EUROPEAN CENTRAL BANK

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WHAT DO ASSET PRICES HAVE TO SAY ABOUT RISK APPETITE AND UNCERTAINTY?

by Geert Bekaert,
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In 2009 all ECB publications feature a motif taken from the €200 banknote.

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Abstract

Implied volatility indices should have information about risk parameters, once they are cleansed of the influence of normal volatility dynamics and macroeconomic uncertainty. Building on intuition from the dynamic asset pricing literature, we uncover unobserved risk aversion and fundamental uncertainty from the observed time series of the VIX and the credit spreads while controlling for realized volatility, expectations about the macroeconomic outlook, and interest rates. We apply this methodology to monthly data from both Germany and the US. We find that implied volatilities contain a substantial amount of information regarding risk aversion whereas credit spreads have a lot to say about both risk aversion and uncertainty. Moreover, there is a significant comovement in the German and US risk aversion.

Keywords: Economic uncertainty, Risk aversion, Time variation in risk and return, Credit spread, Volatility dynamics

JEL Classification: G12, E44

Non-Technical Summary

In recent times, it has become increasingly commonplace to assume that changes in risk appetites are an important determinant of asset prices. Not surprisingly, the behavioral finance literature has developed "sentiment indices," and there is now a wide variety of "risk aversion indicators" available, created by financial institutions. Global risk appetite also plays a large role in international finance and development economics work on contagion. The formal "structural" dynamic asset pricing literature has meanwhile proposed time-varying risk aversion as a potential explanation for salient asset price features (see Campbell and Cochrane (1999) and a large number of related articles), whereas the reduced-form asset pricing models, focused on simultaneously explaining stock return dynamics and option prices, have also concluded that time-varying prices of risk are important drivers of stock return and option price dynamics (see Bollerslev, Gibson and Zhou, 2004). Finally, some recent studies point to a potential link between loose monetary policy and the risk appetite of market participants, spurring a literature on what structural economic factors exactly would drive risk aversion changes (see, e.g., Rajan, 2006).

In this paper, we develop a measure of time-varying risk aversion that is relatively easy to estimate or compute, so that it can be compared to the practitioners' indices. However, the model we use is inspired by the dynamic asset pricing literature. We view risk aversion and economic uncertainty as two main drivers of asset pricing dynamics and model them as latent variables. We achieve identification by using many asset prices (as is often the case in the practitioners' literature) and economically inspired restrictions on the dynamics of these variables. In particular, we lean heavily on the idea that the implied volatility indices (like the VIX) should have information about risk parameters, once they are cleansed of the influence of normal volatility dynamics and uncertainty. This idea is prevalent in the reduced form stock return dynamics literature (see, e.g., Duan and Yeh, 2007). Moreover, dynamic asset pricing theory suggests that risk premiums and asset prices likely depend on both economic uncertainty and risk aversion. To measure risk aversion, macroeconomic uncertainty has to be controlled for.

The identification strategy we employ is akin to the identification strategy in old work by Hamilton (1985) and Fama and Schwert (1979), trying to identify the real rate process from data on nominal interest rates and inflation through parametric assumptions on the dynamics of the various variables. The methodology is simple and easily generalizable to include additional asset prices and other potential determinants of risk aversion.

We apply the technique to uncover risk aversion and uncertainty for Germany and the US. Our sample period is January 1992 to March 2008. We find both series to be highly persistent in both countries. Moreover, the two risk aversion series show a significant comovement across countries. We also analyze links between the uncovered variables and various observable series. Implied volatility of the stock market contains a substantial amount of information regarding risk aversion. Credit spreads contain information about both risk aversion and economic uncertainty. Finally, when risk aversion is high, there are significant flight-to-safety effects in both Germany and the US.

1 Introduction

It has become increasingly commonplace to assume that changes in risk appetites are an important determinant of asset prices. Not surprisingly, the behavioral finance literature (see, e.g., Lemmon and Portnaiguina (2006) and Baker and Wurgler (2008) for a discussion) has developed "sentiment indices," and there is now a wide variety of "risk aversion indicators" available, created by financial institutions (see Coudert and Gex (2008) for a survey). Global risk appetite also plays a large role in international finance and development economics work on contagion (see, e.g., González-Hermosillo, 2008). The formal "structural" dynamic asset pricing literature has meanwhile proposed time-varying risk aversion as a potential explanation for salient asset price features (see Campbell and Cochrane (1999) and a large number of related articles), whereas reduced-form asset pricing models, focused on simultaneously explaining stock return dynamics and option prices, have also concluded that time-varying prices of risk are important drivers of stock return and option price dynamics (see Bollerslev, Gibson, and Zhou, 2004). Finally, some recent studies point to a potential link between loose monetary policy and the risk appetite of market participants, spurring a literature on what structural economic factors would drive risk aversion changes (see, e.g., Rajan, 2006).

Our goal is to develop a measure of time-varying risk aversion that is relatively easy to estimate or compute, so that it can be compared to the practitioners' indices. However, the model we use is inspired by the dynamic asset pricing literature. We view risk aversion and economic uncertainty as two main drivers of asset pricing dynamics and model them as latent variables. However, we do not impose the strong restrictions structural models would impose on the dynamics of asset prices. Instead, we achieve identification by using many asset prices (as is often the case in the practitioners' literature) and economically inspired restrictions on the dynamics of these variables. In particular, we lean heavily on the idea that the implied volatility indices (like the VIX) should have information about risk parameters, once they are cleansed of the influence of normal volatility dynamics and uncertainty. This idea is prevalent in the reduced form stock return dynamics literature (see, e.g., Duan and Yeh, 2007). Moreover, dynamic asset pricing theory (see, for instance, Bansal and Yaron (2004), Bekaert, Engstrom, and Xing (2009) for recent examples and Abel (1988) for older work) suggests that risk premiums and asset prices likely depend on both economic uncertainty and risk aversion. To measure risk aversion, macroeconomic uncertainty has to be controlled for.

The identification strategy we employ is akin to the identification strategy in old work by Hamilton (1985) and Fama and Schwert (1979), trying to identify the real rate process from data on nominal interest rates and inflation through parametric assumptions on the dynamics of the various variables. The methodology is simple and easily generalizable to include additional asset prices and other potential determinants of risk aversion.

We apply the technique to uncover risk aversion and uncertainty for Germany and the US. Our sample period is January 1992 to March 2008. We find both series to be highly persistent in both countries. Moreover, the two risk aversion series show a significant comovement across countries. We also analyze links between the uncovered variables and various observable series. Implied volatility of the stock market contains a substantial amount of information regarding risk aversion. Credit spreads contain information about both risk aversion and economic uncertainty. Finally, when risk aversion is high, there are significant flight-to-safety effects in both Germany and the US.

The rest of the paper is organized as follows. Section 2 gives a literature review. Section 3 presents the model and estimation strategy in detail. Section 4 briefly outlines the data we use. Section 5 extracts risk aversion and uncertainty from asset prices and discusses the links between the risk aversion estimates and various financial variables. The final section concludes and previews future work.

2 Related Literature

Our work is related to four strands of literature: 1) structural dynamic asset pricing models, 2) empirical option pricing, 3) behavioral finance, and 4) practitioners' measures of risk aversion.

Recent structural dynamic asset pricing models, such as Campbell and Cochrane (1999) and Bansal and Yaron (2004), have identified changes in risk aversion and economic uncertainty as potentially important drivers of asset price dynamics. Campbell and Cochrane (1999) show that a model with countercyclical risk aversion accounts for a large equity premium, substantial variation in returns and price-dividend ratios and long-horizon predictability of returns. According to their model, investors fear stocks primarily because they do poorly in recessions, when their consumption levels fall close to a "habit stock". Menzly, Santos, and Veronesi (2004) propose a general equilibrium model with multiple securities in which investors' risk preferences and expectations of dividend growth are time-varying. They primarily focus on the implications for the predictability of returns and for dividend growth. Brandt and Wang (2003) and Wachter (2006) present related consumption-based models of time-varying risk aversion, whereas Bekaert, Engstrom, and Grenadier (2004) show that changes in risk aversion that are not fully driven by fundamentals are essential in fully capturing asset price dynamics.

Bansal and Yaron (2004) and Bansal, Khatchatrian, and Yaron (2005), among others, focus on economic uncertainty as a source of fluctuations in asset prices and risk premiums. Our model builds primarily on Bekaert, Engstrom, and Xing (2009). The model features stochastic risk aversion, using "external habit" preferences as in Campbell and Cochrane, but also time-varying uncertainty in the fundamentals. They find that variation in asset prices is primarily driven by changes in risk aversion, but variation in the equity premium is driven by changes in both risk aversion and uncertainty.

Second, this paper is related to the literature on extracting information about risk and risk preferences from option prices (for a survey, see Gai and Vause, 2006)[1]. Bollerslev et al. (2004) estimate the stochastic volatility risk premium from S&P 500 option-implied volatilities and high-frequency-based realized volatilities. They link this estimate to macroeconomic variables and they find that the extracted volatility risk premium helps predict future stock market returns. Drechsler and Yaron (2008) show that the variance premium, defined as the difference between the squared VIX index and expected realized variance, only depends on risk parameters and non-Gaussian components of the fundamental variance. They model investors' preferences using the Epstein and Zin (1989) specification which allows to separate risk aversion and the intertemporal elasticity of substitution. They find that both variation in fundamental uncertainty and a preference for early resolution of uncertainty are required to generate a positive variance premium that is time-varying. Beber and Brandt (2008) measure macroeconomic uncertainty using prices of economic derivatives and uncover a strong link with implied volatilities of stock and bond returns around macroeconomic announcements.

Third, in the behavioral literature, our paper is related to Baker and Wurgler (2006), Lemmon and Portnaiguina (2006), and Qiu and Welch (2006). Baker and Wurgler (2006) create an index of investor sentiment using the closed-end fund discount, share turnover, IPO information etc. They study how investor sentiment affects the cross-section of stock returns, arguing and showing that investor sentiment disproportionately affects securities whose valuations are highly subjective and difficult to arbitrage, such as small, young, and high volatility stocks. Qi and Welch (2006) show that the Michigan consumer confidence index correlates much more strongly with a direct survey measure of investor sentiment than does the closed-end fund discount. Lemmon and Portnaiguina (2006) explore the time-series relationship between investor sentiment and the small-stock premium using consumer confidence as a measure of investor optimism. They decompose consumer confidence into components related to economic fundamentals and investor sentiment. They find that over the

[1]Specific articles include Ait-Sahalia et al. (2001), Broadie et al. (2007), Chernov and Ghysels (2000), Duan and Yeh (2007), Pan (2002), Rosenberg and Engle (2002), and Scheicher (2003).

last 25 years, investor sentiment forecasts the returns of small stocks and stocks with low institutional ownership in a manner consistent with the predictions of models based on noise-trader sentiment.

Fourth, practitioners have developed various measures of risk aversion. Coudert and Gex (2008) assess the performance of these indicators, testing whether they are able to forecast crises. The main finding is that the indicators seem to be good leading indicators of stock market crises, but not of currency crises.

The dynamic asset pricing and options literatures indirectly reveal the difficulty in interpreting many existing risk aversion indicators. Often they use information such as the VIX or return risk premiums that are obviously driven by both the amount of risk and risk aversion. Disentangling the two is not straightforward. Articles such as Bollerslev et al. (2004) and Drechsler and Yaron (2008) point towards the use of the VIX in combination with the (conditional) expected variance as particularly informative about risk preferences. While both should be closely associated with economic uncertainty, the conditional variance of equity returns is likely to be much less affected by risk preferences than the VIX.

3 The Model

We develop a parsimonious empirical strategy to uncover unobserved risk aversion and fundamental uncertainty from observed time series of the VIX, realized volatility, and other asset prices. Our approach is to follow the dynamic asset pricing literature in spirit. That is, we specify the state variable dynamics with risk aversion and uncertainty as two key latent variables. However, we do not model the pricing kernel. There is much disagreement about how preferences must be modelled and hence, the specification of the kernel would very much color what risk aversion process is implied. Instead, we simply assume that there is a linear mapping between the VIX, the conditional volatility, and other asset prices on the one hand and the state variables on the other hand. While this relationship cannot literally be linear in any asset pricing model, it may prove a good first-order approximation. For example, Bekaert, Engstrom, and Xing (2009) show that in their model the equity premium and price–dividend ratio are well approximated by a linear function of the two key state variables, uncertainty, and risk aversion. The cost of the approach is that we cannot rely on a model to attain identification. Hence, our identification comes from restrictions on the dynamics of the state variables and the mapping between state variables and endogenous variables.

Let's start with a simple model with four state variables, which we collect in the vector X_t:

$$X_t = [uc_t, ra_t, i_t, muc_t]',$$

where uc_t denotes fundamental uncertainty, ra_t denotes risk aversion, i_t is the short-term interest rate, and muc_t stands for survey uncertainty about the macroeconomic outlook. While i_t and muc_t are observable, uc_t and ra_t are latent variables.

In a structural model, the interest rate process would be endogenous. While we take it to be exogenous in our framework, we will model its dynamics to be consistent with standard structural asset pricing models. We add uncertainty about the macroeconomic outlook as an observable proxy to true uncertainty. The model could be easily generalized to allow for a large number of proxies for macroeconomic uncertainty, and we could also introduce observable proxies for risk aversion.

Our major identifying assumption is to model uncertainty and risk aversion as simple univariate but heteroskedastic autoregressive processes:

$$\begin{aligned} uc_t &= \mu_{uc} + \phi_{uc} uc_{t-1} + \sigma_{uc}\sqrt{muc_{t-1}}e_t^{uc} \\ ra_t &= \mu_{ra} + \phi_{ra} ra_{t-1} + \sigma_{ra}\sqrt{muc_{t-1}}e_t^{ra}. \end{aligned} \tag{1}$$

Hence, we assume that the variability of uncertainty and risk aversion increases when macroeconomic uncertainty is higher.

The interest rate process is inspired by a standard consumption-based asset pricing model, such as Bekaert, Engstrom, and Xing (2009):

$$i_t = \gamma_1 ra_t + \gamma_2 muc_t + \phi_i i_{t-1} + \sigma_i \sqrt{i_{t-1}} e^i_t. \tag{2}$$

We would expect γ_2 to be negative, reflecting precautionary savings demand. However, the link between risk aversion and the interest rate cannot be signed, as it may reflect both utility smoothing and precautionary savings motives. We also introduce heteroskedasticity of the square-root form.

We treat survey uncertainty muc_t as a proxy for the unobserved fundamental uncertainty:

$$muc_t = uc_t + \phi_{muc} muc_{t-1} + \sigma_{muc} \sqrt{muc_{t-1}} e^{muc}_t,$$

i.e. muc_t provides a noisy signal about true uncertainty. Most empirical measures of economic uncertainty are clearly imperfect proxies to true economic uncertainty. We also allow for additional autoregressive effects, because our measure of uncertainty forecasts over a somewhat longer horizon than our data frequency, so this term helps clean up autocorrelation in the observed muc_t series. Finally, we model muc_t as heteroskedastic with its variance increasing in its level.

If we bring these processes together, X_t follows a simple first-order autoregressive process:

$$X_t = \mu_x + \Phi_x X_{t-1} + \varepsilon^x_t,$$

where $\mu_x = [\mu_{uc}, \mu_{ra}, \mu_i, \mu_{uc}]'$ is the vector of drifts of the state variables, ε^x_t is the vector of innovations, and

$$\Phi_x = \begin{bmatrix} \phi_{uc} & 0 & 0 & 0 \\ 0 & \phi_{ra} & 0 & 0 \\ 0 & \gamma_1\phi_{ra} & \phi_i & \gamma_2\phi_{muc} \\ \phi_{uc} & 0 & 0 & \phi_{muc} \end{bmatrix}. \tag{3}$$

Let $\varepsilon_t^x = \Sigma_{x,t-1} e_t^x$ with $e_t^x \sim N(0, I)$. It follows that

$$\Sigma_{x,t-1} = \begin{bmatrix} \sigma_{uc}\sqrt{muc_{t-1}} & 0 & 0 & 0 \\ 0 & \sigma_{ra}\sqrt{muc_{t-1}} & 0 & 0 \\ 0 & \gamma_1\sqrt{muc_{t-1}} & \sigma_i\sqrt{i_{t-1}} & \gamma_2\sigma_{muc}\sqrt{muc_{t-1}} \\ \sigma_{uc}\sqrt{muc_{t-1}} & 0 & 0 & \sigma_{muc}\sqrt{muc_{t-1}} \end{bmatrix} \tag{4}$$

so that $\Sigma_{x,t-1}$ contains the standard deviations of the state variables' shocks.

To identify the dynamics of the state variables, we conjecture that a number of observable asset prices or asset price characteristics are an affine function of the state variables:

$$Y_t = b_y + B_y X_t + u_t.$$

For identification purposes we will set $b_y = 0$. Two elements of Y_t are simply the "observed" state variables, in our case i_t and muc_t. The dimension of Y_t can be arbitrarily large but it must be at least as large as the dimension of X_t. When $\dim(Y_t) > \dim(X_t)$, stochastic singularities arise, which is why we introduce measurement error, u_t. Our identification strategy is to split up $Y_t = [Y_t^{1\prime}, Y_t^{2\prime}]'$, where Y_t^1 has the same dimension as X_t and is used to "invert" the state variables. The remaining elements in Y_t, Y_t^2, are then assumed to be measured with error relative to the model; consequently, $u_t = [0, u_t^{2\prime}]'$. For future reference, let us also decompose

$$B_y = \begin{bmatrix} B_y^1 \\ B_y^2 \end{bmatrix}.$$

With this notation in hand, it is straightforward to write down the likelihood function. Using $X_t = \left[B_y^1\right]^{-1} Y_t^1$, the dynamics for Y_t can be described as follows:

$$\begin{aligned} Y_t^1 &= \mu_y^1 + A_y^1 Y_{t-1}^1 + B_y^1 \varepsilon_t^x && (5) \\ Y_t^2 &= B_y^2 \left[B_y^1\right]^{-1} Y_t^1 + u_t^2, && (6) \end{aligned}$$

where $\mu_y^1 = B_y^1 \mu_x$ and $A_y^1 = B_y^1 \Phi_x \left[B_y^1\right]^{-1}$. Define $\varepsilon_t^y = \left[\left(B_y^1 \varepsilon_t^x\right)', u_t^2{}'\right]'$, then,

$$\Sigma_{y,t-1} = \begin{bmatrix} B_y^1 \Sigma_{x,t-1} & 0 \\ 0 & \Sigma_u \end{bmatrix}$$

where Σ_u is a diagonal matrix of measurement error standard deviations. The likelihood function can then be written as

$$\mathcal{L} = -\frac{Tn}{2} \log(2\pi) - \frac{T}{2} \log\left[\det\left(\Sigma_y\right)\right] - \frac{1}{2} \sum_{t=1}^{T} \left(\varepsilon_t^y{}' \Sigma_{y,t-1}^{-1} \varepsilon_t^y\right). \tag{7}$$

As a practical application, we let

$$Y_t^1 = [cs_t, vix_t, i_t, muc_t]'$$

and

$$Y_t^2 = [ts_t, rv_t]'$$

where cs_t is the credit spread, which is generally believed to be very sensitive to investor risk appetites and vix_t is the "risk-neutral" implied volatility. Other variables that may have additional information on risk aversion and uncertainty are the term spread, ts_t, and the realized volatility, rv_t. These variables should react to both risk aversion and uncertainty and the interest rate.[2]

Our crucial identifying assumption is that vix_t varies only due to the two unobserved factors, uc_t and ra_t. In particular, we impose that:

$$B_y^1 = \begin{bmatrix} B_{cs}^{uc} & B_{cs}^{ra} & B_{cs}^{i} & 0 \\ B_{vix}^{uc} & B_{vix}^{ra} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{8}$$

[2] At this point, we do not use stock market information because it is quite difficult to control for cash flow expectations in the context of the current model, without considerably increasing the state space. Moreover, we simply do not have adequate data for Germany to do so.

and

$$B_y^2 = \begin{bmatrix} B_{ts}^{uc} & B_{ts}^{ra} & B_{ts}^{i} & 0 \\ B_{rv}^{uc} & B_{rv}^{ra} & B_{rv}^{i} & 0 \end{bmatrix}.$$

To obtain identification, we also assume that $B_{vix}^{ra} = 1$. This is tantamount to using cs and vix to determine the level of uc_t and ra_t. Moreover, we assume that, once movements of uncertainty are controlled for, the VIX and risk aversion move one-to-one.

If we substitute the Y_t^1 dynamics in the Y_t^2 equation in (6), we have a VAR on Y_t with a number of cross-equation restrictions. A necessary condition for identification is that the number of parameters in the unconstrained VAR for Y_t exceeds the number of parameters in the model we specify. It is easily verified that this is the case in the current specification. A natural test of the model will be to compare the likelihood of an unconstrained VAR relative to the likelihood of our model.

While only cs_t, vix_t, and i_t are used directly in uncovering the unobservables, information content in ts_t and rv_t enters the estimation of the parameters in B_y. Naturally, alternative specifications are possible in which, for example, rv_t is used to estimate the unobservables directly, while cs_t enters the estimation indirectly. We have estimated such alternative models, finding the implied risk aversion measures to be highly correlated across different specifications.

4 Data

Our sample, extending from January 1992 to March 2008, comprises US and German stock prices, volatilities, interest rates, credit spreads, and survey information. Table 1 lists the variables, their definitions, and data sources.

We use volatility indices to measure the option-implied volatility of stock returns. VIX represents implied volatility for the S&P 500 index and VDAX for the DAX index of 30 major German stocks. Both VIX and VDAX represent the implied volatility of a hypothetical at-the-money option with a horizon of 30 calendar days. Both volatility estimates are model-free approaches, i.e. they no longer rely on the Black-Scholes option pricing model, as the first generation of implied volatility indices did.

In particular, the VIX is based on a weighted average of S&P 500 options that straddle a 30-day maturity, i.e. a fixed horizon of 22 trading days (see CBOE (2004) for more details). The basis is provided by European-style out-of-the money puts and calls of 2 nearest to 30 calendar days expiries, covering a wide range of strikes. The shorter-horizon options are restricted to a maturity in excess of eight days. The number of strike prices included is dependent on the out-of-the-money (call or put) option at a given strike having a non-zero price (based on the mid-quote). The result is an estimate of the square root of implied variance across options of all strikes on the S&P 500. The same procedure is used by EUREX to calculate the VDAX. The implied volatility indices also form the underlying instruments for volatility futures and variance swaps and are calculated at an intraday frequency.

Our estimate of the realized volatility is given by the summation of daily squared returns on the S&P 500 or DAX index within a given month (see Andersen et al. (2003) for more details on this approach).

Expectations about macroeconomic outlook are based on the ZEW Financial Market Survey (Zentrum für Europäische Wirtschaftsforschung, Mannheim, Germany). The survey polls about 350 financial market analysts every month on their expectations regarding the developments in each of the G7 countries. We extract information on macroeconomic uncertainty from the following question: In the medium-term (six months) the overall macroeconomic situation will: 1) Improve; 2) No Change; 3) Worsen. We have proportions of responses in each category for every month. To quantify these qualitative data, we follow the Carlson and Parkin (1975) method (see Appendix for details).

Short-term interest rates are given by the 3-month T-bill for the US and the corresponding German government bill yield.[3]

Figure 1 plots the time series of the model inputs. The plots of the volatilities are

[3]The market for these securities in Germany is less liquid than the US T-bill market, but it is important to keep the rates comparable in terms of (lack of) default risk.

dominated by three periods of turbulence, namely the collapse of LTCM in October 1998, the aftermath of the "irrational exuberance" in the early 2000s and the financial turmoil which started in the summer of 2007. The VIX recorded its sample high with a value of 45.74 on 08/10/1998 and its low of 9.31 on 22/12/1993. In the case of the VDAX, the low of 9.35 was on 22/05/1992 and the sample high of 62.63 on 07/10/2002. Figure 1 also shows that uncertainty about the US macroeconomic outlook rises sharply following the onset of the financial turmoil in August 2007. It reaches its sample high in March 2008. By contrast, while uncertainty about the German macroeconomic outlook has been rising since June 2007, its level remains well below the sample high recorded in January 1992, which reflects the aftermath of re-unification.

5 Empirical Results

5.1 Parameter Estimates

In estimating the model, we fix the scale of the unobserved fundamental uncertainty at 0.01, i.e. $\sigma_{uc} = 0.01$. Table 2 presents the parameter estimates for Germany and the US, respectively. A number of results are notable.

First, we find high persistence of the two unobservable series. The autocorrelation coefficient of the risk aversion process is 0.93 for Germany and 0.89 for the US. As for the uncertainty process, persistence is slightly lower for Germany (0.81) than for the US (0.92). Hence, both processes are characterized by a high level of autocorrelation in their time series and the effect of past shocks decays only slowly. This also implies that market participants' attitude to risk contains a sizable predictable component.

Second, the estimated state variable dynamics reveal interesting relationships between risk aversion and macroeconomic uncertainty, on the one hand, and the short rate, on the other hand. We find that the US short-term rate is negatively related to uncertainty ($\gamma_2 < 0$). This is consistent with theory: in times of high uncertainty, investors desire to save more (precautionary savings effect) and so bond prices rise, while interest rates fall. In Germany, γ_2 is insignificantly different from zero. The relation between risk aversion and the short-term rate is in theory subject to two offsetting effects: the aforementioned precautionary savings effect but also a utility smoothing effect. Higher risk aversion today leads to an expectation that future risk aversion will be relatively lower (due to stationarity). This induces a desire to borrow from the future, forcing down bond prices and raising interest rates (see Bekaert et al., 2009). We find a negative relation between the risk aversion and the short-term rate for both Germany and the US. Hence, the precautionary savings channel dominates the utility smoothing channel.

Of course, such effects can also be interpreted as flight-to-quality effects. When risk aversion increases, investors shift from stocks to bonds. This rebalancing of investors' positions leads to a rise in bond prices and a fall in the short-term interest rates. Such a phenomenon has been observed during episodes of severe financial market stress such as the LTCM collapse in October 1998 or the current financial crisis.

The elements in B_y are mostly significant at the 5% level. Credit spreads are positively related to all state variables, i.e. uncertainty, risk aversion, and the interest rate. Perhaps surprisingly, the VIX, which is assumed to move one for one with risk aversion, loads negatively on uncertainty. This is also true for realized volatility, which has a similar dependence on risk aversion and uncertainty as the VIX does. Its relation with the interest rate is positive but not very significant. The term spread is negatively correlated with all three state variables.

Next, we study model fit. Because the model implies a restricted VAR for the observed Y_t variables, we have a natural alternative hypothesis, namely the unconstrained VAR, appended with the same heteroskedasticity structure as the model. The model fits the unconstrained dynamics very well. The likelihood ratio test yields values of 3.19 for the US and 3.66 for Germany. Because the model is parsimonious - 21 parameters govern the feedback dynamics instead of 42 for a full VAR - these test statistics yield p-values of 0.999. The Akaike information criterion (AIC) selects the constrained model for both countries. For the US, the unrestricted VAR yields an AIC value of 0.31, versus 0.1 for the restricted model. Similarly, for Germany, the values are 0.31 and 0.099, respectively.

5.2 Time Series Behavior

Our main output are estimates of the risk aversion and uncertainty series for Germany and the US, which we plot in Figures 2 and 3. Risk aversion is expressed as a deviation from the sample average (set equal to 100) and uncertainty is re-scaled to match annualized GDP volatility on average.

The time series plots of risk aversion are dominated by several periods of turbulence (shaded episodes in Figure 2): 1) the Asian crisis in the second half of 1997; 2) the collapse of LTCM in October 1998; 3) the aftermath of the "irrational exuberance" and period of accounting uncertainties (2000 - 2003) with a peak in 2002; and 4) the credit market turmoil (since summer 2007). Both risk aversion series recorded their sample highs in the aftermath of the irrational exuberance episode (March 2003 for Germany and September 2002 for the US) and their lows in the middle of the 1990s (October 1996 for Germany and January 1994 for the US).

Investigating the behavior of the risk aversion estimates in the current market turmoil is of obvious interest. The market turmoil started in summer 2007 in the US subprime market. A market-wide reassessment of risk led to sharp increases in credit spreads across all segments of the credit market. The rapidly falling market values of credit instruments reduced both the capital as well as the profitability of the banking system and investors embarked on a "flight to safety". One illustration of the intensity of the subprime turmoil is the collapse of Bear Stearns, a major US investment bank, in March 2008. In this episode, the risk aversion series show similar but not equal increases for the US and for Germany. Risk aversion increases more in the US as compared to Germany since the impact of the subprime turmoil was more immediate for the US.

The time series plots of uncertainty exhibit business cycle-like variation (we discuss correlations with business cycle variables in the next Section). The uncertainty series for Germany recorded its sample high in March 2003 and its sample low in October 1997. For the US, the sample high of the uncertainty series was in January 2002 and its sample low in October 1997. It is interesting to note that the second highest recorded value of uncertainty for the US is in March 2008, the last data point of our sample. This reflects the effects of the ongoing credit market turmoil. Uncertainty estimates for Germany are positively correlated with the US uncertainty estimates, with a correlation equal to 0.43. This is consistent with the international business cycles literature that documents the large international impact of US shocks.[4]

The B_y^{-1} matrix reveals how risk aversion and uncertainty load on the three observed series (the credit spread, implied volatility, and the short-term rate). We report these loadings in Table 3. All are quite precisely estimated. Risk aversion loads positively on the credit spread and on implied volatility in both Germany and the US. This is consistent with the common perception that credit spreads and implied volatility indices can serve as indicators of investors' risk attitude. Uncertainty loads positively on the credit spread and negatively on implied volatility. The latter finding is somewhat counterintuitive. It indicates that implied volatility has become primarily an indicator of risk aversion and, unlike credit spreads, does not contain much information on uncertainty. This is consistent with Beber and Brandt (2008) who find no evidence of a relationship between macroeconomic uncertainty and trading activity in stock index options.

The estimation implicitly uses information on realized volatilities and term spreads as well. To gauge the relationship with all variables used, we project our estimates of risk aversion on all six variables used: implied and realized volatility, the credit spread, the term spread, and the short-term interest rate. The projection coefficients are reported in Table 4. All variables are significant for the US and all but one (realized volatility) for Germany. Risk aversion loads positively on the credit spread, the VIX and the term spread in both countries; the term spread seems relatively more

[4]See, e.g., Canova and Marrinan (1998). Eickmeier (2007) also finds an increased comovement between the German and US confidence measures, particularly since the end of the 1990s.

important in Germany than in the US. In the US, there is still a positive relation between risk aversion and realized volatility but the coefficient is rather small. The short rate is positively associated with risk aversion in Germany and negatively in the US.

5.3 Correlation analysis

Risk aversion

In Panel A of Table 5, we report the correlation between the two risk aversion series. At 0.798, it is quite high. This comovement is also clearly visible in Figure 2. Related findings have been obtained by a number of authors. Tarashev et al. (2003) also find that there is a common component in option-price-based estimates of risk aversion for major stock markets. Furthermore, Scheicher (2003) documents that an estimate of German risk aversion shows a significant reaction to information from US financial markets. Finally, González-Hermosillo (2008) finds that global market risk factors are fundamental driving forces of international bond spreads during periods of high market volatility. It is conceivable that such comovement is entirely US driven. Stathopoulos (2008) develops a general equilibrium two-country model where each country's risk aversion is priced in securities of the other country, with its importance depending on the extent of trade between the countries and their relative wealth. An important question for future research is to determine to what extent German risk aversion indeed depends on US risk aversion, or whether both react to global risk events.

Panel A also reports the correlation with a widely-used practitioner's risk aversion measure, the JP Morgan G10 Risk Tolerance Index, or the RTI. It attempts to capture three distinct types of risks: 1) liquidity risk (measured by the spread on US swaps versus Treasuries), 2) credit risk (measured by the spread of the Emerging Bond Market Index over US treasuries), and 3) financial market volatility (measured by the VIX and the trade weighted Swiss Franc, a safe haven currency and thus a proxy for risk aversion in currency markets).

The correlation between the US estimate of risk aversion and the RTI is 0.42, but for Germany, it is 0.15. The former estimate is significant at all conventional levels whereas the latter is statistically different from 0 only at the 10% level. This finding is not surprising given the composition of the RTI which is tilted towards US variables.

In Panel B of Table 5, we report simple correlations between the risk aversion estimates and financial variables. We start with variables used in the analysis: the VIX/VDAX, credit spreads, and the T-bills. For the VIX/VDAX and credit spreads, the signs and strong correlations are not surprising. The VIX is more correlated with risk aversion than the credit spread is for the US, but the reverse is true for Germany. For T-bills, the partial correlation was positive for the US (see Table 3) but the unconditional correlation is negative and quite similar to the correlation recorded for Germany. Consequently, periods of low interest rates are associated with high risk aversion. The last three rows report correlations with stock market variables: returns, the dividend yield, and the price-earnings ratio. The correlations between risk aversion measures and stock returns are contemporaneously negative for all cases. For dividend yields (price earnings ratios), we expect a positive (negative) relationship with risk aversion when risk aversion is priced. While these correlations are as expected for Germany, they are not for the US.

Of course, we should control for other variables affecting these price ratios, in particular, growth expectations. For example, the US risk aversion estimate has a correlation of 0.6 with the log of the seasonally adjusted price-earnings ratio of the S&P 500 whereas for Germany this value is -0.26. Correlations with the dividend yield are only significant for the US pair (-0.47).

Uncertainty

Table 5 (panel B) also produces the correlation between risk aversion and the uncertainty measures. For Germany, these are quite weak but for the US they are significant and positive. For both Germany and the US, higher values of uncertainty are associated with economic downturns in the near future. For example, US uncertainty has a correlation of -0.22 with four-month ahead GDP growth in the US. It has a correlation of -0.5 with one-month ahead industrial production growth.

For Germany, we compare the uncertainty estimates with a business sentiment index, namely the Economic Sentiment Index (a harmonized survey of business sentiment provided by the European Commission which uses weighted sentiment indicators in five economic sectors). We find that the estimates are negatively correlated with the current ESI and the correlation is around -0.3 with two-to-three month ahead ESI. This is higher than the correlation of the German uncertainty estimates with the ZEW survey uncertainty. This is because our uncertainty estimates are uncovered from financial market data, which are not particularly correlated with the ZEW survey uncertainty in the case of Germany. One reason for that could be that several financial variables we use derive from the DAX index which consists of only 30 stocks. Moreover, many of the firms in the DAX index are major exporters and thus have a sizable exposure to the international economy, while influence of the German economy is relatively smaller. The ZEW survey may on the other hand reflect uncertainty about more German-specific developments. This is in contrast with the S&P 500 index which has a much more diversified portfolio and is heavily affected by the US economy. In line with this reasoning, the correlation between the ZEW survey uncertainty and the US uncertainty estimates equals to 0.6.

5.4 Stock returns and risk appetite

If risk aversion is priced in the stock market, we would expect risk aversion to predict stock returns with a negative sign and stock return and risk aversion innovations to be negatively correlated. To examine this, we estimated vectorautoregressions (VARs) on excess stock market returns and three predictive variables: the T-bill rate, the dividend yield and risk aversion. We report the results for the first-order VAR in Table 6, Panel A. Surprisingly, the standard result that T-bill rates negatively predict the equity risk premium (see, for instance, Ang and Bekaert, 2007) does not hold for the US in this sample. Dividend yield is only significant for the US (at the 10% level), whereas the coefficient on risk aversion is not significant for either country. Bollerslev et al. (2004) actually found a positive and significant relationship between the "variance premium" and stock returns (at both monthly and quarterly horizons). We do find that risk aversion residuals and stock return residuals are strongly negatively correlated. This is also true for a third–order VAR. That VAR already reveals that risk aversion may have effects extending over several lags. In unreported analysis, we also uncovered some non-linear effects in the relationship between stock returns and risk aversion. Regression results reported in Panel B, Table 6 informally hint at such non-linear effects. In this regression we regress the excess stock return on past risk aversion and an interaction term multiplying the risk aversion measure with a dummy variable that is negative when the stock return is negative (at time t). Note that this is no longer a predictive regression as the dummy variable embeds information at time t. We see a very strong negative interaction effect; in other words, high risk aversion is significantly associated with bear markets. Controlling for this association, the relationship between past risk aversion and future stock market returns is significantly positive. This suggests a non-linear model, where high risk aversion may indeed predict higher stock market returns, but periods of high risk aversion may last for a while and be associated with low prices and low returns. A transition between regimes is likely associated with a strong negative jump in prices. Coudert and Gex (2008) also found some association between risk aversion and stock market downturns. We defer a further analysis of such relationships to future work.

6 Conclusions

We propose a new method of extracting time-varying risk aversion from asset prices which is inspired by the dynamic asset pricing literature. We measure risk aversion and economic uncertainty by combining information in option-implied volatilities of stock prices, credit spreads, realized volatilities, interest rates, and survey-based measures of macroeconomic uncertainty. We apply this methodology to monthly data from both Germany and the US.

While we uncovered some interesting relationships between risk aversion and other variables, more work is needed. For example, our analysis suggests that risk aversion is priced in the stock market, but we need to further explore the intricacies of the relationship between stock returns and our risk aversion measures. Also, we uncovered a strong correlation between US and German risk aversion that deserves further scrutiny. It seems logical to specify a joint model where German risk aversion may depend on US risk aversion, and to explore the dynamic interactions between the two series. The current crisis also offers an interesting laboratory to study the interactions between financial markets and risk aversion. Does the current crisis constitute a structural break? If not, are the current levels of risk aversion unprecedented or does the high level of the VIX and credit spreads also reflect high levels of macroeconomic uncertainty? Our aggregate measure of risk aversion can also be brought to bear on the issues studied in the "sentiment" literature: are certain stocks more sensitive to risk aversion changes than others, and what does that tell us about the cross-section of expected returns?

Finally, we can generalize our model to study the relation between risk attitudes and monetary policy. Estimating the response of risk aversion to changes in monetary policy is complicated by the endogeneity of policy decisions and the fact that both interest rates and asset prices react to numerous other variables. The structure of our model offers some hope that we can disentangle the above links and try to assess the direction of causality. Other measures of liquidity in the financial system and their interaction with risk aversion can also be considered. This is left for future research.

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7 Appendix: Quantifying Qualitative Data

A widely used method for quantifying survey data is the so-called Probability Approach of Carlson and Parkin (1975).[5] Their method assumes that respondents have a common subjective probability distribution over the future development of a variable and that they report a variable to go up or down if the median of their subjective probability distribution lies above or below an indifference interval.

Respondent i bases his qualitative answer on a subjective probability distribution over the possible values of the variable in question. These subjective probability distributions are statistically independent and normally distributed with finite mean and variance. The respondents are supposed to report the mean of the distribution. An individual respondent states in his response whether the variable in question will worsen/decrease ($DOWN_{i,t}$); improve/increase ($UP_{i,t}$) or remain unchanged ($SAME_{i,t}$).

The individual answer is $DOWN_{i,t}$, if the mean of the expected value of the change in the variable x by the end of time $t+k$, $E\left[\Delta x_{i,t+k}\right]$, is smaller than $a_{i,t}$ (an upper indifference bound):

$$E\left[\Delta x_{i,t+k}\right] < a_{i,t}.$$

Similarly, the individual answer is $UP_{i,t}$, if $E\left[\Delta x_{i,t+k}\right]$ is larger than $b_{i,t}$ (a lower indifference bound):

$$E\left[\Delta x_{i,t+k}\right] > b_{i,t}.$$

Finally, the individual answer is $SAME\, i,t$, if $E\left[\Delta x_{i,t+k}\right]$ is between the lower and upper boundary of the indifference interval $a_{i,t}$ and $b_{i,t}$:

$$b_{i,t} \leq E\left[\Delta x_{i,t+k}\right] \leq a_{i,t}.$$

[5] The probability approach was first employed by Theil (1952) and was rediscovered by Carlson and Parkin (1975) who used the method to construct quantitative measures for inflation expectations.

Further assumptions of the Probability Approach:

1) Making use of the Central Limit Theorem, the aggregate distribution of the basic population can be approximated by a normal distribution.[6]

2) The upper and lower indifference bounds are identical for all respondents in the population:

$$a_{i,t} = a_t \text{ and } b_{i,t} = b_t.$$

These assumptions allow us to interpret survey results as an independent drawing from the aggregate distribution of expectations with mean $E[\Delta x_{t+k}]$ and standard deviation σ_{t+k}. Hence, the percentages of the responses expecting a rise and a fall, denoted by UP_t and $DOWN_t$, converge to the corresponding population values:

$$1 - UP_t = \Phi\left(\frac{b_t - E\Delta x_{t+k}}{\sigma_{t+k}}\right)$$

and

$$DOWN_t = \Phi\left(\frac{a_t - E[\Delta x_{t+k}]}{\sigma_{t+k}}\right),$$

where Φ is the cumulative distribution function of a standard normal. The quantiles are given by:

$$r_t = \Phi^{-1}(1 - UP_t) \text{ and } f_t = \Phi^{-1}(DOWN_t).$$

3) Indifference bounds are symmetric and time-invariant: $-a_t = b_t = c$.

Solving for $E[\Delta x_{t+k}]$ and σ_{t+k} yields

$$E[\Delta x_{t+k}] = \frac{b_t f_t + a_t r_t}{f_t - r_t} = c\frac{f_t + r_t}{f_t - r_t}$$

[6] Other distributions have been suggested in the literature, e.g. t-distribution. In our sample, using t-distribution yields very similar results.

and

$$\sigma_{t+k} = -2c\frac{1}{f_t - r_t}.$$

4) Determining c: Since we are only interested in the time series of the standard deviation, all the relevant information is contained in r_t and f_t variables (quantiles). We choose c to scale $\frac{-2}{f_t - r_t}$ such that the resulting time series is of an order of magnitude corresponding to the Survey of Professional Forecasters data.[7]

[7] We thank M. H. Pesaran for a very helpful discussion of issues surrounding quantification of qualitative expectations. For a survey, see Nardo (2003) and Pesaran and Weale (2005).

Table 1: Description of model input variables

	Germany	USA
Model inputs		
Macro uncertainty	Survey dispersion (ZEW)	Survey dispersion (ZEW)
Implied volatility	VDAX	VIX
Realized volatility	DAX	S&P 500
Credit spread	Corporate - Public bond yield spread (Bundesbank)	AAA - BAA yield spread (FRED)
Short rate	3-month government bill rate	3-month Treasury bill rate
Long rate	10-year government bond rate	10-year government bond rate
Other series		
Price/earnings ratio	De-seasonalized (GFD)	De-seasonalized (GFD)
Stock returns	DAX (GFD)	S&P 500 (GFD)
Dividend yield	DAX (GFD)	S&P 500 (GFD)

Source: Bloomberg unless indicated otherwise. ZEW stands for Zentrum für Europäische Wirtschaftsforschung, Mannheim, Germany; FRED is Federal Reserve Economic Data; GFD stands for Global Financial Data.

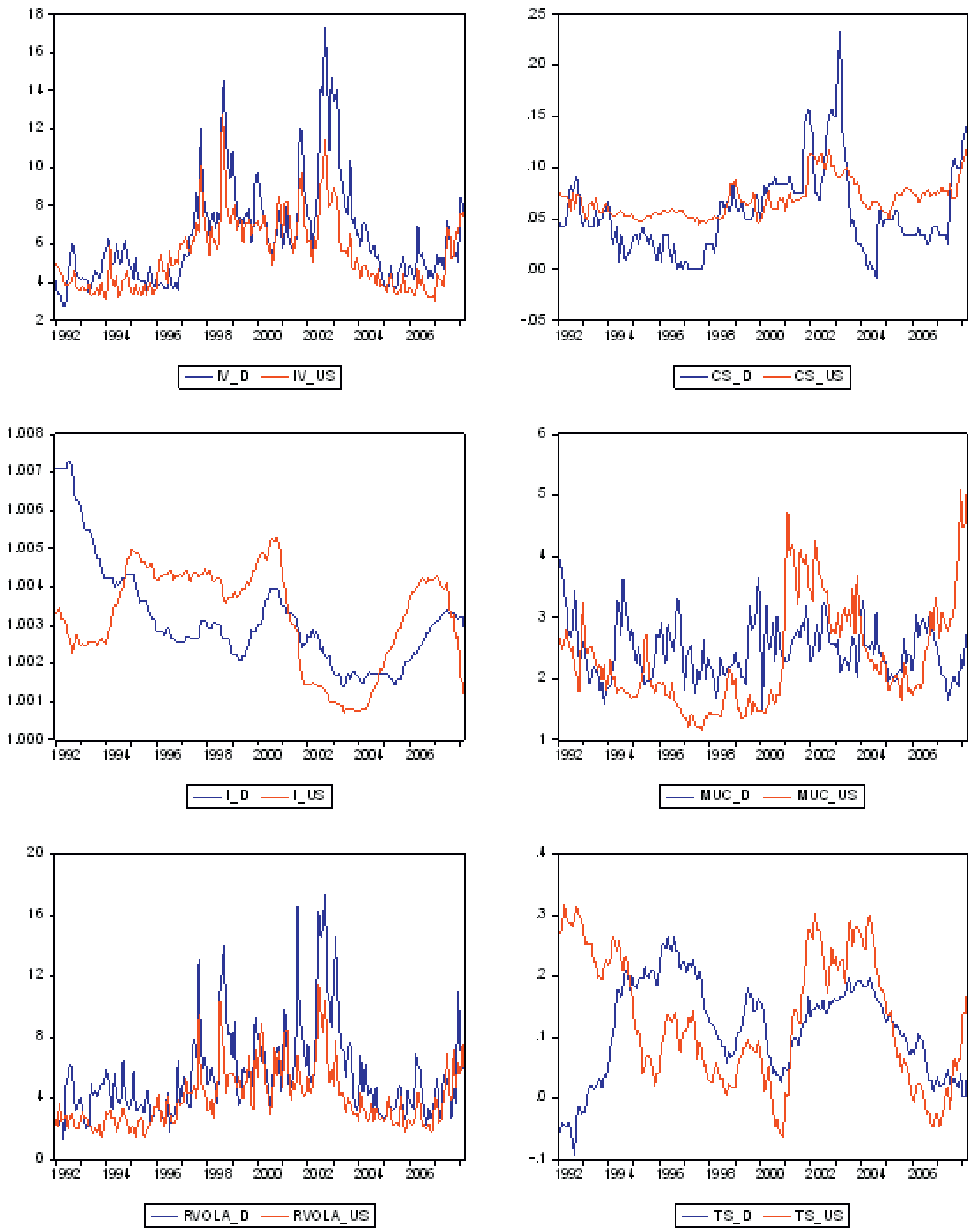

Figure 1: Plots of model inputs (implied volatility, IV; credit spread, CS; 3-month rate, I; survey uncertainty, MUC; realized volatility, $RVOLA$; term spread, TS)

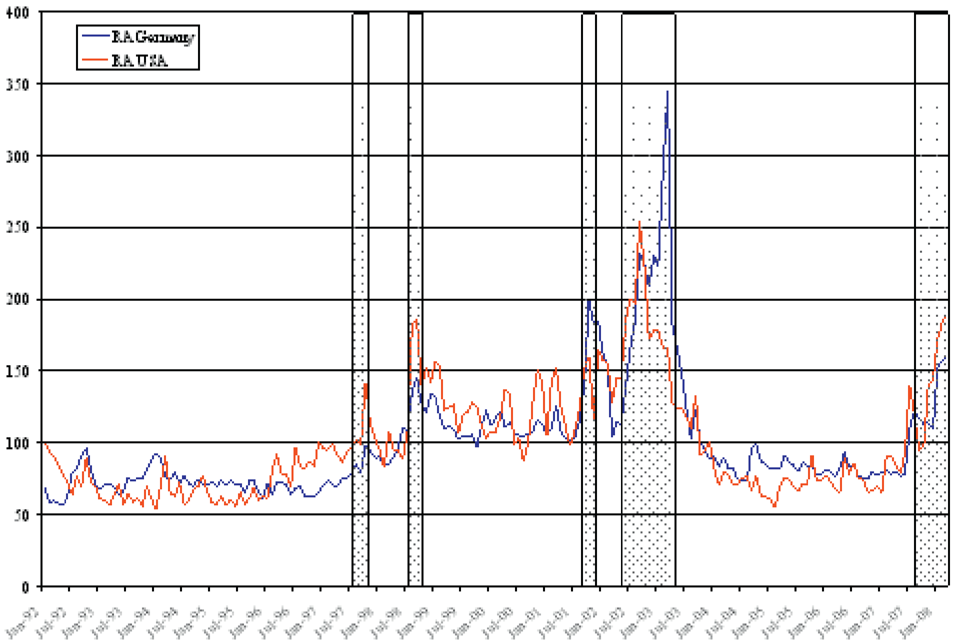

Figure 2: Time series of risk aversion RA (mean set to 100)

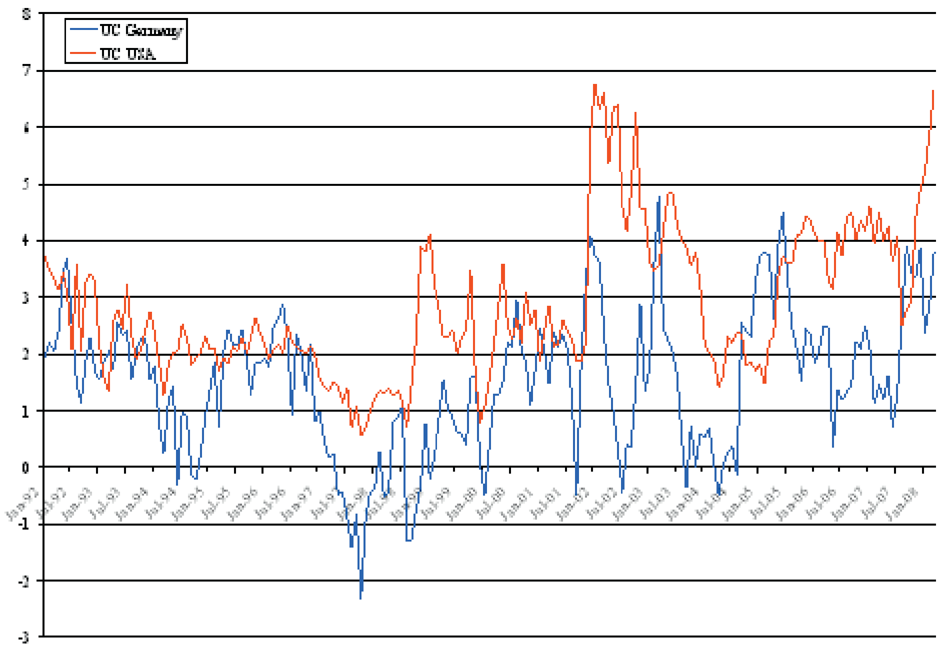

Figure 3: Time series of uncertainty UC (scaled by the GDP volatility)

Table 2: Parameter estimates

Parameters	Germany	USA
ϕ_{uc}	0.8090*** (9.9142)	0.9206*** (15.9549)
ϕ_{ra}	0.9277*** (47.8196)	0.8923*** (22.1965)
ϕ_i	0.9683*** (105.2500)	0.9517*** (95.1700)
ϕ_{muc}	0.6391*** (10.9811)	0.7097*** (17.4803)
γ_1	-0.0103** (-2.5122)	-0.0136*** (-3.1628)
γ_2	0.0066 (1.3469)	-0.0378*** (-8.3440)
σ_{ra}	0.3461*** (20.6012)	0.4371*** (38.6814)
σ_i	0.1637*** (40.9250)	0.1713*** (-53.5313)
σ_{muc}	0.4270*** (33.1008)	0.4007*** (47.1412)
B_{cs}^{uc}	0.1546*** (6.5232)	0.1042*** (15.5522)
B_{cs}^{ra}	0.1205*** (7.0882)	0.0152*** (4.0020)
B_{cs}^{i}	0.0898** (2.2792)	-0.0306** (-2.2334)
B_{vix}^{uc}	-1.9459*** (-10.5412)	-1.1108*** (-3.5512)
B_{ts}^{uc}	-0.1454** (-2.3414)	-0.1595*** (-3.1092)
B_{ts}^{ra}	-0.0626*** (-3.0388)	-0.0550*** (-2.8646)
B_{ts}^{i}	-0.4006*** (-6.4405)	-0.6716*** (-10.9739)
σ_{ts}	0.0576*** (13.3953)	0.0657*** (17.2895)
B_{rv}^{uc}	-1.7758*** (-6.3263)	-0.6753* (-1.7903)
B_{rv}^{ra}	1.0786*** (12.7044)	1.1046*** (16.0786)
B_{rv}^{i}	0.2983* (1.6572)	0.1903 (1.0090)
σ_{rv}	0.2855*** (23.0242)	0.2602*** (19.7121)

Notes: The two models were estimated by maximum likelihood, using 195 monthly observations. The t-statistics, repeated in parentheses, are based on White (1980) standard errors, which are robust to heteroskedasticity and distributional misspecification.

Table 3: Loadings of risk aversion and uncertainty

B_y^{-1} elements	Germany	USA
B_{uc}^{cs}	2.5705^{***} (9.3631)	8.2597^{***} (16.3164)
B_{uc}^{vix}	-0.3096^{***} (-11.2801)	-0.1257^{***} (-4.4083)
B_{uc}^{i}	-0.2308^{**} (-2.3360)	0.2528^{**} (2.2121)
B_{ra}^{cs}	5.0019^{***} (15.0334)	9.1752^{***} (4.0511)
B_{ra}^{vix}	0.3975^{***} (5.1796)	0.8604^{***} (13.8758)
B_{ra}^{i}	-0.4491^{**} (-2.3693)	0.2808^{*} (1.7947)

Note: We report estimates of the matrix $\left[B_y^1\right]^{-1}$ (see below). The standard errors are computed using the delta method.

$$\left[B_y^1\right]^{-1} = \begin{bmatrix} B_{uc}^{cs} & B_{uc}^{vix} & B_{uc}^{i} & 0 \\ B_{ra}^{cs} & B_{ra}^{vix} & B_{ra}^{i} & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

Table 4: Risk aversion projections

	Germany	USA
Intercept	79.5936^{***}	-287.8889^{***}
	(8.2820)	(-7.6760)
$VDAX/VIX$	0.1601^{***}	1.3590^{***}
	(19.6807)	(38.2342)
$RVOLA$	-0.0095	0.0793^{***}
	(-1.1878)	(3.1502)
$3MTB$	-78.9443^{***}	281.4910^{***}
	(-8.2880)	(7.5576)
CS	16.9850^{***}	95.4234^{***}
	(13.1481)	(29.4861)
TS	1.4019^{***}	1.6119^{***}
	(4.1459)	(4.0468)
Adjusted R^2	0.9648	0.9866

Note: Risk aversion estimates (RA) are regressed on the implied volatility index $(VDAX\ or\ VIX)$, respectively, realized volatility $(RVOLA)$, 3-month rate $(3MTB)$, credit spread (CS), and term spread (TS); t-statistics based on White standard errors are reported in parentheses:

$$RA_t = a_1 + a_2 VIX_t + a_3 RVOLA_t + a_4 3MTB_t + a_5 CS_t + a_6 TS_t + e_t.$$

Table 5: Correlation analysis

Panel A:

	RA_D	RA_{US}	RTI
RA_D	1		
RA_{US}	0.7983*** (18.4115)	1	
RTI	0.1553* (1.7290)	0.4201*** (5.0928)	1

Panel B:

		RA_D	RA_{US}	RTI
Germany	UC_D	0.1255* (1.7570)	-0.1413** (-1.9831)	-0.2727*** (-3.1182)
	$VDAX$	0.8350*** (21.0832)	0.8432*** (21.7909)	0.3359*** (3.9232)
	CS_D	0.8737*** (24.9547)	0.6710*** (12.5733)	0.1104 (1.2219)
	$3MTB_D$	-0.3422*** (-5.0598)	-0.2823*** (-4.0888)	0.2823*** (3.2365)
	RET_D	-0.2398*** (-3.4233)	-0.3599*** (-5.3442)	-0.4107*** (-4.9554)
	DIV_D	0.0257 (0.3572)	-0.1111 (-1.5536)	0.1549* (1.7245)
	P/E_D	-0.2699*** (-3.8946)	-0.1171 (-1.6383)	0.1504* (1.6738)
USA	UC_{US}	0.3847*** (5.7907)	0.4269*** (6.5589)	-0.0457 (-0.5030)
	VIX	0.6865*** (13.1165)	0.9042*** (29.4040)	0.4770*** (5.9702)
	CS_{US}	0.6100*** (10.6948)	0.6602*** (12.2118)	0.0591 (0.6518)
	$3MTB_{US}$	-0.4591*** (-7.1784)	-0.2800*** (-4.0514)	0.0844 (0.9314)
	RET_{US}	-0.1472** (-2.0618)	-0.3102*** (-4.5217)	-0.2679*** (-3.0586)
	DIV_{US}	-0.3722*** (-5.5702)	-0.4780*** (-7.5601)	0.1356 (0.1347)
	P/E_{US}	0.5436*** (8.9981)	0.6045*** (10.5413)	-0.0970 (-1.0724)

Note: The list of variables (D for Germany and US for the US): RA, estimates of risk aversion; RTI, JP Morgan G10 Risk Tolerance Index; UC, estimates of uncertainty; $VDAX$ / VIX, implied volatility index; CS, credit spread; $3MTB$, 3-month rate; RET, stock returns; DIV, dividend yield; P/E, log of the seasonally adjusted price-earnings ratio.

Table 6: Risk aversion and stock returns

Panel A:

Germany	$3MTB$	RA	DIV	$ERET$
$3MTB_{t-1}$	0.9925***	0.0068	0.0423***	-0.1088*
	(76.7371)	(0.2197)	(3.3470)	(-1.9436)
RA_{t-1}	-0.0049	0.8991***	0.0107	-0.0852
	(-0.3309)	(25.0141)	(0.7343)	(-1.3207)
DIV_{t-1}	-0.0880***	-0.0472	0.8650***	0.2039
	(-2.6726)	(-0.5956)	(26.8746)	(1.4312)
$ERET_{t-1}$	0.0035	-0.0857**	-0.0143	-0.0022
	(0.2006)	(-2.0276)	(-0.8322)	(-0.0295)
Adjusted R^2	0.9872	0.8234	0.9150	0.0002
USA				
$3MTB_{t-1}$	0.9785***	-0.0195	-0.0075**	2.4031
	(89.0937)	(-0.2634)	(-2.2651)	(1.0645)
RA_{t-1}	-0.0270***	0.8609***	-0.0031	1.3793
	(-4.3559)	(20.6745)	(-1.6309)	(1.0846)
DIV_{t-1}	-0.0488	-0.6048***	0.9728***	13.7815*
	(-1.3790)	(-2.5410)	(90.8136)	(1.8960)
$ERET_{t-1}$	0.0005	0.0004	0.0001	0.0161
	(1.2319)	(0.1765)	(-0.2142)	(0.2080)
Adjusted R^2	0.9795	0.8070	0.9842	0.0009

Panel B:	Estimates
RA_{t-1}	3.5624***
	(12.1945)
$ERET_{t-1}$	-0.0129***
	(-8.1101)
$dummy * RA_{t-1}$	-7.4917***
	(-10.1202)
Adjusted R^2	0.6144

Notes: Intercept is always included. Panel A presents first-order VAR on excess stock market returns $(ERET)$, the 3-month rate $(3MTB)$, the dividend yield (DIV), and risk aversion (RA). Panel B presents pooled regression of excess stock market returns $(ERET_t)$ on lagged risk aversion estimates (RA_{t-1}), lagged excess stock returns $(ERET_{t-1})$,and an interaction term multiplying the risk aversion measure with a dummy variable that is negative when the stock return is negative at time t; t-statistics based on White standard errors are reported in parentheses:

$$RET_t = b_1 + (b_2 + b_4 dummy)\, RA_{t-1} + b_3 RET_{t-1}.$$

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