 Two multivariate state space models were developed

State space model have advantages over Box Jenkins models. We can use variables with different sampling frequencies because we are estimating a latent local level rather than the observed variable, alone. We can model untransformed variables with State space models [25], [7]. When we discover that the dependent variables are highly correlated, we can model psychosocial distress and post-traumatic stress in a multivariate model with a common local level. When we discovered that the dependent variables in both male and female models, we formed such a model for both males and females. In our models civilian PTSD is dependent on our Psychosocial distress scale (Depression/anxiety). A multivariate state space model for females with common levels. The female measurement model Y = trend + irregular + explanatory variables + interventions. A multivariate state space model for males with common levels and slopes. The male measurement model Y = level + slope + irregular + explanatory variables + interventions [7].

14 State space model equations

14.1 measurement and transition equations

In univariate state space equations, the transition equation is

$$\mu_{t+1} = \mu_t + \eta_t \;\; \eta_t \sim NID(0, \sigma_\eta^2) \tag{2}$$

and the measurement equation is

$$y = \mu_t + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{i=1}^{k} B_i x_{t-i} + \sum_{j=1}^{h} \omega_{j,t} I_t + \epsilon_t \;\; \epsilon_t \sim NID(0, \sigma_\epsilon^2) \tag{3}$$

where μ_t = trend, η_t = the innovation of the transition equation, y = an observed vector variables, x_{it} = an exogenous variable, I_t = an intervention blip or level shift, ϵ_t = a measurement error vector. $\phi_i,\ B_i, and\ \omega_{j,t}$ are unknown parameters to be estimated, with $cov(\eta_t, \epsilon_t)$ = 0.

15 Multivariate common local level state space models

μ_t is now a state vector comprising psycho-socical distress and post-traumatic stress The transition equation is

$$\mu_{\mathbf{t+1}} = \mu_{\mathbf{t}} + \eta_{\mathbf{t}} \quad \eta_{\mathbf{t}} \sim \mathbf{NID}(\mathbf{0}, \sum_{\eta}) \tag{4}$$

and the measurement equation is

$$\mathbf{y_t} = \mu_{\mathbf{t}} + \epsilon_{\mathbf{t}} \;\; \epsilon_{\mathbf{t}} \sim \mathbf{NID}(\mathbf{0}, \sum_{\epsilon}) \tag{5}$$

where $\sum_{\eta}$ and $\sum_{\epsilon}$ are both NxN variance matrices, such that they are uncorrelated with one another at all time periods.

16 Dynamic common factor factors

Our models reveal a common local level. They are of less than full rank. When r of the components of highly correlated, and the $rank(\sum_c) = r < p$, where p = the number of variables, the r components can be expressed in terms of their c common factors, such that

$$\sum_c = A \sum_c A' \tag{6}$$

where A is an r x r factor loading matrix and $\sum_c$ is a p x r matrix.

By allowing some elements of the covariance matrices to be dependent on others, we can specify common trends in multivariate matrices. Our models have only one level factor, so we allow the ptsd to be dependent on the depanx2 scale [25, 171]. We specify ones in the principle diagonal of the level covariance matrix. In general, these models fit well and converge strongly to a steady state. The level variance consists of one common factor, for male and female models, explaining 100% of the variance. The female psycho-social distress eigenvalue comprises 87% and female PTSD eigenvalue comprises 13% of the explained variance. The male error variance is almost 100% due to the psycho-social distress. However, we will discuss that model after we elaborate on the female model. While this summarizes the structure of the level variance, the parameter estimates of the models are given below.

17 Female measurement model parameter estimates

We begin with a presentation of the female psychosocial distress factor, which combines the anxiety and depression the women. The model fit for both equations is very high as can be observed from the Rd^2, which Prof. Andrew C. Harvey defines as

$$Rd^2 = 1 - \frac{SEE}{\sum_{t=1}^{T} (\Delta y - \overline{\Delta y})^2}$$

where SEE = the sum of squared errors and the denominator is the sum of squared mean deviation of first differences [21, 268]. For the female model, $Rd^2_{fdepanx2} = 0.919 \; and \; Rd^2_{femptsd} = 0.974$. Pre-eminently, the reaction to Chornobyl and the response to it are the driving factors inhere in the prediction of psychosocial distress and female civilian PTSD. The female models supported no significant level breaks at 1991.

Table 11: Equation fdepanx2: regression effects in final state at time 2005

	Coefficient	RMSE	t-value	Prob
chornblip 1986	0.049	0.006	7.976	[0.000]
Level Break 1998	0.015	0.004	4.018	[0.001]
frepre2	0.022	0.005	4.793	[0.000]

The parameter estimates in the psychosocial distress parameter vector comprise two structural breaks and one perceived Chornobyl related risk exposure. All of these coefficients are positive and significant. The first parameter is a blip outlier at the time of the Chornobyl accident. This has the largest coefficient at 0.049. The second largest parameter vector is that of have female perceived Chornobyl related radiation risk. Finally, we have a level shift at 1998. In July 1998, Ukraine went into a financial crisis when $1 billion in bond payments came due and Parliament failed to take austerity measures [45, A23.]. In September of 1998, Ukraine arranged for a $2.2 billion IMF loan and announced a currency devaluation for the hryvnia to between 2.5 and 3.5 to the dollar [46, A1.].

In this case, we have a mean-centered version of female civilian PTSD as the endogenous variable.

Table 12: Equation femptsdmc: regression effects in final state at time 2005

	Coefficient	RMSE	t-value	Prob
chornblip	0.216	0.011	18.901	[0.000]
frepre2	0.095	0.005	3.575	[0.016]

To show that these models fit well, we present the model fit plots in

18 Male measurement model parameter estimates

The goodness of fit Rd^2 for the male models were also very good with $Rd^2_{mdepanx2} = 0.968$ and $Rd^2 maleptsd = 0.945$. While this model supported exhibited some common level shifts, none of them began or ended at the time of collapse of the U.S.S.R. in 1991.

Table 13: Equation mdepanx2: regression effects in final state at time 2005

	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)	0.006	0.003	2.175	[0.043]
Level break 2004(1)	0.012	0.003	3.554	[0.002]
chornblip	0.049	0.004	13.585	[0.000]
mrpre2	0.029	0.003	9.429	[0.000]

Table 14: Equation maleptsdmc: regression effects in final state at time 2005

	Coefficient	RMSE	t-value	Prob
Level break 2004(1)	0.034	0.009	4.022	[0.001]
chornblip	0.230	0.011	20.638	[0.000]
mrpre2	0.059	0.005	11.804	[0.000]

Neither male nor female model exhibits any statistically significant level shift circa 1991, for which reason we find no empirical evidence to support the BHG inextricable entanglement hypothesis. Without overt evidence of such entanglement, there is either no such entanglement or any entanglement would have to be subsyndromal or latent. Our reduced rank models suggest a one or two factor solution in which these three response time series are highly interrelated. For this reason, we use the multivariate state space with common local levels as models of the psycho-social sequelae.

18.1 Model fit plots

Figure 18: Female multivariate model fit

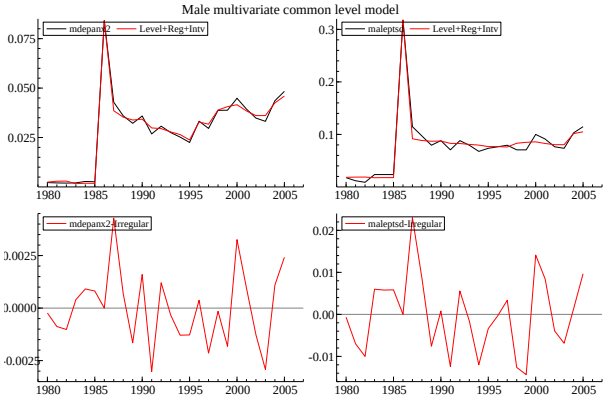


Figure 19: Male multivariate model fit

19 Model forecast plots

Figure 20: Female multivariate model forecast

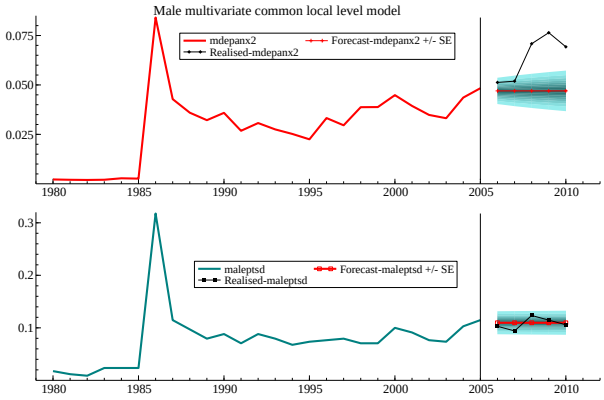


Figure 21: Male multivariate model forecast

20 Ex post forecast evaluations

We can evaluate our forecast accuracy within a test segment of our data. We use the last 8 or 7 observations for this purpose. If our estimation is within normal parameters, there should not be a statistically significant different between our estimates and the actual data within this segment. From the results below, we find that this condition holds.

20.1 female models

An *ex post* forecast evaluation over the last eight observations up through year 2005 reveals a very good forecast accuracy for both psychosocial distress and psychosocial civilian PTSD among the women inasmuch as there is no significant difference between the actual and the forecast over this horizon, as indicated by the χ^2 and Cusum tests, below.

Table 15: Ex post forecast evaluations: fdepanx2

Test type		statistic	p-value
Failure $\chi^2(7)$	test is	10.228	[0.176]
Cusum t(7)	test is	1.655	[0.142]

Table 16: Ex post femptsdmc forecast evaluations: femptsdmc

Test type		statistic	p-value
Failure $\chi^2(7)$	test is	7.443	[0.384]
Cusum $t(7)$	test is	0.274	[0.804]

20.2 male models

The male models exhibit a similar high level of accuracy. The *ex post* forecast evaluations over the last six observations of the sample through the year 2005 reveal no statistically significant difference between the forecast. and actual value of the observations within that horizon.

Table 17: Male post-sample forecast evaluations: Eq. mdepanx2:

Test type		statistic	p-value
Failure $\chi^2(6)$	test is	3.442	[0.752]
Cusum $t(6)$	test is	0.428	[0.684]

Table 18: Male model post-sample tests for equations: Eq. maleptsdmc:

Test type		statistic	p-value
$\chi^2(6)$	test is	6.546	[0.365]
Cusum $t(6)$	test is	1.379	[0.217]

21 *Ex ante* forecast evaluation

21.1 Female models

When we forecast beyond the end of the data— that is, beyond 2005, we obtain the *ex ante* forecast. We provide the forecast, its standard error, and the error of the forecast. To assess the forecast over the last five years of the data, we also use the root mean squared error (RMSE), the root mean square prediction error (RMSPE), the mean absolute error (MAE), and the mean absolute percentage error (MAPE). The forecast accuracy beyond the end of the data in 2005 is not as accurate as the preceding set of *ex post* sample forecasts. Nonetheless, it is respectably small for forecasts of that type for both Ukrainian males and females. When we examine the miniscule magnitude of the forecast error, MAPEs of 29.631% for the female depression/anxiety distress do not appear to be too far off the mark. Because it is within this forecast horizon that external events – such as, the gas cut-offs and later the Great Recession– took place that we expect less accuracy within this period of time. Therefore, this period can be examined as a benchmark of what might have been had all other things remained the same. We were forced to forecast over this period because of our discovery of those external events that could have undermined the internal validity by confounding our endogenous variables had we not ceased our estimation in 2005 before those potentially confounding events took place.

Table 19: Eq: fdepanx2: forecast accuracy measures from 2005 onward

Year	Forecast	Forecast error	Std. Error	RMSE	RMSPE	MAE	MAPE
2006	0.076	-0.001	0.006	0.007	0.877	0.007	8.774
2007	0.076	-0.026	0.007	0.019	1.889	0.017	17.007
2008	0.076	-0.066	0.008	0.041	3.085	0.033	26.764
2009	0.076	-0.069	0.009	0.049	3.569	0.042	31.904
2010	0.076	-0.020	0.010	0.045	3.322	0.037	29.631

Given the very small forecast errors that stem from mean centering of the female PTSD levels, the MAPE tends to be greatly inflated. Therefore, we should not be too surprised when we observe small forecast errors coupled with grossly inflated MAPEs for the female PTSD scores. Hence we find MAPEs ranging from 286 to 605 %, with the largest MAPE associated with the smallest forecast error. To compensate for the scale dependency, which allows small values in the errors to inflate the computed MAPE, we compute the symmetric MAPE (SMAPE) for this 5 period horizon. In so doing, we use the following formula:

$$SMAPE = \frac{100}{h} * \sum_{h=1}^{H} \frac{|Forecast - Actual|}{|Forecast + Actual|} \tag{7}$$

where h = length of forecast horizon, H = final period of forecast horizon (5 years). For

the female fdepanx2 forecast, the SMAPE = 18.316%, whereas the SMAPE for the female PTSD *ex ante* forecast = 19.008%.

Table 20: Eq: femptsdmc: forecast accuracy measures from 2005 onward

Year	Forecast	Forecast error	Std. Error	RMSE	RMSPE	MAE	MAPE
2006	0.013	0.020	0.012	0.020	28.554	0.020	285.540
2007	0.013	0.015	0.012	0.018	68.427	0.018	605.080
2008	0.013	-0.054	0.013	0.034	56.063	0.030	430.184
2009	0.013	-0.040	0.013	0.036	48.698	0.032	341.474
2010	0.013	0.042	0.014	0.037	44.038	0.034	302.239

22 *Ex ante* forecast evaluation

22.1 male models

The male models generally exhibit even tighter confidence boundaries than those of the women, especially with respect to the PTSDels, regardless of the scale dependence of the MAPE measure based on a more minute baseline at the lower levels of the scale. The reason that the mean absolute percentage error (MAPE) criterion is as large as it is stems from its own scale dependence. When the differences between the actual and the forecast is compared to a tiny measure in the denominator leads to relative inflation of the MAPE. For example, if the difference between the forecast and the actual is merely one unit off, an error of two in the forecast horizon is an error of 100%. This defect of scale dependency requires that we try to make an adjustment for assessments at a small scale. To make these adjustments, we will soon introduce a symmetric MAPE (SMAPE) that attempts compensate for the scale dependence of the regular MAPE. Nonetheless, even these forecasts are exceptional given these data.

Table 21: Eq: mdepanx2: forecast accuracy measures from 2005 forwards:

Year	Forecast	Forecast Error	Std. Error	RMSE	RMSPE	MAE	MAPE
2006	0.047	-0.004	0.004	-0.004	0.822	0.004	8.218
2007	0.047	-0.005	0.005	-0.005	0.881	0.005	8.792
2008	0.047	-0.024	0.005	-0.024	2.068	0.011	17.056
2009	0.047	-0.029	. 0.006	-0.029	2.627	0.016	22.404
2010	0.047	-0.022	0.006	0.020	2.754	0.017	24.342

The male depression/anxiety psychosocial distress exhibits a SMAPE = 77.977%, whereas the SMAPE for the male PTSD forecast is 6.737%. As long as we keep in mind that the very tiny errors tend to generate these larger percentage errors in the MAPE , we can understand why the symmetric measures are as large as they are. Although the SMAPE attempts to correct for low-end scale dependency, larger values may stem in the fdepanx2 and mdepanx2 from the anxiety/depression responses to the natural gas cut-offs and the Great Recession.

Table 22: Eq: maleptsdmc: forecast accuracy measures from 2005 forwards for males are very good:

Year	Forecast	Forecast Error	Std. Error	RMSE	RMSPE	MAE	MAPE
2006	0.027	0.007	0.013	0.007	3.537	0.007	35.373
2007	0.027	0.016	0.013	0.012	10.609	0.011	90.591
2008	0.027	-0.014	0.014	0.013	8.881	0.012	71.697
2009	0.027	-0.005	0.014	0.011	7.729	0.010	57.608
2010	0.027	0.004	0.014	0.010	6.959	0.009	49.634

23 Implications

23.1 What we did that was new

We focus our attention on the general population in the Ukrainian oblasts of Kiev and Zhytomyr. Our random selection of telephone numbers provided a representative sample of public opinion of residents of the Ukrainian regions most impacted by the Chornobyl nuclear accident. We did not specifically focus on the fire-fighters, helicopter pilots, active and reserve armed service personnel who served as liquidators (clean-up workers). Nor do we deny that many liquidators experienced acute radiation exposure, sickness, and death. Although we were unable to use standardized scales because they contained specific items that people could not recall so many years later, we did use self-reported endogenous variables of very high reliability that were representative of Ukrainian beliefs and emotions at the time referenced (see section 6.1.1 and Table 1). This enabled us to provide a valid assessment of the Ukrainian public attitudes in Kiev and Zhytomyr oblasts after this tragedy. Our empirical findings are important in that they empirically show that the general population appears to have largely escaped significant biologically reactive levels of radiation exposure, and that any effects experienced are in general psycho-social. This can be a very liberating and enlightening fact when recognized and accepted by the public at large. It can also be used as a template for emergency socio-medical assessment of trauma following a nuclear accident.

We applied structural time series models to overcome problems that confound cross-sectional analysis in a retrospective study of the psychosocial sequelae of the Chornobyl nuclear accident. We do this for two principle reasons. We are using data with different sampling frequencies, and the lengths of our time series were not long; they were short. We are aware that state space models have been used to estimate a latent local levels rather than merely the observed variables sampled at different frequencies [9]. The smoothing algorithms become very useful in this connection. We were also aware that they had been applied to panel data analysis under such circumstances. To our knowledge, structural time series analysis has not previously been applied to the analysis of Chornobyl psychosocial sequelae.

We do confirm that the primary driver of the psycho-social effects experienced after the Chornobyl accident are indeed *perceived* Chornobyl related risk of radiation exposure. We find that this perceptual variable appears to be significant in both male and female models of psycho-social as well as post-traumatic distress (shown in above sections 17 and 18). This finding was expected in the UNSCEAR and WHO reports for those whose lives were impacted by the Chornobyl nuclear accident(cited in section 2.1). We also note that the reconstructed cumulative average of external exposure drops out of the parameter vectors displayed in Tables 11 through 14 above. In sum, we empirically show that the dominant effects on the general public appear to be psycho-social in nature.

With OxMetrics time series regression models, we test the BHG (2011) hypothesis of inextricable entanglement of USSR collapse with our key psychosocial measures: psycho-social depression/anxiety and post-traumatic stress. First, we employ AutoMetrics with step indicator saturation (SIS) to test whether step-indicator systematic testing confirms existence of a 1991 level shift upward in our response or outcome variables. We find simul-

taneity in these models because the errors of the equations and the endogenous variables are highly correlated. To control for simultaneity, we test USSR collapse indicators in dynamic simultaneous equations. However, we find no evidence of significance of the USSR collapse indicators at the $p < 0.05$ level. As an additional check for regime change beginning at 1991, we retest this hypothesis with Markov-switching dynamic regression models. using our principal endogenous time series models. The test results show no evidence that the collapse of the USSR was inextricably entangled with the fall of the U.S.S.R, and that we need to introduce a level shift indicator in 1991 to control for this effect.. By testing this hypothesis with different algorithms, we find methodological confirmation that there the lack of a structural break indicator in 1991 would fail to control for a potentially confounding effect. Thus, we appear to be controlling for all significant structural breaks and can infer that there is no corruption of the internal validity of our model by confounding impacts of external events.

More specifically, to be sure that the collapse of the U.S.S.R. did not confound our series, we subjected our principal response series to tests for parameter stability with three different statistical techniques. With AutoMetrics, we tested our models for fulfillment of the model assumptions underlying their congruency with statistical theory: linear functional form, residual normality, homoscedasticity, and white noise. The models fulfilled these assumptions. But we chose the option that included Step-Indicator Saturation (SIS). This protocol saturates the model with all possible step-indicators and removes all those level-shifts that are not statistically significant. With the dynamic simultaneous equations (DSEM), models were use d to accommodate the correlated endogenous time series used in our models. They were identified as the order and rank conditions were fulfilled with reasonably well behaved residuals. The anxiety and depression time series were combined and exhibited more residual volatility than the civilian PTSD series. While the order condition needs to be fulfilled for there to be enough variables to uniquely identify the equations, it is not sufficient for identification. The order condition is enforced by the program (both in Stata and OxMetrics). Fulfillment of the rank condition assured linear independence of the equations [16, 75,181,232]. To assure covariance stationarity for the DSEM, we had to first difference the response variables combining anxiety and depression within each gender. We also used Markov-switching dynamic regression and parameter switching ARMA models for regime-change to test the retention of a level-shift variable at 1991, the time of the collapse of the U.S.S.R.. These models were tested according to whether they converged when allowing for more than two states (pre-and-post Chornobyl accident). We tested the models for converge with three or four states as well as whether the 1991 level shift was indicated as statistically significant in any of these models. Our criteria were whether the model converged with a significant increase in level of our key endogenous variables. Both convergence and a non-significant 1991 level shift were required for the test to be deemed completed.

Upon identifying potentially confounding events that could significantly impact our response series, near the end of those series, we take measures to neutralize those end-effects. Pre-eminent among these events were natural gas energy cut-offs, later identified as part of Russian coercive petrol-power diplomacy or a diplomatic dimension of hybrid warfare in January of 2006 and 2009, that Russia was inclined to apply to former peripheral U.S.S.R. countries that manifested too much independence or Western-leaning tendencies,

for which previous studies failed to take into account. If we model these response series observe all the way to 2010, we can observe the impacts of these events in the form of spikes or level-shifts in the mean-level near the end of those series. We avert potentially confounding impacts by estimating only prior to the instance of the first natural gas cut-off event in January 2006. We end our estimation at the end of 2005, and forecast over the remaining part of the series (up through 2010), which prevents corruption of our estimation process by the impacts on psycho-social and post-traumatic distress of Russian gas-cut-offs in January of 2006 and 2009 along with the impact of the Great Recession from 2008-2010. The forecast over 2006 though 2010 provides us a baseline level of what might have been had there been no change in the environment over that forecast horizon.

Although BHG indicated that the entanglement was probably sub-clinical, we were hoping to discover that it was not subsyndromal with our time series models. With no empirical evidence for such psychological regime change at the time of 1991, their hypothesis appears to be inconsistent with our data. The implication seems to be that if such entanglement exists it must be unobservable and unmeasurable by these data. If such empirical entanglement does not exist, it should not pose a challenge to the validity of our self-reported measures.

23.2 Controlling for bias

We went to great length to control for bias. We randomly selected respondents to avoid selection bias. To counter nonresponse bias, we had four call-backs for each respondent.We stratify by gender to avoid sex bias. All analyses are conducted with gender-specific analysis. When we had to use a time series, it was short so we used small sample corrections for it. Early termination of estimation limits our power and renders our model vulnerable to small sample bias. We model them or circumvent them by early termination of estimation. To counter interpretation bias, we did back-translation verification. We took special steps to minimize recall bias, though it may not have been completely eliminated. Special mnemonic measures were applied to perform this analysis. To minimize specification error, we test for impacts of major political and economic events. We test for and model significant outliers and level shifts. We even test them with Step and Level Indicator Saturation. We therefore base conclusions on trimmed models to conserve statistical power of the mode. We apply a symmetric MAPE to compensate for low-end scale dependency in the forecast evaluation criterion. We also have to test for misspecification of the models to assure congruency with statical theory.

23.3 Potential applications in Public health planning for post-disaster mitigation

Timely and reliable information dissemination in the event of a disaster is of utmost importance. Trust in government is necessary. We have demonstrated a method for performing a retrospective post-disaster analysis after there may have been intervening and confounding events near the end of the series. The method can be applied when the disaster has taken place 25 or more years before, even if there may have been some potentially confounding events near the end of the time series devised. We have been able to predict with reasonable

accuracy the incidence of civilian PTSD developed after perceived exposure to the disaster. We find that fear of being exposed is a significantly strong driver of the psycho-social and post-traumatic distress [50] These methods were employed after our discovery of the potentially confounding events of Russian gas cut-offs in 2006 and 2009, and their impact on the energy and economic security of Ukraine. We hope these methods may be applied for post-disaster psychological assessment under similar circumstances.

23.4 Limitations

We have a short time series and need to correct for it. AutoMetrics employs general-to-specific (GETS) modeling for variable selection in the model building process. However, AutoMetrics can handle datasets with more variables than observations. We use only full time series for dynamic simultaneous equation methods(DSEM) to accommodate the simultaneity among the variables identified by the Geweke (1982) tests . We had to perform a lot of misspecification tests of our univariate and multivariate models. Our dataset contains variables that were sampled at different frequencies. Fortunately, we had use of an excellent State Space Package, STAMP 7.1, developed by Koopman, Harvey, Shephard, and Doornik, which could be used to analyze such data.

The structural breaks that took place in the forecast horizon may not have been averted had they taken place much before the *ex post* forecast. We were able to avert confounding of our endogenous variables by ceasing estimation before the 2006 gas-cut off, and therefore the 2009 gas cut-off and the Great Recession. However, without anticipation of these events, there were not enough break drivers in our dataset to predict these breaks [8, 1-3].

23.5 Generalizability

Because we have a random sample, we may generalize to the population of the Kiev and Zhytomyr Oblasts in which sampling was performed. This is the best defense against selection bias. We do not find that the end of the Soviet Union is inextricably entangled with our structural time series analysis and therefore does not the collapse of the U.S.S.R. does not appear to undermine the internal validity of our analysis. Regardless of the fact that standardized scales are not amenable to long-term retrospective studies, we have found a way of resurrecting valid public opinion applicable in emergency socio-medical analysis. Using these techniques, we hoped to overcome the challenges we encountered in our pursuit of valid and reliable knowledge. The sampling method assures the model of external validity within the boundaries of the target Oblasts based on our representative sample conducted between 2009 and 2011.

Discussion of the rationale behind the Russian gas-price manipulation is important for several reasons. If we understand what drives the Russian gas price increases, perhaps we can anticipate them in the future. If we recognize that gas price increases depend on Russian foreign policy interests, we can include variables relating to their incidence. When former Soviet states lean toward joining NATO, Russia perceives this as a threat to its strategic national interest. To deter such alliance membership, Russia might squabble over gas prices, payments of gas supplies, flow, resulting in diversions, constrictions, disruptions, or even shut-offs. If border areas, such as Crimea or Donbass, contain gas supplies

or even a coveted warm-water port, that area might become subject to domestic unrest or even demands for secession. As was the case in Crimea, where the Russian navy leased its only warm-water port at Sevastopol, the territory was annexed in March 2014, violating Russia's previous commitments to protect Ukrainian sovereignty, independence, and territorial integrity that were part of the 1994 Budapest Memorandum. If these issues are not effective in bring about the desired objectives, Russia might also engage in cyberattacks or other hybrid warfare activities.

As for predicting a Great Recession, researchers would have to collect data, assuming these data were available, on "sub-prime loans, moral-hazard driven risk-taking, high leverage, increasing unsecured credit outstanding, growing income inequality, " increasing systemic risk, etc., It is likely that repeal or weakening of regulations imposed by the Dodd-Frank Act and the rulings of the Consumer Financial Protection Board would weaken safeguards against systemic risk and increase the likelihood of a recurrence of the Great Recession. If these variables were included in the dataset, researchers might be able to construct models to analytically predict a recession or its combined effects from the study [8]. Unfortunately, they were not included in our dataset.

23.6 Predictive validity

Our ability to test our models sheds some light on their predictive validity. The models appear to provide a modicum of that as a benchmark for what could be expected under *ceteris paribus* assumptions. Under some circumstances, *ceteris paribus* is more likely than others. We can test our models for predictive validity before the end of the data, as we do with our *ex post* forecast evaluations. We can also assess the forecast validity after the end of the estimation in 2005. The January 2006 gas cut-off occurred amidst a Russian demand for quadruple the previous prices. While the Russians claimed to be merely adhering wanting to be paid for an accumulated debt and to rely more on the market prices than before, they insisted that was that there was no political motive behind their demands. Ukraine complained that political considerations were driving the Russian demands and that the Russians were not providing the same discount given to them as before. The country had been discussing the joining of NATO shortly before this dispute erupted in the cut-off. At that time, Europe began to worry about the gas-cut-off as it was effecting European supplies. Europe became immediately concerned about energy security of their current Russian pipeline supply. Russia began to dread the big backlash and quickly resolved the matter before Putin became the focus of Western European ire. The 2009 gas-cut lasted for three weeks during the Great Global Recession, both of which effects contributed to the rise in anxiety and depression on the part of the respondents. We will endeavor to compare different methods for forecasting these series in the near future. To the extent that our model forecasts hold beyond the end of the data is the real measure of its ability to project the future condition of these endogenous variables.

23.7 Implication

We demonstrate that the multivariate state space model with a common local level is a particularly robust procedure that may be used for emergency psycho-social medical as-

sessments in a retrospective analysis of a post-disaster situation. It is a method that can apply mixed frequency sampling of reasonably short time-series for its analysis. We show that our self-report measures have excellent reliability. Our random sampling technique allows for a valid representative assessment of public opinion, although we cannot use standardized tests because the items are too detailed for people to recall over a long period of time.. We test the Bromet-Haanenar-Guey hypothesis for the first time, and find that it is to a very large extent inconsistent with the manifest empirical data. We use a variety of statistical methods to test that hypothesis, and to a very large extent find no evidence in support of it. We control for impacts of external events with blip-dummies and level-shift indicators where appropriate and arrive at a very useful model to assess post-disaster psychosocial sequelae. We hope that others may find this approach useful in their research under similar circumstances.

24 Appendices

24.1 Appendix 1: Principal endogenous variables

- **fdepanx2:** Annual mean of combination of female depression and anxiety scores.
- **mdepanx2:** Annual mean of combination of male depression and anxiety scores.
- **femptsdmc:** mean- centered measure of annual female reported PTSD scales.
- **maleptsdmc:** mean-centered measure of annual male self-reported PTSD scales.
- **dfdepanx2**: First difference of annual mean female depression and anxiety scale.
- **dfptsdmc**: First difference of annual mean female PTSD respondent reports.
- **dmdepanx2**: First difference of male mean depression and anxiety scale.
- **dmptsdmc**: First difference of annual mean male PTSD respondent reports.

24.2 Appendix 2: Event-indicators, somatic discomfort/pain, & pain-pill usage

- **ussrfall :** indicator variable, coded 1 if year == 1991, and 0, otherwise.
- **ussrlev:** level shift variable, coded 1 if year > 1991, and 0, otherwise.
- **chornblip:** Chornobyl indicator, coded 1 if year == 1986, and 0 otherwise.
- **dlnfpdisl:** 1st difference of natural log of annual mean percent of female pain and/or somatic discomfort.
- **dlnmpdisl:** 1st difference of natural log of annual mean percent of male pain and/or somatic discomfort.
- **dlnfpainq:** 1st difference of natural log of annual mean percent of female use of pain pills.
- **dlnmpainq:** 1st difference of natural log of annual mean percent of male use of pain pills.

24.3 Appendix 3: Health-harming habits and number of MD visits

- **dlnfdoctn:** 1st diff of ln(Average annual number of doctor visits for females.)
- **dlnmdoctn:** i1st diff of ln(Average annual number of doctor visits for males.)
- **d2lnfsmokel:** 2nd diff of ln(weekly rate of cig or cigar smoking for females).
- **d2lnfvodkaq:** 2nd diff of ln(weekly rate of vodka consumption for females).
- **d2lnmdrinl:** 2nd difference of natural log of female weekly wine/beer consumption).
- **d2lnmsmokel:** 2nd diff of ln(weekly rate of cig or cigar smoking for males).
- **d2lnmvodkaq:** 2nd diff of ln(weekly rate of vodka consumption for males).
- **d2lnmdrinl:** 2nd difference of natural log of male weekly wine/beer consumption).

24.4 Appendix 4: Female and Male measurement model variables

- **mrpre2**: male rescaled perceived risk exposure to Chornobyl radiation.
- **chornblip**: 1986 dummy variable for year of Chornobyl accident.
- **D.chornblip**: First difference of (year of 1986 indicator variable).

24.5 Appendix 5: File references

- **male model**: OxMetrics 7.1 1) OutputName: maleFinalFinal6fc.out ; 2)model name: uc1; line number11.
- **female model**: OxMetrics 7.1 1) OutputName: ffinalRep4fc.out; 2)model name: uc14; line number 2911.

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