To: Rosemarie Foster and Tom Borak

From: Robert Yaffee

Date: 21 July 2010

Re: Preliminary linear models regarding perceived health risk of Chornobyl radiation on the part of Ukrainian residents of Kiev and Zhitomer

Files: do files= Jul16_2010.do

Output files: GeneralRadhlw3linearmodels.smcl

Data file: "C:\users\ray2\stats\stata11\research\chwk\wide\chwide15jul2010.dta"

Basic linear modeling strategy

We pursued three approaches to selecting candidate variables for model-building. The first approach was that of graphical review of functional for deviations from linearity of the relationship, the second was that of bivariate screening without graphical assistance, and the third approach was that of the general-to-specific multipath search of different routes to developing an broadly theoretically encompassing regression model advocated by Sir David F. Hendry and Hans-Martin Krolzig in their general-to-specific ("gets") modeling strategy. This approach was further developed by Doornik and Hendry into a computer program called Autometrics.

To begin, we examine the relationship between our endogenous variable and candidate explanatory variables to detect nonlinear patterns. If possible, we attempt transformations which will render these relationships linear and amenable to conventional statistical testing. If the relationships are not intrinsically linear, we may deal with them by means of nonlinear or nonparametric approaches later. For the time being, we are trying to model linear relationships. We developed a set of linear models for the whole sample and for gender-specific segments of the sample. The reason for doing so is that the biological differences might predispose one sex from experiencing different effects than the other would Therefore, we began with a full-general model, and trimmed out the nonsignificant effects to arrive at a pruned or trimmed model This was done for each of the three sets of data, leaving us with six basic models.

The trimming was performed on the basis of nonsignificance of variables. Nonsignificance was determined as anything with significance level higher than 0.10. We decided that this was the appropriate cut-off level in general because the residuals of our sample were frequently found to be nonnormal based on the Shapiro-Wilk and Kolmogorov-Smirnov tests. Therefore, we decided to be more liberal in our estimation of what may be of interest. We indicate levels of significance greater than 0.05 but less than 0.10 by a # sign. Conventional applications of asterisks are used otherwise to indicate statistical significance. As a matter of convention, when the data are presented in the tables or sentences below, we round upward for the last figure to the right of the decimal point.

Following Hendry and Krolzig (1999), we take these six models and assign a value for each time a variable is statistically significant. By summing these values, the variable is given a reliability score. We then sort the variables according to the reliability score to obtain a sense of robustness of the variables comprising the model. Because the general to specific methodology of Hendry and Richard (1982) proceeds along a multipath tree-search from the general unrestricted model down each possible route of adding variables to the model, until a specification assumption is violated, at which point the model terminates. The models are built with a view toward encompassing theory. The more encompassing the model the better, as long as assumptions of the model are met. Model specification proceeds until any competing models are tested against one another. Attempts to combine them are made and the best fitting model that encompasses the most theory is selected. In case of ties, the Schwartz Bayesian criterion is used as a tie-breaker.

George E. P. Box once was reported to have said that "all models are wrong, but some are useful." We will test each of our models for regression specification requirements of residual normality, homogeneity of variance, independence of observations and identical distributions, dearth of multicollinearity, lack of outlier distortion, and for lack of omitted variable bias. If there are too many outliers, we shall endeavor to use an outlier down weighting algorithm to fit the model. If there is heteroskedasticity of the residuals, we can employ robust sandwich variance estimators to find the correct standard errors. From this analysis, we hope to gain a sense of which models are reliable and robust, as well as which are more fragile than the others.

In the second phase of the analysis, we take the linear models and test for interactions among the variables following any transformation of them that may have been applied. We will examine the nonlinear portions of the model. We will sequentially test these interactions to determine which should be included in the model. Once all the possible interactions have been included, we will simultaneous test the interactions to be sure that these are worthy of retention with a simultaneous test by which all variables and interactions are tested for retention within the model at the same level of power. This is the test of sufficiency to determine which variables need to be retained in the model. Then we will discuss the interactions and graph them to illustrate the nature of their interactions.

The Interim sample

At this stage of the data collection, our sample consists of 281 cases, approximately 29.54% (83) of which consist of males and the remainder of females. Seventy-five and 44/100 percent of the sample lives in the Kiev Oblast. The remainder resides in Zhitomer. The sample consists of fairly well-educated people, 39.5% of whom have a specialists or master's degree. About 38.08% of them have a technical degree. Only one did not finish high school. Four had doctoral degrees of one kind or another.

What factors explain perceived health risk from the Chornobyl radiation?

The full model for both men and women has for its endogenous variable, the perceived health risk from the Chornobyl radiation. The question asked of respondents living in the Ukraine was "In terms of percent, how much of your health has been affected by the Chornobyl radiation?" The answers lead to the development of a simple model consisting of the variables displayed in Table one on the next page.

Males and Females together: Model 1

The first regression model is has a lot of explanatory power. The R^2 for the model is 0.7934 and when that is adjusted for the number of variables in the model, the adjusted R^2 is 0.769. Not all of these variables are statistically significant. We know that the biological systems are have age and gender differences. Therefore, whether age or gender is significant or not, we include these variables in the model to control for such differences. In this way, we hope to control for the basic differences between them. At this juncture we only include first order terms. But the model we develop does explain much of the systematic variation involved. We address these risk factors in terms of their beta weights. The beta weights are the relative impact that the variables after standardization have on the dependent variable. They can be compared with these beta weights because they have been standardized so that they can be compared. Before this standardization, they are measured in different metrics and therefore the regression coefficients by themselves are not strictly comparable.

Perhaps the strongest association with this endogenous variable is the amount of family health that has been affected by the radiation. The relationship is positive so that the more people believe that their health has been affected, the more they believe that their family's health has been affected. This is not surprising. The second most powerful relationship seems to be that of drinking liquor during wave two is about the second most powerful influence. The more respondents believe that their health was affected, the more they drank hard liquor during between 1987 and 1996. Similarly, energy level has the same positive relationship with the belief in the amount of their health that they think was selected. Perhaps the immediate threat raised the adrenaline to deal with the jeopardy in their environment. Perhaps the third most powerful influence is that of the energy level. The next most powerful influence is that of the amount of pollution of the air and water by the Chornobyl radiation. To the extent that was polluted, people tend to think that their health was proportionally compromised. Next in importance is the natural log of the cumulative external dose of CS137 that they got from external sources. This is the excess radiation, over and above background radiation, which affects all of us by dint of our living in a natural setting. We use this transformation to render the variable amenable to linear statistical modeling. The transformation is scale invariant so that whether the cumulative dose is measure in micro or milliGrays, the regression coefficient remains the same. The greater the dose, the more they think that their health has been affected. The next more important is the stresses and hassles to their health is directly related to the amount that they believe their health has been affected. Then the next most important fact seems to be the personal intrusion to their interests and hobbies. Females seem to believe that their health was affected somewhat more than the men did. Next in importance is the number of separations related to the amount of health affected by this radiation. This too was a positive relationship. Most of these relationships seem reasonable and not counterintuitive.

Some of the relationships were inverse rather than direct in their association. Age was one of these, the older the respondent was, and the less he or she thought that their health was affected. Visits to the homeopath were related also. The more the respondent thought that their health was affected, the less the person thought his health was related. The more children the respondent had, the less he or she thought that the relationship wax so. Next was the amount of stresses or hassles on the job, which is inversely related to the amount of health perceived to have been affected. The amount of depression linked to the Chornobyl radiation was next. It appears that the more the person thought his health was affected by the Chornobyl radiation, the less depressed him or she was. This may be a cause attributable to others from which misery found comforting that others were suffering from it too. Then came those who drank hard liquor around the time of the accident during the first wave, the less they thought their health was affected the more they drank hard liquor around the time of the accident and the more they drink hard liquor during the last wave. This latter relationship is perhaps one of the strongest inverse relationships we detected so far.

Table 1 Key variables in preliminary models

```
radhlw3      byte   %8.0g              how much believed personal health is affected by radiation now
age          byte   %8.0g              Age of respondent in years
sex          float  %9.0g    sx        gender of respndnt
childw3      byte   %8.0g              number of children now
radfmw3      byte   %8.0g              how much believed family health is affected by radiation now
airw1        byte   %8.0g              consider hazardous (in percent) - air and water pollution in 1986
airw3        byte   %8.0g              consider hazardous (in percent) - air and water pollution , NOW
ecprw1       byte   %8.0g              consider hazardous (in percent) - economic problems in 1986
injselfr     float  %9.0g    dum       Were u injured because of Chornobyl acc in 1986?
injothr      float  %9.0g    inj       Was anyone u know injured by Chornobyl accident?
enlev        double %9.0g              energy level (el)
liqw1        byte   %8.0g              number of spirits per week in 1976-1986
liqw2        byte   %8.0g              number of spirits per week in 1987-1996
liqw3        byte   %8.0g              number of spirits per week in 1997-now
hospw1       int    %8.0g            * number of days per year as a patient in a clinic for medical condition in 1976-
vishphw1     byte   %8.0g              number of visits per year to a homeopath for a physical condition in 1976-1986
depress      byte   %8.0g              depression
hp2inthob    float  %9.0g    hp2fmt    health causing prb with interests & hobbies
phychot      byte   %8.0g              psychoticism
sepaw3       byte   %8.0g              Total number of separations, experienced in time period 1996-NOW
movew2       byte   %8.0g              Total number of moves, experienced in time period 1987-1996
shjobw2      byte   %8.0g              Percentage of strains and hassles related to job, 1996
shhlw1       byte   %8.0g              Percentage of strains and hassles related to health, 1986
lcumdosew3   float  %9.0g              Ln(cumdosew3)

.  * coding check
. summarize  radhlw3 age sex childw3 radfmw3 airw1 airw3 ecprw1 injselfr injothr enlev liqw1 liqw2 liqw3 hospw1 ///
>    vishphw1 depress hp2inthob phychot ///
>   sepaw3 movew2 shjobw2 shhlw1 lcumdosew3
```

Variable	Obs	Mean	Std. Dev.	Min	Max
radhlw3	268	60.09701	34.20885	0	100
age	281	50.84342	11.95514	28	84
sex	281	.7046263	.4570245	0	1
childw3	281	1.427046	.82105	0	4
radfmw3	271	71.5941	32.44776	0	100
airw1	270	63.79259	32.35757	0	100
airw3	277	46.15523	38.49225	0	100
ecprw1	230	31.72174	32.01652	0	100
injselfr	281	.6797153	.4674184	0	1
injothr	281	.86121	.3463441	0	1
enlev	281	29.22135	34.29539	0	100
liqw1	281	1.081851	2.167221	0	10
liqw2	281	1.298932	2.1187	0	10
liqw3	281	1.096085	2.241178	0	25
hospw1	280	5.096429	16.60617	0	200

Table 2 Full model for males and females

Source	SS	df	MS
Model	118442.795	16	7402.67466
Residual	30838.042	136	226.750309
Total	149280.837	152	982.110767

Number of obs	= 153
F(16, 136)	= 32.65
Prob > F	= 0.0000
R-squared	= 0.7934
Adj R-squared	= 0.7691
Root MSE	= 15.058

radhlw3	Coef.	Std. Err.	t	P>|t|	Beta
age	-.0645008	.1435428	-0.45	0.654	-.0222962
sex	3.428334	3.368783	1.02	0.311	.0512094
childw3	-3.580692	1.81387	-1.97	0.050	-.0864127
radfmw3	.7334324	.0454715	16.13	0.000	.7685719
airw1	.1377916	.0369565	3.73	0.000	.1549096
enlev	.1466435	.0437756	3.35	0.001	.1558308
liqw1	-2.314402	.84321	-2.74	0.007	-.1665128
liqw2	2.676547	.8983654	2.98	0.003	.2027088
liqw3	-2.335569	.6457014	-3.62	0.000	-.1963929
vishphw1	-1.767211	1.280603	-1.38	0.170	-.0563131
depress	-.9206115	.3548281	-2.59	0.011	-.1206354
hp2inthob	13.80775	4.861413	2.84	0.005	.1188435
sepaw3	6.923541	6.457443	1.07	0.286	.0430244
shjobw2	-.0995534	.0421508	-2.36	0.020	-.112795
shhlw1	.141008	.0504808	2.79	0.006	.1367251
lcumdosew3	4.792278	1.577076	3.04	0.003	.1370676
_cons	-26.29338	11.87144	-2.21	0.028	.

This system of relationships is subject to question. Many would want to which of the assumptions of this model hold and which violated and to what extent. If they are violated, how should we alter our view of these relationships to accommodate such a specification test failure? Should we consider altering our model to handle these violations? First, let us examine the fulfillment of the model assumptions.

As a regression model, there are specific conditions which must be fulfilled for us to have complete confidence in these findings.

Table 3 Specification tests for Both Male and Female Full Model				
Assumption	**Test**	**X^2, f, F, or t**	**p-value**	**violation**
Residual normality	*Shapiro-Wilk test* *Kolmogorov-Smirnov test*	3.816 25.16	0.000 0.000	yes
Residual homoskedasticity	*Breusch –Pagan /Cook Weisburg test*	1.67	0.2096	No
No outliers	*Standardized residuals > |3.5|*	1 negative outlier		yes
No omitted variables	*Ramsey reset test*	4.83	0.0032	Yes
No multicollinearity	*VIF < 10*	Mean VIF=14.56		yes

How can we manage these specification violations? We can loosen up our significance criteria to compensate for violation of the residual normality by noting when things are borderline or almost significant by designating them with a pound sign if they are 0.10 in probability. We do not have to use weighted least squares or sandwich variance estimators to handle heteroskedasticity for this model. We could use an outlier downweighting robust regression to deal with the single negative outlier, but our sample size is large enough to diminish the relative effect of this influence on the overall model. When we model our interactions we should attempt to model polynomial versions of the variables to handle the specification error suggested by the Ramsey Reset test. Probably the best solution is to obtain empirical standard errors by bootstrapping and using the bootstrapped model as empirical validation of the full and trimmed models (Harrell, 2002, 94).

We bootstrap the model 998 times and display those results in Table two. We cluster by id owing to the complex sample being applied. In the process, we apply bias correction and acceleration to correct for the asymmetry and skew. The bootstrap works best when there are no outliers in the distribution. With only one negative outlier, it is quite likely that our results will work out nicely. Indeed, we discover that this consistent method accurately replicates the results displayed in Table two. By applying bias correction and acceleration we do not encounter problems with transformed variables. If we transform our variables, this method is transformation respecting so that the end points of the confidence interval are corrected for a transformation of the variable under consideration (Efron and Tibshirani, 1993, 187). As the sample size (number of bootstrap replication increases) the statistic approximates the population parameter. It has as much power as indicated by the almost identical R^2 results. The parameter estimates are identical but the bootstrap standard errors vary a little from those generated by our regression model. Nevertheless, the results are proportional and supportive of the claim to validation of our model and we employ bias correction and acceleration to compensate for possible skewness of the distribution (Efron and Tibshirani, 1993, 138, 184-188, 323-328).

Table 4 Bootstrap Validation

```
Linear regression                               Number of obs      =        153
                                                Replications       =        998
                                                Wald chi2(16)      =     678.51
                                                Prob > chi2        =     0.0000
                                                R-squared          =     0.7934
                                                Adj R-squared      =     0.7691
                                                Root MSE           =    15.0582

                                    (Replications based on 153 clusters in id)
```

radhlw3	Observed Coef.	Bootstrap Std. Err.	z	P>|z|	Normal-based [95% Conf.	Interval]
age	-.0645008	.1605658	-0.40	0.688	-.3792039	.2502024
sex	3.428334	3.038835	1.13	0.259	-2.527673	9.384341
childw3	-3.580692	1.7104	-2.09	0.036	-6.933014	-.22837
radfmw3	.7334324	.0432227	16.97	0.000	.6487175	.8181473
airw1	.1377916	.0380811	3.62	0.000	.0631539	.2124293
enlev	.1466435	.0499217	2.94	0.003	.0487988	.2444883
liqw1	-2.314402	1.222597	-1.89	0.058	-4.710648	.0818444
liqw2	2.676547	.8979844	2.98	0.003	.9165296	4.436564
liqw3	-2.335569	.7475209	-3.12	0.002	-3.800683	-.8704549
vishphw1	-1.767211	2.462538	-0.72	0.473	-6.593696	3.059274
depress	-.9206115	.3616268	-2.55	0.011	-1.629387	-.211836
hp2inthob	13.80775	5.112128	2.70	0.007	3.788161	23.82733
sepaw3	6.923541	11.90627	0.58	0.561	-16.41232	30.2594
shjobw2	-.0995534	.0425842	-2.34	0.019	-.1830169	-.0160899
shhlw1	.141008	.0481963	2.93	0.003	.0465449	.2354711
lcumdosew3	4.792278	1.657119	2.89	0.004	1.544384	8.040172
_cons	-26.29338	12.1052	-2.17	0.030	-50.01914	-2.567624

Trimmed Model for both males and females

Before proceeding to our gender-specific models, we will re-estimate the model by trimming out the nonsignificant effects. We will retain those that are borderline and then re-evaluate the model. After trimming out those variables that are not statistically significant, we obtain a more parsimonious understanding of the risk factors related to perceived Chornobyl radiation health risk on the part of our interim sample. Nevertheless, the model remains powerful with an R^2 = 0.71 and when we adjust for the number of degrees of freedom consumed by the number of variables in our model, we still have about the same goodness of fit (adjusted R^2=.71). For a first pass, the model in Table four has plenty of explanatory appeal.

We will briefly describe the model in terms of decreasing beta weights. Notwithstanding their statistical significance, age and gender remain in the model to account for normal lifecycle effects. Both variables are nonsignificanty related to the Chornobyl perceived heath risk. Apart from age and gender, all other seven variables are highly statistically significant at 0.5 levels.

Table 4 Trimmed Model both males and females

Source	SS	df	MS
Model	212860.597	9	23651.1774
Residual	83885.2011	247	339.616199
Total	296745.798	256	1159.16327

Number of obs	257
F(9, 247)	69.64
Prob > F	0.0000
R-squared	0.7173
Adj R-squared	0.7070
Root MSE	18.429

radhlw3	Coef.	Std. Err.	t	P>|t|	Beta
age	-.0708767	.1177613	-0.60	0.548	-.0244775
sex	-.4350829	3.050774	-0.14	0.887	-.0058433
radfmw3	.8378355	.039044	21.46	0.000	.7984541
airw1	.1357923	.0365322	3.72	0.000	.1294581
liqw1	-2.730379	.679945	-4.02	0.000	-.1777916
hp2inthob	10.99926	3.730547	2.95	0.004	.1110236
shjobw2	-.1107804	.0352072	-3.15	0.002	-.1230737
shhlw1	.0930175	.0429941	2.16	0.031	.0808609
lcumdosew3	4.720468	1.453429	3.25	0.001	.1229101
_cons	-30.13108	10.51535	-2.87	0.005	.

In order of decreasing relative influence, the explanatory variables are amount of family health affected by the Chornobyl radiation, the amount of pollution of the air and water, the computed external effective dose of CS137 accumulated over the years, its interference with interests and hobbies, the stresses and hassles to ones heath, the gender effect, the age effect, the stresses and hassles associated with the job during wave two and the amount of hard liquor consumption. There were direct relationships between the amount of health affected and the amount of family health affected, the amount of air and water polluted, the actual cumulative external dose, the interference with hobbies and interests, and the amount of stresses and hassles with the job. The other relationships were inverse ones.

To evaluate this model, we can refer to Table five. We find that this model fails a number of the specification tests. Indeed, apart from there being no outlier s for this model, all other specifications are violated. One solution is to use robust variance estimators here, which we will do later. This will not change our parameter estimates, but will widen the standard errors somewhat. We need to loosen up on our significance criteria again, allowing borderline cases to be deemed as possibly significant. With no outlier problems, we need not run an outlier downweighting regression. Even if we loosen up on these criteria, we explain about 71% of the variance of the endogenous variable with these few explanatory variables before considering interaction terms.

Bootstrap validation of Trimmed model for both males and females

Table5 Specification tests for Both Male and Female Trimmed Model				
Assumption	**Test**	**X^2, f, F, or t**	**p-value**	**violation**
Residual normality	*Shapiro-Wilk test* *Kolmogorov-Smirnov test*	W=.845 Z=6.60 64.92	0.0000 0.0000	yes
Residual homoskedasticity	*Breusch –Pagan /Cook Weisburg test*	0.62	0.4317	no
No outliers	*Standardized residuals > |3.5|*	Not applicable	none	no
No omitted variables	*Ramsey reset test*	F(3, 244) = 5.40	0.000	yes
No multicollinearity	*VIF < 10*	Mean VIF |	23.04	yes

We are able to replicate the results of the previous model by reproducing the empirical standard errors from a bootstrap in Table 5 below. The parameter estimates again are identical. Although the standard errors are not identical, they are close enough so that this serves as validation of the parameter estimates of the model.

Table 6: Bootstrap validation of the trimmed model for males and females

```
Linear regression                                Number of obs      =        257
                                                 Replications       =       1000
                                                 Wald chi2(9)       =     962.80
                                                 Prob > chi2        =     0.0000
                                                 R-squared          =     0.7173
                                                 Adj R-squared      =     0.7070
                                                 Root MSE           =    18.4287

                                      (Replications based on 257 clusters in id)
```

radhlw3	Observed Coef.	Bootstrap Std. Err.	z	P>|z|	Normal-based [95% Conf.	Interval]
age	-.0708767	.1222838	-0.58	0.562	-.3105486	.1687952
sex	-.4350829	2.770746	-0.16	0.875	-5.865645	4.995479
radfmw3	.8378355	.0354566	23.63	0.000	.7683417	.9073293
airw1	.1357923	.0365666	3.71	0.000	.0641231	.2074614
liqw1	-2.730379	.8722664	-3.13	0.002	-4.43999	-1.020768
hp2inthob	10.99926	3.75268	2.93	0.003	3.644143	18.35438
shjobw2	-.1107804	.0391823	-2.83	0.005	-.1875763	-.0339845
shhlw1	.0930175	.0405443	2.29	0.022	.013552	.1724829
lcumdosew3	4.720468	1.525557	3.09	0.002	1.730431	7.710506
_cons	-30.13108	10.59084	-2.85	0.004	-50.88874	-9.373411

Although we find that the standard errors vary a little from the original output, the parameter estimates are replicated as well as the omnibus goodness of fit statistics. We find this validation of the results and accept this output as support for faith in our findings. That we were able to support our full and trimmed model with bootstrap validation with empirical standard errors lends support to our approach.

Gender-specific Regression Models

By splitting the sample into two segments, we provide an opportunity for additional reliability testing. We save a degree of freedom by not having to include gender in the model, but until our sample size increases, we still have low power to assess the male subpopulation. The question arises whether we can obtain as powerful explanatory models as we did with the general population.

We begin our examination of the full male model. The answer to that question appears to be in the affirmative. The explanatory power of this model reaches and R^2 =0 .872 with an adjusted R^2=0.814. This model is bereft of a lot of nuisance variables. However, this model includes most of the variables we have seen in the earlier models.

However, there is one change that it noteworthy and we will tender some plausible explanations for it. The natural log of the computed cumulative external dose has lost its statistical significance. This loss is suspicious and may be due to the artifact of a temporary loss of power of this model to effects of a medium to small size. It is possible that the listwise deletion, used before we begin the multiple imputations, has engendered this loss. The model has 15 variables in it and a lot of data has dropped out due to the listwise deletion being used until we commence with multiple imputation to replace missing values. The corresponding loss of power to this model might result in a lack of statistical significance. We should be able to test this model with a bootstrap validation as well.

Table 7 Full Male Model

variable name	storage type	display format	value label	variable label
radhlw3	byte	%8.0g		how much believed personal health is affected by
age	byte	%8.0g		Age of respondent in years
childw3	byte	%8.0g		number of children now
radfmw3	byte	%8.0g		how much believed family health is affected by r
airw1	byte	%8.0g		consider hazardous (in percent) - air and water
injselfr	byte	%9.0g	dum	Were u injured because of Chornobyl acc in 1986?
enlev	double	%9.0g		energy level (el)
ecprw1	byte	%8.0g		consider hazardous (in percent) - economic probl
injothr	byte	%9.0g	inj	Was anyone u know injured by Chornobyl accident?
liqw1	byte	%8.0g		number of spirits per week in 1976-1986
liqw2	byte	%8.0g		number of spirits per week in 1987-1996
liqw3	byte	%8.0g		number of spirits per week in 1997-now
vishphw1	byte	%8.0g		number of visits per year to a homeopath for a p 1976-1986
sepaw3	byte	%8.0g		Total number of separations, experienced in time
movew2	byte	%8.0g		Total number of moves, experienced in time perio
lcumdosew3	float	%9.0g		Ln(cumdosew3)

```
. regress radhlw3 age childw3 radfmw3 airw1 injselfr enlev ecprw1 injothr liqw1 liqw2 liqw3 vi
>     sepaw3 movew2 lcumdosew3 if sex == 0, beta
```

Source	SS	df	MS
Model	42390.8425	15	2826.05617
Residual	6235.68812	33	188.960246
Total	48626.5306	48	1013.05272

Number of obs =	49
F(15, 33) =	14.96
Prob > F =	0.0000
R-squared =	0.8718
Adj R-squared =	0.8135
Root MSE =	13.746

radhlw3	Coef.	Std. Err.	t	P>|t|	Beta
age	.1310031	.2452847	0.53	0.597	.0477863
childw3	-6.791034	3.078787	-2.21	0.034	-.1716361
radfmw3	.7955687	.0785506	10.13	0.000	.8405813
airw1	.1877148	.0695692	2.70	0.011	.2039689
injselfr	17.05465	5.415575	3.15	0.003	.2706348
enlev	.2652716	.0757442	3.50	0.001	.2579531
ecprw1	-.2113004	.0763644	-2.77	0.009	-.2130265
injothr	-11.88774	6.537681	-1.82	0.078	-.1520888
liqw1	-3.247168	1.038611	-3.13	0.004	-.3286789
liqw2	1.564941	.944816	1.66	0.107	.1573163
liqw3	-2.025951	.6810037	-2.97	0.005	-.2596001
vishphw1	-14.78002	4.996491	-2.96	0.006	-.1990134
sepaw3	-26.3187	11.36104	-2.32	0.027	-.1653079
movew2	-9.262259	4.631316	-2.00	0.054	-.145255
lcumdosew3	1.133064	3.284673	0.34	0.732	.0305176
_cons	-2.294297	25.317	-0.09	0.928	.

However, let us examine the extent to which the model assumptions are fulfilled. From Table eight, we see that the homoskedasticity assumption is fulfilled here, but the normality assumption is not, even though there is no excess kurtosis or skewness. Most of the assumptions are fulfilled. Because there are no distorting outliers in the residual distribution, we can either relax our hypothesis testing criteria a little or be more assured with a bias corrected and accelerated bootstrap. We decide to select the latter option.

Table 8 Specification tests for Full Male Model

Assumption	**Test**	**X^2, f, F, or t**	**p-value**	**violation**
Residual normality	*Shapiro-Wilk test* *Kolmogorov-Smirnov test*	V=18.325 Z=6.6 64.92	0.0000 0.0000	yes
Residual homoskedasticity	*Breusch –Pagan /Cook Weisburg test*	$X^2(1)$ = 0.62	0.4328	no
No outliers	*Standardized residuals > |3.5|*	Not applicable	none	no
No omitted variables	*Ramsey reset test*	F(3, 30) = 1.57	0.2166	no
No multicollinearity	*VIF < 10*	Mean VIF |	20.34	yes

Although the Ramsey reset test indicates a lack of specification error owing to polynomial transformations, there may be other variables inversely related to the natural log of cumulative dose that are inadvertently excluded from the model. This may not be likely given the adjusted R^2 of the model. However, it is still possible. Owing to listwise deletion, the sample size has been reduced to 49. The fact that this natural log of cumulative external effective dose of CS137 is negatively correlated with 10 of the 15 other parameter estimates in the model could potentially suppress its significance if these correlations were sufficiently large. Yet the largest in negative magnitude is only -0.262. Such specification error could suppress the significance of the natural log of cumulative external dose of CS137. We might want to run a simulation to test whether this could be the case. For the moment, this phenomenon may be an example of something we should investigate but that we do not yet know. If we discover it to be so, then that would explain this loss of statistical significance.

Bootstrap replication brings the consistency of the estimator to bear on the problem, for which reason we can accept the bootstrap as a validation of the former model in Table Six. We compare our clustered bootstrapped results in Table ten to those we obtained in Table seven. Of course, the bootstrap standard errors vary somewhat due to the random resampling with replacement but not enough to say that validation has not occurred. The variation is sufficiently small so that our results appear to be validated. Nevertheless, we set up our bootstrap to accommodate the complex structure of our panel data (Stata Reference A-H, Stata Press, 210).

Perhaps one way to begin the testing is to trim the model. If it is the plethora of small negative correlations that are reducing the significance of this parameter, we should see what happens when we are able to trim some of these from the model. If the significance of this parameter re-emerges, then we have further evidence of the omitted variable bias that could engender a spurious nonsignificance. Therefore, we now turn our attention to the trimmed male model in Table 11.

Table 10 Bootstrap validation of the full male model

Linear regression

Number of obs	=	49
Replications	=	1035
Wald chi2(15)	=	395.33
Prob > chi2	=	0.0000
R-squared	=	0.8718
Adj R-squared	=	0.8135
Root MSE	=	13.7463

(Replications based on 49 clusters in id)

radhlw3	Observed Coef.	Bootstrap Std. Err.	z	P>|z|	Normal-based [95% Conf.	Interval]
age	.1310031	.2414022	0.54	0.587	-.3421366	.6041428
childw3	-6.791034	3.598476	-1.89	0.059	-13.84392	.2618486
radfmw3	.7955687	.0927857	8.57	0.000	.6137121	.9774252
airw1	.1877148	.0773054	2.43	0.015	.0361989	.3392306
injselfr	17.05465	6.219577	2.74	0.006	4.864501	29.24479
enlev	.2652716	.0993308	2.67	0.008	.0705868	.4599563
ecprw1	-.2113004	.0892625	-2.37	0.018	-.3862517	-.0363491
injothr	-11.88774	8.235777	-1.44	0.149	-28.02957	4.254082
liqw1	-3.247168	1.286178	-2.52	0.012	-5.76803	-.7263066
liqw2	1.564941	1.166375	1.34	0.180	-.7211114	3.850994
liqw3	-2.025951	.8515801	-2.38	0.017	-3.695018	-.3568849
vishphw1	-14.78002	2.231581	-6.62	0.000	-19.15384	-10.4062
sepaw3	-26.3187	16.20863	-1.62	0.104	-58.08704	5.449637
movew2	-9.262259	6.089893	-1.52	0.128	-21.19823	2.673713
lcumdosew3	1.133064	3.241864	0.35	0.727	-5.220873	7.487001
_cons	-2.294297	26.28609	-0.09	0.930	-53.81409	49.2255

The Trimmed Male Model

The trimmed male model details are presented in Table 11. The number of parameters in the model is reduced from 15 in Table 10 to nine in Table 11. With only 49 observations that leaves only 37 degrees of freedom for testing. This is not a very large file and although the reduction of the number of explanatory variables leaves more power with which to test, it is not a great improvement in power. If we examine the square of the natural log of the cumulative external dose of CS137 sustained, we observe that the significance level tends toward more significance, but at p=0.221, we cannot say that it statistically significant. However, the reduction of the p-value to 0.221 may reflect the improved power of a still weak model. By the time we obtain our full sample, we hope to have enough male observations such that our assessments will be more definitive. At this juncture, we can only proffer these as interim results awaiting additional power to be obtained from a larger sample size of males.

However, we need to examine the differences between the full and trimmed model to observe what robustly remains and what does not.

Table 11 Trimmed male model

Source	SS	df	MS		
Model	39913.1689	11	3628.4699	Number of obs =	49
Residual	8713.36175	37	235.496264	F(11, 37) =	15.41
				Prob > F =	0.0000
Total	48626.5306	48	1013.05272	R-squared =	0.8208
				Adj R-squared =	0.7675
				Root MSE =	15.346

radhlw3	Coef.	Std. Err.	t	P>|t|	Beta
age	.2128123	.2704167	0.79	0.436	.0776281
childw3	-7.987085	3.290603	-2.43	0.020	-.201865
radfmw3	.852851	.0833552	10.23	0.000	.9011046
enlev	.2073325	.0813314	2.55	0.015	.2016125
injselfr	12.50024	5.083299	2.46	0.019	.1983624
liqw1	-2.853126	1.061364	-2.69	0.011	-.2887939
liqw3	-1.249931	.6386906	-1.96	0.058	-.1601628
vishphw1	-15.88501	5.403158	-2.94	0.006	-.213892
sepaw3	-28.57907	12.25482	-2.33	0.025	-.1795053
movew2	-10.09214	4.95614	-2.04	0.049	-.1582696
lcumdosew3sq	.363855	.2921443	1.25	0.221	.1162601
_cons	-16.0379	17.50836	-0.92	0.366	.

The more robust risk factors are those phenomena that retain their significance and sign in both models. The amount of family health affected remains directly associated with the amount of personal health affected by the radiation. Energy level remains positively significant in both models. Risk may raise energy level for some time. Self-injury as a result of Chornobyl is positively significant in both models. It appears that people were rushed around and in a hurry, which may have results in various kinds of injury in the commotion. Visits to the homeopaths are inversely significant in both male models. Under times of crisis and commotion, homeopathic visits seem to be inversely related to the perceived health risk here. Inverse significant relationships between consumption of hard liquor and the perceived heath risk remains in wave one.

The changes from the full to the trimmed model are several. A number of significances emerged. One of them was the number of children the respondent has is a variable that was not statistically significant in the full model but is statistically significant in the trimmed model among the men in the sample. The total number of moves from one place to another was not significant in the full model but emerged as significant in the trimmed model. The number of marital separations became significant in the trimmed model. In wave three, hard liquor consumption became almost significant from significant. Injury to others dropped from significance in the trimmed model. The economy went from negative significance to nonsignificance in the trimmed model. The basis for these differences may follow from a difference in statistical power or from a transformation of the situation.

In this model, we employed the square of the natural log of the cumulative external effective dose of CS 137 because it was more significantly related to the perceived risk perception of Chornobyl radiation. In this model that transformation provided a better link between the endogenous and exogenous variable under consideration. To appreciate the validity of this model, we need to review the specification requirements. That may give us an indication of where the model weakness may reside. Then, we may still wish to resort to bootstrap validation for more data. Therefore, we resort to this now in hopes of providing more information about what is reliable and what is fragile in these models.

From a review of the model assumptions in Table twelve it is clear that there are more violations than there are fulfillments. Homoskedasticity is not violated so the confidence intervals may be estimated but the residual distribution is nonnormal. This may be due to the presence of outliers that could distort the distribution. We will examine this situation in greater detail because the presence of bad influence from outliers can undermine the coverage of a percentile or a t bootstrap with small sample sizes, even though we use bias correction and acceleration to compensate for the bias that could follow from such bootstraps (Efron and Tibshirani, 1993). In this case we examine the Cook's D as a measure of the adversity of the influence of these outlying observations.

Table 12 Specification tests for the trimmed male model

Assumption	**Test**	**X^2, f, F, t, or z**	**p-value**	**violation**
Residual normality	*Shapiro-Wilk test* *Kolmogorov-Smirnov test*	Z=6.963 Adj X^{2} = 66.74	0.0000 0.0000	yes
Residual homoskedasticity	*Breusch –Pagan /Cook Weisburg test*	$X^2(1)$ = 1.97	0.1601	no
No outliers	*Standardized residuals > |3.5|*	7 outliers 5 negative 2 positive	0.000	yes
No omitted variables	*Ramsey reset test*	F(3, 34) = 1.67	0.1923	no
No	*VIF < 10*	Mean VIF |	13.21	yes

multicollinearity				

Ken Bollen and Robert Jackman (1990) have noted that when Cook's D exceeds 4/n, the observation in question exhibits problematic influence, where n designates the sample size. If our effective sample size is 49, that means Cook's D values in excess of 0.082 would be problematic. The residual distribution is raven with 28 of these observations, nine of which exceed unity while five of which exceed 4.0. Under these circumstances, perhaps a nonparametric bootstrap would be the best approach to arriving at empirical standard errors. According to Bollen and Jackman, Betsey in 1980 suggested that the lower size cut-off for a feta coefficient is 2/√n whereas the upper is unity. With this effective sample size, this amounts to 2/7=0.286. I performed a sensitivity test on the parameter estimate of the natural log of the cumulative external dose of CS137, by listing all of the debates for the natural log of the cumulative external dose for any observation with a Cook's D greater than unity. No feta was indicated. From this I suspect that the changes in significance result either from correlations with omitted variables or from multiple low-level negative correlations with included variables or from the improvement in power by reducing the sample size of the correlation matrix and thus in turn attenuating the power of the model to detect medium to small effects. I suspect that this problem will be alleviated by the input of more male respondents as our data collection continues. With the plethora of outliers, a parametric bootstrap would probably not bear fruit. With that caveat issued, we undertake the bootstrap validation nevertheless.

Table 13 Bootstrap validation of trimmed male model

```
Linear regression                               Number of obs      =        49
                                                Replications       =      1012
                                                Wald chi2(11)      =    386.24
                                                Prob > chi2        =    0.0000
                                                R-squared          =    0.8208
                                                Adj R-squared      =    0.7675
                                                Root MSE           =   15.3459

                                   (Replications based on 49 clusters in id)
```

radhlw3	Observed Coef.	Bootstrap Std. Err.	z	P>|z|	Normal-based [95% Conf.	Interval]
age	.2128123	.2542247	0.84	0.403	-.2854588	.7110835
childw3	-7.987085	3.242337	-2.46	0.014	-14.34195	-1.632222
radfmw3	.852851	.0997553	8.55	0.000	.6573342	1.048368
enlev	.2073325	.0935577	2.22	0.027	.0239627	.3907023
injselfr	12.50024	5.208347	2.40	0.016	2.292067	22.70841
liqw1	-2.853126	1.168345	-2.44	0.015	-5.14304	-.5632128
liqw3	-1.249931	.6963277	-1.80	0.073	-2.614708	.1148468
vishphw1	-15.88501	1.67703	-9.47	0.000	-19.17192	-12.59809
sepaw3	-28.57907	16.03039	-1.78	0.075	-59.99806	2.839913
movew2	-10.09214	7.518164	-1.34	0.179	-24.82747	4.643186
lcumdosew3sq	.363855	.2761775	1.32	0.188	-.1774429	.9051529
_cons	-16.0379	19.53673	-0.82	0.412	-54.3292	22.2534

For the square of the natural log of cumulative external dose of CS137 we observe that the significance level is closer to significance than with our first estimation of this model, but it remains nonsignificant. The number of moves is no longer significant. The number of separations is no longer significant. Otherwise, the model remains very much the same, as far as the parameter estimates and the goodness of fit indices are concerned. At this juncture, we will turn to the female full and trimmed models as well as their validations. At the end of this presentation, we will sort the variable in order of their reliability, which will be computed from the proportion of models in which they were found to be statistically significant.

The Full female model

The female portion of the sample at this time in our current data collection represents about 70% of the sample interviewed thus far. We begin our analysis of this female segment with a standard OLS regression, from which we can glean beta weights, following the general- to- specific modeling technique of Hendry-Richard approach (1982), programmed by Hendry and Krolzig(1999), developed by Hendry and Castle, FILL in Date), as well as Doornik and Hendry (Fill in date). In fact, we use their computer program, Autometrics, to select the model explanatory variables. From this we obtain a model that fits remarkably well (see Figure one), which displays the estimated model fit with the actual data. Sometimes the Hendry et al. approach will retain some variables that do not appear to be statistically significant, perhaps because they improve statistical fit or prediction. We attempt to trim the model of nuisance parameters before deciding whether a robust version is in order. To include a sandwich estimator to robustify our modeling at several waves, we validate our analysis with a cluster-controlled bootstrap.

Our dependent variable in this model is still perceived health risk to Chornobyl radiation on the part of the respondent (radhlw3) at the time of the interview. The full female model variable names and labels are shown in table 14a. This is the first selection as it were. We trim out some of these nonsignificant variables even more and arrive at table 14b. Table 15 contains the parameter estimates and their related significance tests. The full female model is the largest model developed at this interim juncture. We use Doornik and Hendry's Autometrics to select the variables for this model, which contains 28 parameter estimates, and then we trim out some of the retained nonstatistically significant variables and use Stata for modeling with our complex sample, although we are not employing sampling weights at this early juncture. We do control for autocorrelation between the waves (phi = .7 to .9) depending upon whether it is first or second order. Table 14 on the next page lists the variables in this model, beginning with the endogenous variable. Regardless of the discarding of three of the variables both statistical packages report a very respectable goodness of fit.

The full model female Autometrics and Stata report an excellent model goodness of fit. We trim down the model a little and display the resulting model in Table 15. The R^2 of the model is 0.799 and the adjusted R^2 is 0.773. These measures are high by social science standards, so we graphically check the model fit against the actual data to confirm in Figure one. To visually examine the residuals of the model, we examined not only the goodness of fit but also the behavior of the residuals. In the top panel of the three panels in Figure one, we observe what appears to be a remarkably good estimation from the PcGive Autometrics version of the model.

To have confidence in a model, we have to examine the theoretical meaning of the parameter estimates. If we consider the variables core critical variables, they need to add theoretical explanation to the scope of theory of the model. Stata regression output is displayed in Table 15. As with above models, we include the age or its square or cube to control for lifecycle effects of aging, whether they appear to be statistically significant or not. We control for gender and its biological differences by employing a female subsample for this model. Even if these variables turn out not to be statistically significant we leave them in the model to control for these effects insofar as they reside in the model. Because we subset out the females in this case, that subset represents the control for gender.

In the full female model, we trim out eleven of the variables that are not significant and are left with seventeen explanatory variables, most of which are statistically significant. We retain some measure of age, a covariate necessary to control for lifecycle effects that are associated with ailments of one kind or other. We endeavor to retain the natural log of the cumulative external Cesium 137 dose as another important variable, which indicates the extent to which the respondent was actually exposed to the radiation. The *illw1* variable indicates the self-report of the number of diseases experienced by the respondent during the period ending on December 31st of the year of the Chornobyl accident.

We begin with the parameter estimates at the top of Table 15 and work our way down the list of variables to simply the protocol of explanation. Because age is not statistically significantly related to our perceived health risk endogenous variable, the sign and direction of the relationship may be unstable and unreliable. Although we need to control for this potentially confounding effect, even if it is not significant, we do not wish to belabor the nature of this tenuous relationship, where noise appears to overwhelm the signal. It might be plausible that the younger the respondent is, the more likely she may think that a greater proportion of her health has been affected by the Chornobyl radiation. Perhaps older people have a better sense of perspective on what the implications are for their health. The nonsignificance of the relationship makes this conjecture somewhat tenuous and worthy of being put on the back burner for later consideration.

Among these explanatory variables are the gender of the respondent, the cumulative external dose of CS 137 radiation to the respondent, percentage of family health affected by Chornobyl radiation, the health effects of Chornobyl, whether the respondent was injured as a result of Chornobyl, whether the respondent may have injured others, whether the respondent had to evacuate herself, the number of self-reported illnesses during the first period of analysis (till the end of 1986), the extent to which hobbies and interests were interfered with by Chornobyl, the level of danger posed by neighbors since 1996, the danger of the effects of radiation in later years (wave 2 from 1987 through 1996), and the respondent's lifetime exposure to radiation. We turn our attention to these variables in order to assess their face validity.

The belief that the percentage of family health affected by the Chornobyl radiation in waves one, two, and three are the next variables we consider (radfmw1, radmfw2, and radfmw3). These variables were negatively related to our perception of heath risk for the first and second wave. After the second wave, the nature of the relationship reversed so that the relationship turned positive. An increase in the percent of family health affected by Chornobyl radiation shifted from negative to positive in the third wave. The more the family health was believed to be affected, the more the health of the respondent was believed to be affected, whereas for a decade after the disaster, the relationship was believed to be the opposite: the more the respondent's health was affected, the less the family's health was believed to have been affected. The question arises as to what caused this reversal of belief. Was it glasnost? Was it news of all of the inquiry? This question remains to be examined.

Table 14a Table of variables first selected for the full female model

variable name	type	format	label	variable label
radhlw3	byte	%8.0g		how much believed personal health is affected by radiation now
age	byte	%8.0g		Age of respondent in years
radfmw2	byte	%8.0g		how much believed family health is affected by radiation in 1996
radfmw3	byte	%8.0g		how much believed family health is affected by radiation now
airw1	byte	%8.0g		consider hazardous (in percent) - air and water pollution in 1986
medw3	byte	%8.0g		level of danger by general media (in percent) now
jsw2	byte	%8.0g		Job satisfaction on a scale of 0-100%, 1996
radw2	byte	%8.0g		believed % of the radioactively contaminated area in 1996
radw3	byte	%8.0g		believed % of the radioactively contaminated area now
dauthw3	byte	%8.0g		level of danger by authorities (in percent) now
healthef	byte	%8.0g	*	if a person is exposed to any amount of radiation, then they are likely to suffe
injselfr	byte	%9.0g	dum	were u injured because of Chornobyl acc in 1986?
shjobw2	byte	%8.0g		Percentage of strains and hassles related to job, 1996
illw1	byte	%8.0g		Total number of illnesses, experienced in time period 1976-1986
hp2inthob	byte	%9.0g	hp2fmt	health causing prb with interests & hobbies
lcumdosew3	float	%9.0g		Ln(cumdosew3)

From a review of the parameter estimates in Table 15, we endeavor to explain the relationships between the dependent variable, the perceived health risk from Chornobyl radiation (radhlw3) and a number of explanatory variables. If the explanation of the significant relationships seems sensible, those relationships exhibit face validity. If they are counterintuitive, then we need to examine them in greater detail to understand the nature of the drivers of the model.

To avoid uncertainty around non-significant variables, we focus on those relationships indicated by the parameter estimates in Table 15 with p-values less than 0.10. If the significance levels are larger than 0.10, the signal may be indistinguishable from noise and we set aside these relationships from current consideration at this time. Also, we consider these variables in order of their position in the table, from top to bottom. Proceeding in this direction, we note that the first significant variable age. Age is significantly negatively related to the perceived health risk. The magnitude of this risk is merely moderate. The belief in the amount of family health affected by the Chornobyl radiation at waves two and three is also related to the perceived health, and the direction of the relationship is positive for both waves. This is as expected.

The amount of air and water pollution around the time of the accident (airw1) is almost significantly (p=.061) related to the perceived health risk.

We see that the belief in the danger posed by the media (medw3) at the current time is inversely related to the cumulative perceived health risk of the fallout. The media at the time of the accident was the second most common source of information about the problem; thirty-three percent of the information about the disaster came from the media, of which television and radio were major sources of distribution. Glasnost had begun, so people believed in freedom of the press, openness, and transparency more than before. Also very strongly negatively related to perceived health risk from the accident was the number of mental health visits around the time of the accident. It is not surprising that the media was a source of helpful not dangerous information to the public. Hence, the significant negative coefficient is what would have been expected.

The next two significant variables in Table 15 are the percent of the area radioactively contaminated at during the decade following the disaster (radw2) and the percent of the area believed to be contaminated now (radw3). The percent of area covered was inversely related to the percent of perceived health risk to the respondent at first. However, a considerable amount of time has passed since the accident and there may have been information distributed indicating that the amount of distributed radioactivity was not as dangerous as had been originally feared. Distribution of such information could have lead to a significant, small negative relationship between the amount of health risk reported by the respondent and a belief in the percent of the area currently contaminated. Perhaps this is why at the current time there is no statistically significant relationship.

The level of danger posed by the authorities (dauthw3) is also significant, positive, yet not large. Clearly, the amount of danger posed by the Chornobyl radiation is to some extent linked to the incompetence of the authorities. Whether those authorities were in charge of the management of the plant, management of the cleanup, or of protection of the public, to some extent the percent of health affected by the radiation from the accident may have followed from ineptitude by the authorities in handling the matter.

Another effect that suggests possible post-traumatic stress syndrome is the deep distrust of most any exposure to any kind of radiation (healthef) is liable to lead to some kind of suffering. The relationship between the self-perceived health risk from Chornobyl radiation and this intense aversion to any kind of exposure is found to be significant and positive. The significance indicates probable traumatic effect on the people of such a catastrophe.

A significant and strongly positive relationship can be observed in the relationship between injuring oneself as a result of Chornobyl (injselfr) and the self-perceived health risk to the relationship.

A significant negative relationship is found between stresses and hassles on the job (shjobw2) and the self-perceived health risk. Although this relationship is significant, it is not a big one.

However, there is a significant strong relationship between the self-reported count of illnesses at the time of the accident (illw1) and the self-perceived health risk from the radiation during the decade after the accident. Perhaps because of the lack of confounding symptoms, people were better able to distinguish one cause and effect from another.

Although there did some to be some impact on activities devoted to interests and hobbies (hp2inthob), this imposition did not appear to be significant in this full model. Perhaps this significance would emerge as sample size increases or as we trim out nuisance or auxiliary variables to obtain a trimmed model.

Last but not least among the significant relationships that emerged within this full model was the significant, positive, and substantial relationship between perceived health risks stemming from the Chornobyl radiation and that natural log of the actual external exposure from cesium 137 (lcumdosew3) as measured in MicroGrays. This measure is scale invariant and persistently reveals itself in these models.

We should qualify this by recognizing that the constant or average level is – 33.46, suggesting a negative relationship between the average amount of risk to the Chornobyl radiation. In general, this would appear to suggest that such a thing may not be a paramount part of the conscious concerns of these individuals.

The reader might ask, “How much faith can we place in such a model?” From Figure one, we observe a very good fit between the estimated values and the actual data (in the upper panel). We do not see any residuals whose value exceeds 3.5 standard errors (the middle panel of Figure one). But to be sure that we can trust our model, we have to examine the extent to which the regression assumptions are fulfilled to know how much faith to place in the model. Table 16 summarizes the results of the misspecification tests.

We observe in Table 16 that all three of the five model specification tests were violated. Although the residual variance is homoskedastic according to the Breusch-Pagan test, the model residuals are nonnormal as indicated by both the Shapiro-Wilk and the Kolmogorov-Smirnov tests. We do have homoskedasticity of the residuals, according to the Cook/Weisberg test. But we have plenty of multicollinearity, which can bias our significance tests downward. We do not have any significant outliers which might bias our residuals. Yet we find evidence of omitted variable bias following from a significant Ramsey reset test. Without some adjustment for these violations of assumptions, the significance tests for the model are at best only an approximation rather than an exact probability of rejection of the null hypotheses.

Figure 1 Model fit and residual graphics from the first pass at the full female model

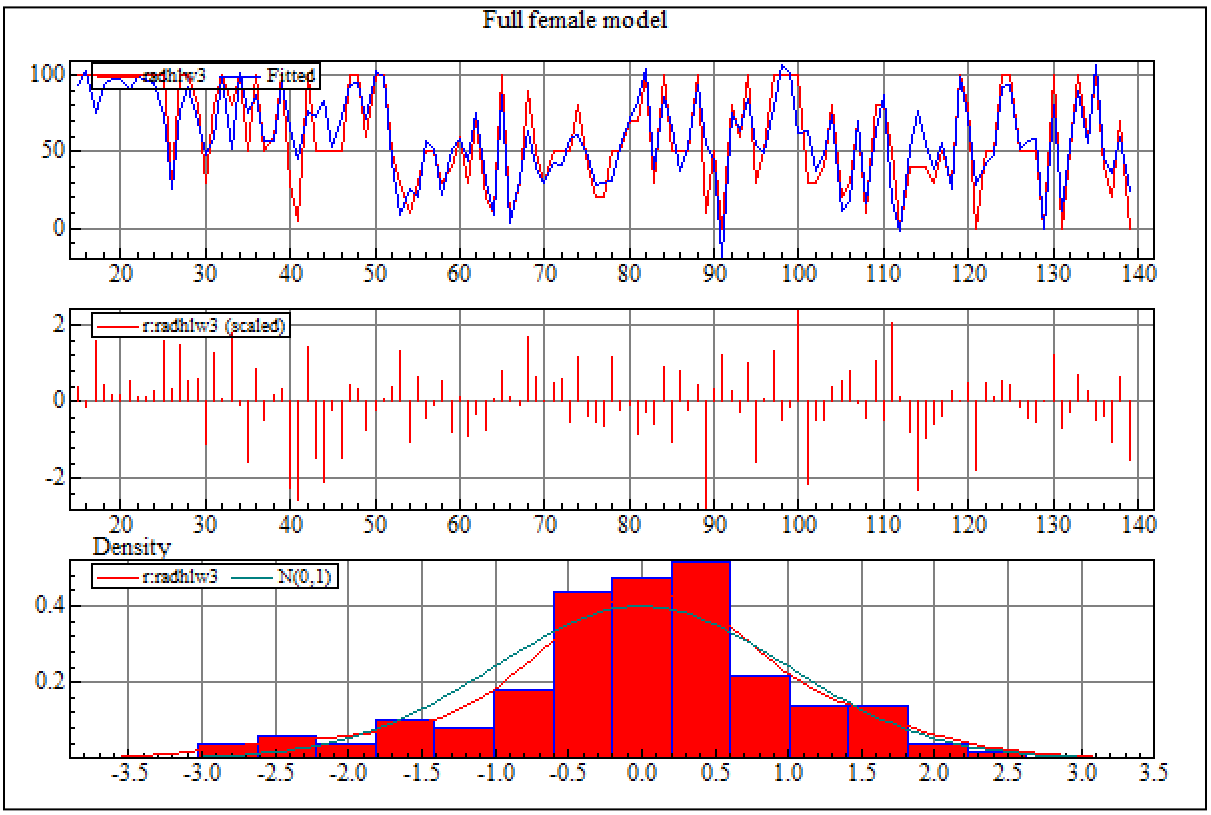

Table 15: The full female model

Source	SS	df	MS		
Model	111007.17	15	7400.478	Number of obs =	131
Residual	27883.456	115	242.464835	F(15, 115) =	30.52
				Prob > F =	0.0000
Total	138890.626	130	1068.38943	R-squared =	0.7992
				Adj R-squared =	0.7731
				Root MSE =	15.571

radhlw3	Coef.	Std. Err.	t	P>|t|	Beta
age	-.3038169	.1510938	-2.01	0.047	-.0946104
radfmw2	.272598	.1057981	2.58	0.011	.2490103
radfmw3	.5622618	.1006332	5.59	0.000	.5774146
airw1	.0874437	.0461524	1.89	0.061	.0864931
medw3	-.1674847	.0640629	-2.61	0.010	-.163723
jsw2	-.0743405	.0508045	-1.46	0.146	-.0636272
radw2	-.1869172	.0893251	-2.09	0.039	-.1719836
radw3	.1229323	.0892775	1.38	0.171	.1142209
dauthw3	.2080689	.0604451	3.44	0.001	.2186378
healthef	.1371077	.0537205	2.55	0.012	.1296794
injselfr	14.72378	3.66454	4.02	0.000	.2067633
shjobw2	-.100339	.0407456	-2.46	0.015	-.1163543
illw1	-9.020986	2.354287	-3.83	0.000	-.1813116
hp2inthob	8.290422	4.943292	1.68	0.096	.0761232
lcumdosew3	6.193443	1.880279	3.29	0.001	.1631171
_cons	-33.46208	15.3946	-2.17	0.032	.

Table 16 Specification tests for the full female model

Assumption	**Test**	**X^2, f, F, t, or z**	**p-value**	**violation**
Residual normality	*Shapiro-Wilk test* *Kolmogorov-Smirnov test*	Z= 2.156 Adj X^{2} = 12.03	0.0156 0.0024	Yes
Residual homoskedasticity	*Breusch –Pagan /Cook Weisburg test*	$X^2(1)$ =0.78	.3774	No
No outliers	*Standardized residuals > |3.5|*	none	n.a.	No
No omitted variables	*Ramsey reset test*	F(3,112) = 3.06	0.0312	yes
No multicollinearity	*VIF < 10*	Mean VIF=	24.04	yes

At this point in time we need to validate our full female model and our robust model with a bootstrap. We control for the autocorrelation between waves by employing a robust estimator that accounts for cluster correlation of observations between the waves. First we turn to our bootstrap version of the full female model.

Table 17: Bootstrapped validation with cluster control

```
Linear regression                               Number of obs      =       131
                                                Replications       =      1000
                                                Wald chi2(15)      =    724.30
                                                Prob > chi2        =    0.0000
                                                R-squared          =    0.7992
                                                Adj R-squared      =    0.7731
                                                Root MSE           =   15.5713

                                  (Replications based on 131 clusters in id)
```

radhlw3	Observed Coef.	Bootstrap Std. Err.	z	P>|z|	Normal-based [95% Conf.	Interval]
age	-.3038169	.1805706	-1.68	0.092	-.6577288	.050095
radfmw2	.272598	.1070354	2.55	0.011	.0628124	.4823836
radfmw3	.5622618	.1040837	5.40	0.000	.3582614	.7662622
airw1	.0874437	.0449644	1.94	0.052	-.0006849	.1755723
medw3	-.1674847	.0709812	-2.36	0.018	-.3066053	-.0283642
jsw2	-.0743405	.0388308	-1.91	0.056	-.1504474	.0017665
radw2	-.1869172	.102681	-1.82	0.069	-.3881683	.0143339
radw3	.1229323	.1116475	1.10	0.271	-.0958927	.3417574
dauthw3	.2080689	.071227	2.92	0.003	.0684666	.3476711
healthef	.1371077	.0549569	2.49	0.013	.0293941	.2448212
injselfr	14.72378	4.813633	3.06	0.002	5.289234	24.15833
shjobw2	-.100339	.0405047	-2.48	0.013	-.1797268	-.0209512
illw1	-9.020986	3.714953	-2.43	0.015	-16.30216	-1.739812
hp2inthob	8.290422	5.168376	1.60	0.109	-1.839409	18.42025
lcumdosew3	6.193443	2.173823	2.85	0.004	1.932828	10.45406
_cons	-33.46208	16.62766	-2.01	0.044	-66.05168	-.8724717

The parameter estimates are identical to our full model. The bootstrapped standard errors are almost the same. What is different? Age is less significant. The impact on interests and hobbies remains nonsignificant as does the decline in significance in the amount of area currently polluted. The air and water pollution is almost significant, yet not quite. Job satisfaction is more but not yet statistically significant. The goodness of fit tests yield the same results. It is clear that the bias corrected and accelerated bootstrap tends to confirm our full female model.

If we trim out some of the nuisance variables, we wonder whether this will hold. In the trimmed female model, we try to remove all but significant variables in hopes of conserving power to detect significant effects. We arrive at a model that is displayed in Table 18 below. We note that the goodness of fit remains high at 0.799 and the adjusted goodness of fit remains at 0.788. The small difference between these two measures suggests that there is little excess baggage in our model as far as carrying what counts in the fit of the model.

The Trimmed Female Model

Table 18 the Trimmed Female Model

Source	SS	df	MS
Model	157753.255	9	17528.1395
Residual	39815.2946	170	234.207615
Total	197568.55	179	1103.73492

Number of obs =	180
F(9, 170) =	74.84
Prob > F =	0.0000
R-squared =	0.7985
Adj R-squared =	0.7878
Root MSE =	15.304

radhlw3	Coef.	Std. Err.	t	P>|t|	Beta
age	-.2163813	.1155508	-1.87	0.063	-.075808
radfmw2	.2815784	.0855072	3.29	0.001	.2555046
radfmw3	.5988896	.0809581	7.40	0.000	.584237
airw1	.084669	.0375522	2.25	0.025	.082121
illw1	-9.336928	2.137204	-4.37	0.000	-.1634565
hp2inthob	8.458827	3.659904	2.31	0.022	.0925371
injselfr	11.36841	3.140457	3.62	0.000	.1451339
shjobw2	-.0739095	.031792	-2.32	0.021	-.0853095
lcumdosew3	5.520209	1.453196	3.80	0.000	.1439299
_cons	-33.87275	10.21534	-3.32	0.001	.

All of the variables in the trimmed version of the model were in the full female model. What has changed is that we now have nine explanatory variables rather than fifteen. All of these variables are statistically significant with the exception of age, which is almost significant. 6767Whereas in the full model, we had eleven significant variables, now we have eight. The goodness of fit approximates 0.80 if we round off to the nearest hundredth and this remains about. In short, we have a more parsimonious model.

What is noteworthy is that in both models we find a positive significant relationship between the actual external exposure to cesium 137 and the self-perceived health risk from the Chornobyl radiation and that this is inversely proportional to the count of illnesses that the respondent reports. It may be that the fewer the number of illnesses to contend with, the easier it is to properly attribute the source of the ailments.

Among the variables that were trimmed out of the model were the danger from the authorities, job satisfaction in the decade after the accident, current danger from the media, and stresses and hassles related to the job in the ten years after the accident, along with the percent of the area contaminated during waves two and three. Whereas in the full model the positive relationship between that health risk and the amount of air and water believed to be polluted by the radiation was not significant at the 0.05 level, the relationship is significant in the trimmed model. In both models, we see a significant relationship between injury to oneself because of Chornobyl and perceived self-health risk due to Chornobyl radiation. In both models, perceived self-health risk due to radiation is statistically significant, positively, and several times greater than unity in magnitude in its association with external exposure to cesium 137 radiation.

When we ask whether the model is well specified, we observe that four out of five assumptions are violated by the specification of this model. The residuals are not normal. They are significantly non-normal according to the Shapiro-Wilk and Kolmogorov-Smirnov tests. Although the homoskedasticity of the model is not violated, there is one negative outlier, substantial multicollinearity, and evidence of omitted variable bias from the Ramsey Reset test.

Table 19 Specification tests for the trimmed female model

Assumption	**Test**	**X^2, f, F, t, or z**	**p-value**	**violation**
Residual normality	*Shapiro-Wilk test* *Kolmogorov-Smirnov test*	Z= 4.135 Adj X^2 = 19.01	0.0002 0.0001	Yes
Residual homoskedasticity	*Breusch –Pagan /Cook Weisburg test*	$X^2(1)$ =1.53	0.2154	No
No outliers	*Standardized residuals > |3.5|*	1 negative outlier t=-3.6007		yes
No omitted variables	*Ramsey reset test*	F(3,167) =4.95	0.0026	yes
No multicollinearity	*VIF < 10*	Mean VIF= 25.82		yes

Unless we can confirm our model with a bootstrap validation, it is likely that the model residuals will not give us an exact basis for rejecting our hypotheses about the variables we are testing. For this reason, we turn to our cluster controlled bootstrap method.

The Trimmed female bootstrapped model

Can we validate this with a bootstrap? Again, we endeavor to find empirical standard errors through resampling with replacement. Because we replace the observations, we may get several of the same observations each time we sample. The samples will not be the same. Over the long haul, the consistency of the variance estimator should lead us to fairly precise estimates of the standard errors after we correct for bias with bias correction and correct for skewed results with acceleration of the process.

Table 20 Bootstrapped Trimmed Female Model

```
Linear regression                               Number of obs      =        180
                                                Replications       =       1000
                                                Wald chi2(9)       =    1260.79
                                                Prob > chi2        =     0.0000
                                                R-squared          =     0.7985
                                                Adj R-squared      =     0.7878
                                                Root MSE           =    15.3038

                                   (Replications based on 180 clusters in id)
```

radhlw3	Observed Coef.	Bootstrap Std. Err.	z	P>|z|	Normal-based [95% Conf.	Interval]
age	-.2163813	.1163617	-1.86	0.063	-.4444461	.0116835
radfmw2	.2815784	.089908	3.13	0.002	.105362	.4577947
radfmw3	.5988896	.0838497	7.14	0.000	.4345472	.763232
airw1	.084669	.0418968	2.02	0.043	.0025527	.1667853
illw1	-9.336928	3.838602	-2.43	0.015	-16.86045	-1.813407
hp2inthob	8.458827	3.524806	2.40	0.016	1.550334	15.36732
injselfr	11.36841	4.204483	2.70	0.007	3.127777	19.60905
shjobw2	-.0739095	.0318832	-2.32	0.020	-.1363993	-.0114196
lcumdosew3	5.520209	1.649261	3.35	0.001	2.287717	8.752701
_cons	-33.87275	11.09931	-3.05	0.002	-55.627	-12.1185

As before, we observe that the parameter estimates of the regression coefficients are identical. The goodness of fit measures are the same. The signs of the coefficients in both the bootstrapped and nonbootstrapped models are identical. Furthermore, we note that in both the bootstrapped and nonbotstrapped models, the significances are all significant at the 0.05 level with the exception of the age variable, which is significant at the 0.10 level. In short, all of the variables that are statistically significant in the nonbootstrapped model are statistically significant in the bootstrapped model. The net conclusion is that the model has been validated by the bootstrap.

Model reliability

We have endeavored to demonstrate the reliability of the models with bootstrap validation. We now examine the proportion of the total number of models the core variables are significant in. This will give us a sense of which variables are meaningful explanations of the self-perceived health risk stemming from the Chornobyl radiation. We have a total of six models for the whole dataset, and for each gender. We have a full and a trimmed model for each of these subsets. We now tally the number of models in which the core variables are statistically significant. Hendry advocates testing the candidate models against the general unrestricted model to test whether the candidate model is more theoretically encompassing that the general unrestricted model. His retention of variables often facilitates this process. Some of these variables are not theoretically critical variables. They tend rather to be auxiliary variables, whose inclusion may facilitate model fit, specification, or prediction, but are not essential to explanatory appeal or power. We could watch the variation in the core variables to observe their extreme bounds to assess the reliability of the model. Instead, we use the Hendry and Krolzig method to assess variable reliability (Leamer, E.E., 1982; Lu and White, 2010).

Variable reliability

From our collection of full and trimmed models, we have a total of six models, not including the bootstrapped validation. We could compute a reliability score for each variable (Hendry and Krolzig, 1999). We could weight these scores in accordance with the level of significance found. Wherever the variable was found almost significant ($p < .10$), we could give half a credit. Wherever the variable was found significant ($p < .05$ or $p < .001$), we could assign a count of one. We tally the count for each variable used in one or more of these models and multiply that tally by a weight of 16.67 to obtain a total reliability score.

The variable reliability table for the 37 variables that were found significant or non-significant can be found on the next page. We employ a method similar to that of Hendry D.F. and Krolzig, H-M., 1999, 2001).

Directions for future research:

After collecting more of the total sample, we will set up the sampling weights. We will then use models based on the complex samples to find the proper variances for our household survey. We will use multiple imputation to replace missing values. Then we will rerun these models.

When we rerun these models, we will retest the relationship between the perceived health risk of Chornobyl radiation and our explanatory variables. As Frank Harrell, Jr. has suggested, we will not assume linearity and will use lowess plots to discern possible nonlinear functional form between our endogenous variable and its explanatory variables. We will test each variable for functional form by generating lowess plots for the relationship between our dependent variable and each of the explanatory variables especially where the reset test has yielded a significant result. If necessary, we will transform the explanatory variable to improve the linear fit, perhaps with a squashing function or polynomial (Hendry, D.F., 2010, Castle, J., 2009 and Politis, D., 2008)." If we can find that this improves model fit, we can use this transformation instead of the original variable. We will then test the first-order and possibly higher order interactions between these linear main effects and their predictor variables.

Table 21: Variable Reliability

var #	Variable	reliability
1	lcumdossq	0.00
2	sex	0.00
3	airw2	0.00
4	airw3	0.00
5	anxiety	0.00
6	jsw2	0.00
7	radw1	0.00
8	radw3	0.00
9	illw2	0.00
10	illw3	0.00
11	injothr	8.33
12	radfmw1	16.67
13	liqw2	16.67
14	depress	16.67
15	ecprw1	16.67
16	medw3	16.67
17	radw2	16.67
18	dauthw3	16.67
19	healthef	16.67
20	age	25.00
21	movew2	25.00
22	radfmw2	33.33
23	sepaw3	33.33
24	shhlw1	33.33
25	illw1	33.33
26	childw3	41.67
27	liqw3	41.67
28	enlev	50.00
29	vishphw1	50.00
30	liqw1	58.33
31	hp2inthob	58.33
32	shjobw2	66.67
33	lcumdosew3	66.67
34	injselfr	66.67
35	cons	66.67
36	airw1	75.00
37	radfmw3	100.00

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