School of Economics Working Paper 2016-01

University of East Anglia

SCHOOL OF ECONOMICS

A Coefficient of Risk Vulnerability

by Philomena M. Bacon*
Anna Conte**
Peter G. Moffatt***

*Aviva UK & Ireland,
**Westminster Business School, University of Westminster
***School of Economics, University of East Anglia

Abstract
Panel data from the German SOEP is used to test for risk vulnerability (RV) in the wider population. Two different survey responses are analysed: the response to the question about willingness-to-take risk in general; and the chosen investment in a hypothetical lottery. A convenient indicator of background risk is the VDAX index, an established measure of volatility in the German stock market. This is used as an explanatory variable in conjunction with HDAX, the stock market index, which proxies wealth. The impacts of these measures on risk attitude are identifiable by exploiting the time dimension of the panel, and matching survey months with corresponding observations from these time-varying factors. Both of the survey responses allow us to test for decreasing absolute risk aversion (DARA); in one case we find strong evidence of DARA, while in the other, we do not. Both survey responses also allow us to test for RV, and in both cases we find strong evidence. In the case of the hypothetical lottery response we are also able to estimate a "coefficient of risk vulnerability" (CRV). This is defined as the absolute amount by which absolute risk aversion rises in response to a doubling of background risk. We estimate CRV to be between 1.03 and 1.27.

JEL classification codes
D81; D91; C23
Keywords
risk vulnerability; background risk; panel data; survey data.

School of Economics
University of East Anglia
Norwich Research Park
Norwich NR4 7TJ
United Kingdom
www.uea.ac.uk/economics

A Coefficient of Risk Vulnerability

Philomena M. Bacon[a,*], Anna Conte[b] and Peter G.Moffatt[c]

[a] *Aviva UK & Ireland, Life Analytics, Surrey St, Norwich, United Kingdom, NR1 3DR*

[b] *Westminster Business School, University of Westminster, London, United Kingdom, NW1 5LS*

[c] *School of Economics, University of East Anglia, Norwich, United Kingdom, NR4 7TJ*

January 26, 2016

Abstract

Panel data from the German SOEP is used to test for risk vulnerability (RV) in the wider population. Two different survey responses are analysed: the response to the question about willingness-to-take risk in general; and the chosen investment in a hypothetical lottery. A convenient indicator of background risk is the VDAX index, an established measure of volatility in the German stock market. This is used as an explanatory variable in conjunction with HDAX, the stock market index, which proxies wealth. The impacts of these measures on risk attitude are identifiable by exploiting the time dimension of the panel, and matching survey months with corresponding observations from these time-varying factors. Both of the survey responses allow us to test for decreasing absolute risk aversion (DARA); in one case we find strong evidence of DARA, while in the other, we do not. Both survey responses also allow us to test for RV, and in both cases we find strong evidence. In the case of the hypothetical lottery response we are also able to estimate a "coefficient of risk vulnerability" (CRV). This is defined as the absolute amount by which absolute risk aversion rises in response to a doubling of background risk. We estimate CRV to be between 1.03 and 1.27.

Keywords: risk vulnerability; background risk; panel data; survey data.

JEL: D81; D91; C23

*We acknowledge access to the Germany Social and Economic Panel for use in this research under licence number: 2596.

1 Introduction

There is much empirical evidence of decreasing absolute risk aversion (DARA), the phenomenon of an individual becoming more willing to take risk when their wealth increases by an absolute amount. This evidence comes from both the field (e.g., Hamal and Anderson, 1982) and the laboratory (e.g., Levy, 1994). A related concept is risk vulnerability (RV) (Gollier and Pratt, 1996). This is the phenomenon of an individual becoming less willing to take risk when mean-zero background risk (independent of other risks) is added to their wealth.

Risk vulnerability is an important hypothesis, especially in the light of the 2008 global financial crisis, and the global recession that followed. The period of (and immediately following) the crisis amounted to a textbook example of a period of abnormally high background risk. It is important to understand the impact of this on individuals' risk attitude in order to gain greater insight into our understanding of the overall impact of the crisis for future reference. It has been shown, for example, that risk vulnerable agents respond to an increase in background risk by adjusting their portfolio in favour of safe assets, and by demanding more insurance (Gollier and Pratt, 1996).

In many theoretical studies, RV is assumed. For example, Heaton and Lucas (2000) invoke the assumption in their explanations of portfolio puzzles. However, perhaps surprisingly, there is comparatively little empirical evidence of RV.

Experimental evidence of RV has been found by Beaud and Willinger (2014), Lusk and Coble (2008) and others. However, there appears to be little consensus on how background risk can be convincingly generated in a controlled way in the domain of the laboratory. An obvious logical problem is that any sort of risk that is generated within the experiment should surely (by definition) be classified as "foreground" risk.

Survey data provide an alternative testing ground for the RV hypothesis. A notable contribution in this regard is Guiso and Paiella (2008). They consider a single cross section of Italian individuals who participated in an experiment involving a hypothetical investment question. The interpretation of background risk used is the variance over time in per capita GDP in the province of residence for each participant. Their findings suggest that this measure of background risk has a strongly negative impact on individuals' risk tolerance, implying consistency with RV.

Extending this style of investigation with the use of repeated observations per individual, West and Worthington (2014) explore the dynamics of an Australian panel data set to estimate the impact of macroeconomic conditions on risk tolerance. They do this by exploiting annual variation in the macroeconomic variables. Although they do not explicitly refer to background risk, they find that interest rates and consumer price level both have significantly negative effects on risk tolerance. Our methodology is similar to theirs in respect of exploiting a panel data set, and bringing in time-varying factors. Within this framework we extend the avenue of research to embrace the concept of risk vulnerability.

The panel data we use is the German Socio-Economic Panel (SOEP). This consists of repeated data on a large number of individuals. We focus on two outcome variables. The first is the response to the direct question about willingness to take risks in general. This response is provided on a 0-10 Likert scale (Likert, 1932). Hence, the random effects ordered probit model is used for the analysis of this outcome. The second outcome is the response to a hypothetical lottery investment question. An individual's response to this question may be taken to imply that that individual's coefficient of absolute risk aversion lies in a particular interval. Consequently, the random effects interval regression model is used for the analysis of this outcome.

In order to test for DARA and RV, we match repeated responses to these risk-related questions in the panel, to observations (from the month immediately preceding the survey date) on the time-varying factors, HDAX and VDAX. HDAX is the German stock market index, which acts as a proxy for wealth, and hence a test of the impact of HDAX on risk attitude amounts to a test of DARA. VDAX is an established indicator of volatility in the German stock market,[1] thereby having a direct interpretation as a measure of background risk prevailing in any given time period. Consequently, a test of the impact of VDAX on risk attitude may be interpreted as a test of RV.

In addition to testing for risk vulnerability in the manner described above, we will go a step further by deducing an estimate of the "coefficient of risk vulnerability" (CRV), which will be defined in due course.

The paper is organized as follows: Section 2 describes the data; Section 3 discusses the modelling strategies; Section 4 reports and discusses the results, and also constructs an estimate of the CRV; and Section 5 concludes.

2 The SOEP data set

The German Socio-Economic Panel Survey (SOEP) has been running since 1984, and surveys a cohort of approximately 20,000 households annually, inquiring into lifestyle and economic activities (Frick et al., 2007, Jürgen and Gert, 2007). In 2004 the survey broadened to include the first questions associated with risk attitude.

What we will refer to as the "general risk question" was repeated biennially until 2008 after which it was asked annually, with the last observation considered in the research being in 2012. The "general risk question" is given by:

> *How do you see yourself? Are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?" Please tick a box on the scale, where 0*

[1] More specifically, the VDAX represents the expected volatility of the DAX index in the next 30 days. It is expressed in percentage points. The equivalent of VDAX in the US stock market is the well-known VIX, which is also known as the "fear index".

means "risk averse" and the value 10 means "fully prepared to take risks"

☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
0	1	2	3	4	5	6	7	8	9	10

For the sake of homogeneity, we consider head-of-households only. The resulting sample consists of 11,903 individuals observed an average of 3.68 times each. Histograms of the general risk response for each year separately are presented in Figure 1. The most interesting feature of these histograms is the changing shape of the distribution of responses between years. In 2004 and 2006, it appears that the distribution is fairly symmetric around the midpoint of 5, roughly implying risk neutrality. In 2008, 2009, and 2010, however, there is a definite sense that the distribution is more concentrated on the lower half, implying a tendency to risk aversion. These years, of course, correspond to the global recession which followed the 2008 global financial crisis. The asymmetry is seen most clearly in 2009, and this is not surprising since 2009 is considered to be the nadir of the crisis. In 2011 and 2012, we see an apparent return to symmetry, and the distribution for 2012 appears surprisingly similar to the pre-crisis distributions seen in 2004 and 2006. Since the impact of the crisis on the response is exactly the sort of effect in which we are most interested, repeated responses over this particular set of years appear ideal for testing the hypothesis of RV.

Data on responses to the general risk question forms the focus of our first model described in Section 3.1 below.

The second question that is of interest to us is the "hypothetical lottery question". The question takes the following form:

> *Imagine that you have won €100,000 in the lottery. Immediately after receiving your winnings you receive the following offer: You have the chance to double your money. But it is equally possible that you will lose half the amount invested. You can participate by staking all or part of your €100,000 on the lottery, or choose*

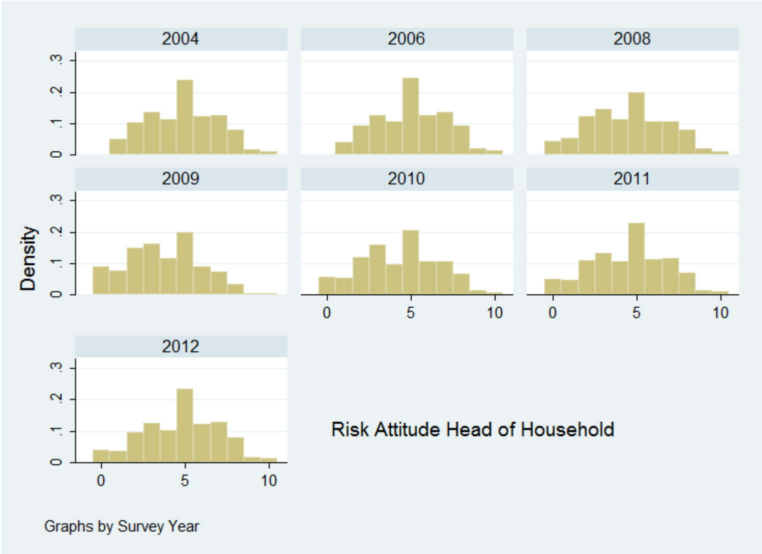

Figure 1: Distribution of self-reported risk attitude (household head)

not to participate at all. What portion of your lottery winnings are you prepared to stake on this financially risky, yet potentially lucrative lottery investment?

€100,000 (i.e. all of it);

€80,000;

€60,000;

€40,000;

€20,000;

Nothing: I would decline the offer

The hypothetical lottery question was asked only twice, in 2004 and in 2009. Histograms of responses for these two years are shown in Figure 2. Again it is illuminating to compare the histograms between years. In both cases, we see a mode at the choice of a zero investment, implying risk aversion. However, this mode appears much more prominent in 2009 than in 2004, and again it is reasonable to hypothesize that this is a consequence of 2009 coinciding with the nadir of the global recession that followed the financial crisis.

Data on responses to the hypothetical lottery question form the focus of our second model

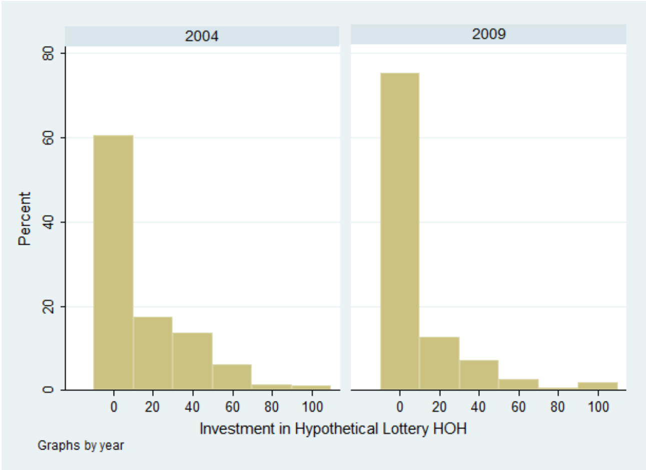

Figure 2: Distribution of response to hypothetical lottery question

which is described in Section 3.2.

From the SOEP data we also extract a number of demographic variables which are used as explanatory variables in the two models.[2] These include age, gender, marital status, and years of education. Descriptive statistics of all variables used, along with SOEP dataset codes, are supplied in Table A.1 of the Appendix.

As mentioned in Section 1, the financial variables we use are the German stock market index (HDAX) and the German stock market volatility index (VDAX).[3] On the assumption that a significant portion of an individual's wealth is held in common stock, the former is a suitable proxy for an individual's wealth, while the latter is a proxy for the prevailing level of background risk. In Figure 3, we present time series plots of these two variables (HDAX, left pane, and VDAX, right pane). The solid sections of the lines represent years in which data on responses to the general risk question are available; the shaded bars represent periods in which the hypothetical lottery question was asked. The most important features of these plots are the steep *fall* in HDAX and the even steeper *rise* in VDAX that coincide with the onset of the global financial crisis in 2008.

[2]Demographic variables are obtained from the longitudinal SOEPv29 files: *SOEP pl_en* and *SOEP pequiv_en*.
[3]Monthly data on HDAX and VDAX are obtained from Datastream.

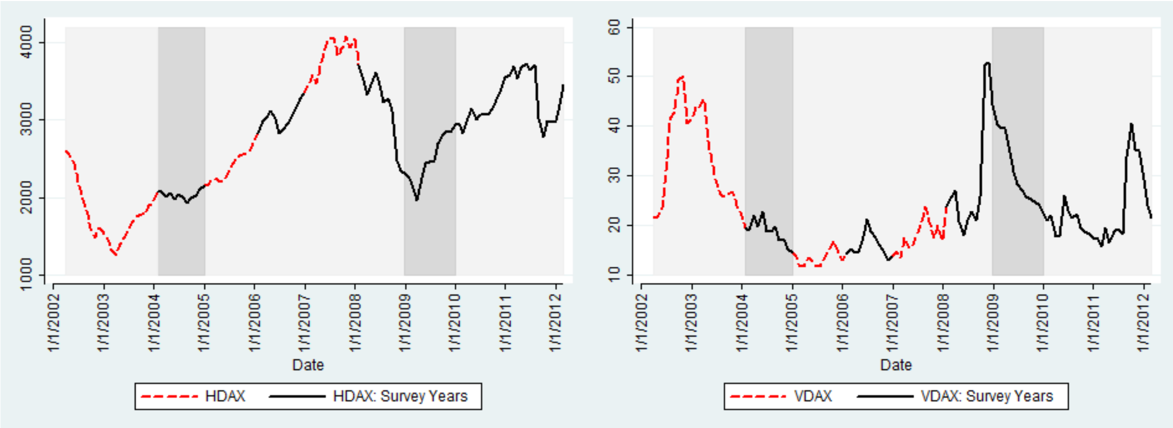

Figure 3: HDAX, Stock market index (left pane), and VDAX, Stock market volatility (right pane), over time. Source: Datastream. Solid sections of the lines represent periods in which data on responses to the general risk question are available; the shaded vertical bars represent the periods in which the hypothetical lottery question was asked.

Linking together the observations made from the two time series graphs (Figures 3) with those from the two histograms of response data (Figures 1 and 2) leads directly to the two testable hypotheses that are the focus of this paper. A positive effect of HDAX on willingness to take risk (or a negative effect on absolute risk aversion) will amount to evidence of DARA. A negative effect of VDAX on willingness to take risk (or a positive effect on absolute risk aversion) will amount to evidence of RV.

3 Modelling strategies

In this section, we shall develop modelling strategies for the responses to the two risk-related survey questions presented and discussed in Section 2.

3.1 General risk attitude: Model 1

For responses to the general risk question, we shall use the random effects ordered probit model, which is outlined as follows.[4]

Let i index respondent, $i = 1, \ldots, n$, and let t index time period, $t = 1, \ldots, T$. Let y_{it} be

[4] For further details of the random effects ordered probit model, see Greene and Hensher (2010, chapter 9). Maximum likelihood estimation of its parameters may be obtained using the `xtoprobit` command available in STATA (StataCorp, 2011).

respondent i's response to the general risk question about risk-taking in period t, and assume that this can take one of the integer values $1, 2, 3, \ldots, J$. Let $y^*_{it}(-\infty < y^*_{it} < +\infty)$ be the underlying latent variable representing respondent i's propensity to risk-taking in period t. Let x_{it} be a vector of characteristics relevant in explaining the risk-attitude of respondent i at time t. Let z_t be a vector of financial variables. The random effects ordered probit model is based on the assumption that y^*_{it} depends linearly on x_{it} and z_t, according to:

$$y^*_{it} = x'_{it}\beta + z'_t\gamma + u_i + \epsilon_{it} \tag{1}$$

$$u_i \sim N(0, \sigma^2_u), \quad \epsilon_{it} \sim N(0, 1) \qquad i=1, \cdots, n, \quad t=1, \cdots T.$$

β and γ are vectors of parameters; neither contains an intercept. There are two stochastic terms: the individual-specific term u_i, and the random error term ϵ_{it}. Note that these are both assumed to be normally distributed with mean zero; the variance of u_i is a free parameter, while the variance of ϵ_{it} is, for identification, normalised to 1. This normalisation is required in order to set the otherwise arbitrary scale of the latent variable y^*. The latent variable y^* is linked to the observed variable y via a set of $J - 1$ cut-point parameters, which are estimated along with the other parameters.

We will be particularly interested in the elements of γ. The parameter estimate associated with HDAX (resp. VDAX) will enable us to test DARA (resp. RV).

3.2 The hypothetical lottery question: Model 2

For responses to the hypothetical lottery question, we shall use the random effects interval regression model, which is outlined as follows.[5]

We will assume that each individual has the Constant Absolute Risk Aversion (CARA) utility function:

$$U(x) = 1 - \exp(-rx) \qquad -\infty < r < \infty; \quad x > 0 \tag{2}$$

[5]The interval regression approach is similar in many ways to the ordered probit approach outlined in Section 3.1. One important difference is that in the former, the cut-points defining the intervals are known numbers, while in the latter, the cut-points are unknown and are therefore parameters to be estimated.

so that the individual's coefficient of absolute risk aversion is r. Recall from Section 2 that the hypothetical lottery question requires respondents to choose one of six possible "investments" in a particular lottery.[6] It is easily established using (2) that (assuming expected utility maximisation) each of the six possible investment choices implies a range for r, and the limits of these ranges are presented in Table 1.[7]

Investment	r lower	r upper
€100,000	$-\infty$	0.50
€80,000	0.50	0.70
€60,000	0.70	0.95
€40,000	0.95	1.50
€20,000	1.50	4.70
€0	4.70	∞

Table 1: Ranges of coefficient of absolute risk aversion (r) implied by different investment choices in hypothetical lottery question, assuming expected utility maximisation.

As in Section 3.1, let i index respondent, $i = 1,\ldots,n$, and let t index time period, t=1,...,T. For respondent i in period t let y_{it} be the investment choice and let r_{it} be the coefficient of absolute risk aversion. Since observations on y_{it} imply intervals for r_{it}, we model the variable r_{it} as follows.

$$\begin{aligned} r_{it} &= x_{it}'\beta + z_t'\gamma + u_i + \epsilon_{it} \qquad i = 1,\ldots,n; \quad t = 1,\ldots,T \\ u_i &\sim N\left(0, \sigma_u^2\right); \epsilon_{it} \sim N\left(0, \sigma_\epsilon^2\right) \end{aligned} \tag{3}$$

The relationship between the observed investment choice y_{it} and the (latent) risk attitude variable r_{it} is (using the values from Table 1):

[6]Please refer back to Section 2 for a description of the lottery.

[7]To understand where the numbers in Table 1 come from, consider the first row. For simplicity, let us measure money amounts in units of €100,000. If a respondent indicates that they would invest the entire €100,000, they are opting for a 50:50 gamble between 0.5 units and 2 units, and the expected utility of this gamble is $1 - 0.5\exp(-0.5r) - 0.5\exp(-2r)$. If they instead chose the next riskiest investment of €80,000, they are opting for a 50:50 gamble between 0.6 units and 1.8 units, with expected utility $1 - 0.5\exp(-0.6r) - 0.5\exp(-1.8r)$. The value of r that equalises these two expected utilities is 0.50. Hence, anyone whose CARA parameter is less than 0.50 will invest €100,000, while anyone whose CARA is greater than 0.50 will invest a smaller amount. This explains the upper limit of 0.50 appearing in the first row of Table 1. Numbers appearing in other rows are obtained using similar reasoning.

$$
\begin{aligned}
y_{it} = 100,000 \quad &\Rightarrow \quad -\infty < r_{it} \leq 0.50 \\
y_{it} = 80,000 \quad &\Rightarrow \quad 0.50 < r_{it} \leq 0.70 \\
y_{it} = 60,000 \quad &\Rightarrow \quad 0.70 < r_{it} \leq 0.95 \\
y_{it} = 40,000 \quad &\Rightarrow \quad 0.95 < r_{it} \leq 1.50 \\
y_{it} = 20,000 \quad &\Rightarrow \quad 1.50 < r_{it} \leq 4.70 \\
y_{it} = 0 \quad &\Rightarrow \quad 4.70 < r_{it} \leq \infty
\end{aligned}
\tag{4}
$$

(3) and (4) together define the random effects interval regression model whose parameters may be estimated using Maximum likelihood.[8]

With reference to (3), the risk attitude for respondent i at time t, r_{it}, depends on the respondent's characteristics, contained in x_{it}, and also on financial variables as pertaining at time t, contained in z_t. Once again, we are interested in the elements of γ. In particular, let γ_v be the coefficient associated with the logarithm of our background risk measure, VDAX. If we define the coefficient of risk vulnerability (CRV) to be the absolute change in absolute risk aversion resulting from a doubling of background risk, then[9]

$$
\text{CRV} = \gamma_v \log(2) \tag{5}
$$

An estimate of CRV, defined in (5), will be obtained in the next section.

4 Results

The estimation results are presented and discussed in the following subsections.

[8]Using the `xtintreg` command in STATA (StataCorp, 2011).

[9]To understand (5), assume that $r = \alpha + \beta \log v$ and suppose that v doubles from v to $2v$. Before this change, the value of r is $\alpha + \beta \log v$ and after the change it is $\alpha + \beta \log 2v = \alpha + \beta \ln v + \beta \log 2$. The change in r resulting from the doubling of v is therefore $\beta \log 2$.

4.1 Testing for risk vulnerability using self-reported risk attitude

In Table 2, we present results from the application of the random effects ordered probit model, described in Section 3.1, to panel data on self-reported willingness to take (general) risk. Model 1 in Table 2 explains the response purely in terms of demographic characteristics of the individual, and the effect of each of these variables is strongly significant. In particular, we see a greater propensity to take risks by younger, more highly-educated, unmarried, males. These findings are in agreement with previous research using the same data source on the determinants of risk attitude (Dohmen et al., 2011).

Model 2 in Table 2 includes an income/wealth variable in the form of the logarithm of income from asset flows. This variable has a strongly positive effect on the propensity to take risk, and this result is consistent with decreasing absolute risk aversion (DARA).

Finally, Model 3 in Table 2 includes the two financial variables $\log(\text{HDAX})_{-1}$ and $\log(\text{VDAX})_{-1}$, respectively the logarithm of the two indices HDAX and VDAX in the month previous to the month of the interview. As explained previously, HDAX is included to capture the effect of changes in wealth, while VDAX captures the effect of changes in background risk. The strongly positive coefficient on HDAX therefore amounts to further evidence of DARA. The strongly negative effect of VDAX indicates that individuals are less willing to take risks at times when the stock market is more volatile. Treating stock market volatility as a measure of background risk, this result may be interpreted as strong evidence of risk vulnerability (RV).

4.2 Testing for risk vulnerability using hypothetical lottery choice

We now turn to the results from estimating Equation 3 using the random effects interval regression model, as explained in Section 3.2. Recall that the underlying latent variable in this model is the respondent's coefficient of absolute risk aversion. Hence we expect the coefficient estimates in this model to be of opposite signs to the corresponding estimates reported in table 2 (since the latent variable underlying that model was willingness to take risk).

General Risk	Model 1	Model 2	Model 3
Male	0.488***	0.486***	0.489***
	(0.0163)	(0.0163)	(0.0166)
Married	-0.0679***	-0.0756***	-0.0783***
	(0.0140)	(0.0141)	(0.0143)
Age	-0.0187***	-0.0189***	-0.0185***
	(0.000445)	(0.000447)	(0.000461)
# Years of education	0.0312***	0.0287***	0.0301***
	(0.00254)	(0.00259)	(0.00263)
Log(income asset flows)		0.00953***	0.0101***
		(0.00202)	(0.00204)
Log(HDAX)$_{-1}$			.0593**
			(0.0223)
Log(VDAX)$_{-1}$			-0.646***
			(0.0148)
σ_u	0.937***	0.958***	0.959***
	(0.008)	(0.008)	(0.008)
n	21903	21903	21903
T (mean of)	3.68	3.68	3.68
Log-likelihood	-162745.0	-162733.9	-161488.31

Dep. var.: Willingness to take risks (Likert scale 0-10, over 2004-2012)
Standard errors in parentheses.* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: Random Effects Ordered Probit Results (cut points estimates not reported).

The results of the random effects interval regression model are reported in Table 3. Again we start with a base specification (Model 1) in which only characteristics of the respondent are included. The signs of each of these effects are consistent with those in table 2, and with results elsewhere in the literature.

The second specification (Model 2) is one which includes a measure of individual wealth, in the form of the logarithm of income from assets. As expected, this has a strongly negative effect, implying decreasing absolute risk aversion (DARA).

Finally, Model 3 includes the two financial variables log(HDAX)$_{-1}$ and log(VDAX)$_{-1}$. Log(HDAX)$_{-1}$ appears to have a strongly positive effect on risk aversion. This can only be seen as an unexpected result. Given the role of HDAX as a proxy for wealth, decreasing absolute risk aversion leads to the prediction that the coefficient of log(HDAX)$_{-1}$ in this model

	Model 1	Model 2	Model 3
Male	-0.877***	-0.8412***	-0.7926***
	(0.0664)	(0.0660)	(0.0656)
Married	01383*	0.2699***	0.3150***
	(0.0641)	(0.0647)	(0.0641)
Age	0.0492***	0.0528***	0.0477***
	(0.00194)	(0.00196)	(0.0020)
# Years of education	-0.1607***	-0.125***	-0.1346***
	(0.0102)	(0.0105)	(0.0105)
Log(income asset flows)		-0.1424***	-0.1357***
		(0.0114)	(0.0113)
Log(HDAX)$_{-1}$			2.8234***
			(0.3402)
Log(VDAX)$_{-1}$			1.6557***
			(0.0902)
Constant	6.1296***	6.129***	-20.6948***
	(0.166)	(0.1664)	(2.5200)
σ_u	1.8957***	1.857***	1.953***
	(0.0562)	(0.0566)	(0.0532)
σ_e	2.997***	2.998***	2.862***
	(0.0277)	(0.0276)	(0.0287)
n	23,448	23,448	23,488
T (mean of)	1.5	1.5	1.5
Log-likelihood	-26620.072	-26541.034	-26246.513

Dep. var.: Coefficient of absolute risk aversion (r)
left censored=340; right censored=15,973; interval= 7,126.
Standard errors in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3: Random effects interval regression using investment choices in hypothetical lottery.

will be negative. However, note that the coefficient of asset income is still strongly negative, suggesting that asset income is successfully performing the role of a wealth proxy, while we must look elsewhere for the source of the positive effect of HDAX.

Once again the coefficient of log(VDAX)$_{-1}$ is consistent with the hypothesis of risk vulnerability: Log(VDAX)$_{-1}$ has a strongly positive effect on risk aversion. If we apply (5) to the coefficient of +1.66, we obtain a coefficient of risk vulnerability (CRV) of +1.15, with a 95% confidence interval of (1.03,1.27).[10] The point estimate is interpreted as follows. If background risk doubles, as it appeared to do at the onset of the global financial crisis (see

[10]The 95% confidence interval is obtained as the point estimate ± 1.96 standard errors. In accordance with (5), the standard error of the estimate of CRV is simply obtained by multiplying the relevant standard error from Table 3 by ln(2).

Fig. 3, right pane), a typical agent's coefficient of absolute risk aversion is expected to rise by an amount 1.15.

5 Conclusion

We have used two very different survey questions from the German SOEP to test for risk vulnerability (RV). The first is self-reported risk attitude, and the second is investment choice in a hypothetical lottery. Analysis of the two outcomes has called for the use of two different econometric models: random effects ordered probit and random effects interval regression. Our chosen measure of background risk is the VDAX, which represents the level of volatility in the German stock market. In both estimations, this variable is strongly significant with a sign consistent with RV.

Given our objective of testing RV, it has been particularly useful to have used data from a time period (2004-2012) that includes what is now widely recognized to be a period of higher-than-normal background risk, the 2008 global financial crisis.

The concept of a coefficient of risk vulnerability (CRV) has been introduced for the first time. Using the hypothetical lottery choice data, we have obtained an estimate of CRV of 1.15. The 95 % confidence interval for CRV of (1.03,1.27), being far from zero and reasonably narrow, indicates firstly that a typical agent does indeed display RV, and secondly that CRV is being estimated with admirable precision.

Appendix: Summary statistics

Dataset Code	Survey year	2004	2006	2008	2009	2010	2011	2012
plh0204 &plh0205	General risk question							
plh0203	Risk-win-lottery question							
d11101	Age Mean	51.32	52.15	53.06	53.45	54.06	54.73	55.00
	Age SD	16.32	16.58	6.64	16.62	16.62	16.68	16.73
	Age Min	18	18	18	18	18	19	18
	Age Max	97	97	98	99	100	101	102
d1110211	% Male	60.93	59.62	58.19	57.57	57.02	56.73	56.33
d11104	% Married	57.52	55.60	55.11	54.38	54.09	53.37	53.0
d11106	YoE Mean	12.12	12.14	12.24	12.26	12.33	12.25	12.30
	YoE SD	2.93	2.98	2.97	2.96	2.99	3.00	3.02
	YoE Min	5	5	5	5	5	5	5
	YoE Max	18	18	18	18	18	18	18
i11104	Asset Inc Mean	3,161.59	3,163.66	3,245.14	2,245.2	2,357.32	2,186.05	2,284.25
	Asset Inc SD	53,762.19	60,757.58	35,554.53	15,149.99	11,678.75	14,366.41	20,069.16
	Asset Inc Min	0	0	0	0	0	0	0
	Asset Inc Max	5,231,467	6,332,078	2,898,971	887,204	746,290	1,112,222	1,736,389
	N	11,729	12,437	11,064	11,858	10,822	12,295	12,316

Table 4: Table A.1: Descriptive statistics. First column shows SOEP data codes for each variable. YoE is years of education. N is number of individuals (household heads) per survey year that answered the general risk question.

References

Beaud, M. and Willinger, M. (2014), 'Are people risk vulnerable?', *Management Science* **61**(3), 624–636.

Dohmen, T. J., Falk, A., Huffmann, D., Schupp, J. and Wagner, G. (2011), 'Individual risk attitudes: Measurement, determinants, and behavioral consequences', *Journal of the European Economic Association* **9(3)**, 522–550.

Frick, J. R., Jenkins, S. P., Lillard, D. R., Lipps, O. and Wooden, M. (2007), 'The cross-national equivalent file (cnef) and its member country household panel studies', *Schmollers Jahrbuch* **127**(4), 627–654.

Gollier, C. and Pratt, John, W. (1996), 'Risk vulnerability and the tempering effect of background risk', *Econometrica* **64**(5), 1109–1123.

Greene, W. H. and Hensher, D. A. (2010), *Modeling ordered choices: a primer*, Cambridge University Press.

Guiso, L. and Paiella, M. (2008), 'Risk aversion, wealth and background risk', *Journal of the European Economic Association* **6**(6), 1109–1150.

Hamal, K. and Anderson, J. R. (1982), 'A note on decreasing absolute risk aversion among farmers in Nepal', *Australian Journal of Agricultural Economics* **26**(3).

Heaton, J. and Lucas, D. (2000), 'Portfolio choice in the presence of background risk', *The Economic Journal* **110**(460), 1–26.

Jürgen, S. and Gert, W. (2007), 'The german socio-economic panel study (soep): Scope, evolution and enhancements', *SOEPpapers on Multidisciplinary Panel Data Research* .

Levy, H. (1994), 'Absolute and relative risk aversion: An experimental study', *Journal of Risk and Uncertainty* **8**(3), 289–307.

Likert, R. (1932), *A Technique for the Measurement of Attitudes*, Vol. Archives of Psychology, No. 140, Columbia University Press, New York.

Lusk, J. L. and Coble, K. H. (2008), ‘Risk aversion in the presence of background risk: Evidence from an economic experiment’, *Risk aversion in experiments* **12**, 315–340.

StataCorp (2011), *Stata Statistical Software: Release 12*, College Station, TX: StataCorpLP.

West, T. and Worthington, Andrew, C. (2014), ‘Macroeconomic conditions and Australian financial risk attitudes, 2001-2010’, *Journal of Family and Economic Issues* **35**(2), 263–277.