The Variance Risk Premium around the World*

Job Market Paper

Juan-Miguel Londono†

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Abstract

This paper investigates the variance risk premium in an international setting. First, I provide new evidence on the basic stylized facts traditionally documented for the US. I show that while the variance premiums in several countries are, on average, positive and display significant time variation, they do not predict local equity returns in countries other than the US. Then, I extend the domestic model in Bollerslev, Tauchen and Zhou (2009) to an international setting. In light of the qualitative implications of my model, I provide empirical evidence that the US variance outperforms all other countries' variance premiums in predicting local and foreign equity returns.

JEL Classification: E44, F36, G12, G13, G15.

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1 Introduction

Traditional asset pricing models have mainly focused on characterizing the reward for equity risk. However, such models typically fail to capture the reward for bearing variance risk. The variance risk premium is formally defined as the difference between the risk neutral and the physical expectation of the total return variation. It can be estimated using model-free measures as the difference between the option implied variance and the expected realized variance. The observed variance premium in the US is large and varies significantly over time. In order to generate a time-varying variance premium, standard asset pricing models have been adjusted in different ways. One strand of the literature, and the one that will be followed in this paper, links the variance risk premium to macroeconomic

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†CentER, Department of Finance Tilburg University. E-mail: j.m.londono@uvt.nl. http://center.uvt.nl/phd_stud/londono/

uncertainty. This strand follows the intuition behind the long-run risk model in Bansal and Yaron (2004) (BY hereafter), and the idea that agents have a preference for an resolution of uncertainty in Bansal et al. (2005). Extending BY's model, Bollerslev, Tauchen and Zhou (2009) (BTZ hereafter) show that the variance premium predicts equity returns; an implication for which they find empirical evidence for the US. An alternative strand of the literature relates the variance premium to agents' attitudes towards non-normalities in the distribution of returns. In Bakshi and Madam (2006), for example, the variance risk premium is explained by the desire of risk averse agents to buy protection against extreme events. In a similar vein, Bekaert and Engstrom (2010), Todorov (2010), and Gabaix (2009), using different methodologies, focus on the interplay between returns, risk aversion and extreme events to explain many asset pricing regularities, including the variance risk premium.

Existing work, both theoretical and empirical, has predominantly focused on the US market. This paper adds to the literature by extending the variance premium analysis to an international setting. The contribution is threefold. First, I provide new evidence on the basic stylized facts related to the variance premium for a total of eight countries. I show that while the variance premiums display significant time variation in all countries analyzed, the local return predictability does not hold internationally. Then, I extend the domestic model in Bollerslev, Tauchen and Zhou (2009) to an international setting. My model links the variance premium to local and aggregate macroeconomic uncertainty and yields a qualitative explanation for the local predictability puzzle. Finally, I provide new empirical evidence to investigate the main qualitative implications of my model. The empirical evidence suggests that the US variance premium predicts the equity returns in the US as well as in any other country in the sample. In addition, the evidence also suggest that the US variance premium plays a key role in predicting the variance premium correlations as well as the equity return correlations across countries.

I now discuss the different parts and contributions of the paper in more detail. In the first part, I investigate the main stylized facts related to the variance premium previously documented for the US in an international setting. In particular, I investigate whether the time-varying and positive nature of the variance premium as well as its capacity to predict returns holds internationally. In order to do so, I collect data for the US, Germany, UK, Japan, Switzerland, The Netherlands, Belgium, and France for the sample period 2000 to 2009. As it has become standard in the literature, the variance premiums for all countries are estimated using model-free measures of the expected variance of returns. Thus, the (squared of the) model-free implied volatility (IV) index for each equity market approximates the expectation of the total return variation under the risk neutral measure (Carr and Madan, 1998; and Britten-Jones and Neuberger, 2000) while the expectation under the physical measure is approximated by a conditional forecast of the actual realized variance.

The single-country evidence shows that the variance premiums display significant time variation and are, on average, positive for all countries in the sample. This international

evidence is in line with previous findings for the US.[1] However, I show that the variance premium can predict local equity returns only in the US. For any other country analyzed, the evidence suggests that the local variance premiums cannot predict local equity returns. This finding suggests a puzzle that cannot be solved by the existing domestic models where the variance premium implicitly explains the variation in the local equity premium.[2]

The strictly domestic nature of the existing models motivates the theoretical contribution of this paper. In the second part, I propose a model to investigate the role of the variance premium in explaining the interactions across international equity and option markets. The model is a two-country extension of that in BTZ and extends the intuition that agents have a preference for an early resolution of uncertainty to an international setting. The macroeconomic uncertainty is characterized in my model by the volatility dynamics of the consumption growth of each country and is allowed to be transmitted across countries given a unique representative agent endowed with recursive preferences. In such a setting, the shocks to macroeconomic uncertainty in any country characterize the variance premium in all countries. In particular, the variance premiums of the two countries reveal the volatility of volatility of consumption generated in both countries. Now, given that changes in the volatility of volatility also explain a portion of the total risk premiums of any country, the model not only implies that variance risk is priced but also provides the intuition for the potential role of the variance premium of any country in predicting local and foreign equity returns. In other words, agents demand a reward for the existing local and foreign sources of risk (i.e., the volatility and the volatility of volatility of consumption). Although this uncertainty transmission mechanism is bidirectional, the model explicitly assumes a leader economy. The consumption process of this leader economy is entirely driven by local shocks. However, the shocks of the leader country consumption process can be partially transmitted to a second country, the follower.

My model yields several qualitative implications for the interactions across international equity and option markets that explain the inability of the variance premium to predict local equity returns in countries other than the US. The first main implication of my model is that the variance premium in each country is uniquely characterized by the volatility of volatility of consumption (VoV) of the two countries. The load of each country's VoV increases with the relative size of its economy and the degree of economic dependence among countries (leader-follower relation). As a consequence of having common components, the variance premiums are highly correlated across countries; and the cross-country variance premium correlation is mainly driven by the VoV generated in the leader country. Thus, the leader country variance premium plays the key role in predicting the variance premium correlations across countries. The second main implication of my model is that the VoV of the two countries also load on all countries' equity premiums. Similar to the implication for the variance premiums, the load of VoV increases with the

[1] See for instance Britten-Jones and Neuberger (2000), Jiang and Tian (2005), Bakshi and Madan (2006), Carr and Wu (2009), Bollerslev, Gibson and Zhou (2010), and BTZ, among others.

[2] BTZ, Zhou (2010), and Drechsler and Yaron (2010) find empirical evidence for their respective model-implied return predictability. However, Bekaert and Engstrom (2010) find weak evidence of return predictability.

relative size of each economy and the implied correlation of the consumption processes. This second implication links the variance premium to all countries' equity premiums. As a consequence, this implication explains the possibility that the variance premium of a leader economy predicts other countries' equity returns which in turn implies that the leader country variance premium plays the key role in predicting equity return correlations across countries.

The third contribution of this paper is that it provides new empirical evidence on the two main implications of my model. That is, I investigate the fundamental linkages between the variance premiums across countries as well as the interplay between the variance premiums and international equity returns. To do so, I first provide evidence that the variance premiums are highly correlated across countries as suggested by the common loads of volatitility of volatility in the variance premiums suggested by my model. As a natural extension of the high variance premium correlation across countries, I also investigate the role of the variance premium in explaining unusual variance premium correlations across countries at the daily frequency. The analysis of unusual correlations closely follows the contagion literature (Bekaert, Harvey, and Ng, 2005) and suggests that the variance premiums are unusually correlated after extreme US variance premium episodes. The US variance premium contagion pattern only holds in the very short term, from 1 to 10 days.

Next, I investigate the second main implication of my model which suggests that the leader country variance premium plays the key role in predicting local and foreign equity returns. On the one hand, I confront the evidence on the poor performance of the local variance premiums in predicting local returns for countries other than the US. Thus, I provide new evidence that the US variance premium predicts equity returns for all countries in the sample. The predictive power of the US variance premium over international equity returns holds for horizons between 1 to 6 months, and reaches its maximum at the quarterly horizon. In addition, I show that the US variance premium outperforms all other countries' variance premiums in predicting local and foreign equity returns. On the other hand, I provide evidence that international equity returns tend to comove more intensely following episodes of increasing US variance premium. The predictive power of the variance premium for both equity returns and cross-country return correlations holds for horizons between 3 and 6 months and is additional to that of traditional (local or US) variables such as the term spread and the dividend yield.

The remainder of the paper is organized as follows: Section 2 introduces the main definitions and data used throughout the paper. Section 3 provides international single-country evidence on the regularities related to the variance premium. Section 4 introduces the international consumption based general equilibrium model and analyzes its qualitative implications. Section 5 analyzes the empirical evidence in light of the implications of the model. Finally, Section 6 concludes.

2 Data and Definitions

In this section, I introduce the data used to estimate the monthly variance premiums for the following countries: US, Germany, Japan, UK, Switzerland, The Netherlands, Belgium and France. The variance premium is defined as the difference between the risk neutral and the physical expectation of the market return variation between time t and one month forward $t+1$ for each market. It is estimated, as it has become standard in the related literature, using model-free measures for the expectations of the total return variation.

I approximate the risk neutral expectation of the market return variation as (the square of) the model-free options implied volatility (IV) index for each market. The methodology for the IV index was initially proposed by Carr and Madan (1998) and Britten-Jones and Neuberger (2000). The IV index has shown to provide a much better approximation to the expected risk neutral return variation than previously Black-Scholes based measures (Bollerslev, Gibson and Zhou, 2010). The IV indices are constructed from a portfolio of European calls where the underlying is a representative market index for each country as in

$$iv_{j,t} = 2\int_0^\infty \frac{C_{j,t}(t+1, \frac{K}{B_j(t,t+1)}) - C_{j,t}(t,K)}{K^2} dK,$$

where $C_{j,t}$ are the prices of calls with strikes from zero to infinity, and $B_j(t,t+1)$ are the local prices of zero-coupon bonds with one month ahead maturity.

The availability of the IV index for the countries analyzed is limited by the recent development of their option markets. The index was first reported for the US by the Chicago Board Options Exchange (CBOE), the VIX, in 1993 (with data from 1990). The VIX was adapted to the model-free methodology in 2003, and was then called the New-VIX. An index for the German market, the VDAX, was released by the German Stock Exchange (Deutsche Beurse and Goldman Sachs) in 1994 (with data from 1992). The Swiss Exchange introduced the index for Switzerland, the VSMI, in 2005. Currently, Eurex estimates and reports both VDAX and VSMI following a unified New-VIX methodology. The Center for the Study of Finance and Insurance (CSFI) at Osaka University launched an index for Japan, the VXJ, with data from 1995. Finally, in 2007, Euronext announced IV indices for France (VCAC), Belgium (VBEL), the UK (VFTSE, in partnership with FTSE), and The Netherlands (VAEX) with data from 2000.[3] Considering the data restrictions for the European markets, the empirical analysis in this paper is centered on the sample period 2000 to 2009.

Now, in order to construct the variance premiums, an expectation of the total return variation under the physical measure has to be estimated. I estimate a measure based on the first order autoregressive forecast of the total realized return variation or realized variance from the following equation:

[3] Both, the UK (FTSE) and France (French March des Options Negociables de Paris) had previously introduced IV indices separately.

$$rv_{j,t+1} = \gamma_o + \gamma_1 rv_{j,t} + \epsilon_t,$$

where the realized variance is calculated summing the squared daily equity returns for each market as in

$$rv_{j,t} = \sum_{t_i=1}^{N_t} (r_{j,t_i})^2,$$

where r_{j,t_i} are daily local returns within month t. I rely on daily returns since data at a higher frequency are not available for all countries in the sample.[4]

Now, in order to make the results comparable to those in the literature, and as a preventive solution to the possible underperformance of this benchmark measure, all results are checked using three alternative approximations of the expected realized variance. In the first measure, I use the martingale measure where the expected realized variance is approximated as the current realized variance ($E_t(rv_{t+1}) = rv_t$). In the second one, I estimate a forecast of the realized variance that includes the local IV index as in the following equation:

$$rv_{j,t+1} = \gamma_o + \gamma_1 rv_{j,t} + \gamma_2 iv_{j,t} + \epsilon_t.$$

Finally, in the third one, I estimate a forecast of the realized variance that includes the range-based variance for each country as in

$$rv_{j,t+1} = \gamma_o + \gamma_1 rv_{j,t} + \gamma_2 RangeV_{j,t} + \epsilon_t,$$

where $RangeV_{j,t}$ is the range-based variance calculated as

$$RangeV_{j,t} = \frac{1}{4\ln 2} \sum_{t_i=1}^{N_t} range_{t_i}^2,$$

where $range_{t_i}$ is the daily difference between the highest and the lowest price of the index.[5]

In order to estimate the variance premiums, the monthly data (end of the month) for the IV indices as well as the daily returns for the underlying index returns for all countries are obtained from Datastream. All returns are expressed in local currencies.[6] Now, in order to obtain the local excess returns to investigate the return predictability, I consider the 3-months T-bill rates for each country. These T-bill rates are also obtained from Datastream. In order to save space, the discussion in this section is centered on the components of the variance premium. All other variables used in the paper are described in Appendix B.

[4] It has been shown in the literature that the use of intradaily returns outperforms lower frequency data in the estimation of the realized variance (Andersen et. al., 2001, Barndorff-Nielsen and Shephard, 2002; and Meddahi, 2002).

[5] Martens and van Dijk (2007) provide a description of the range based estimation of volatility. Jacob and Vipul (2008) analyze the extension of the range based measure to forecast the variance.

[6] The results are checked for robustness when all returns are expressed in US dollars.

3 Variance Premium: Single-Country Evidence

In this section, I investigate whether the stylized facts observed for the variance premium in the US also hold internationally. In a first step, I analyze the positive and time-varying nature of the variance premium. Then, I investigate the ability of the local variance premium in predicting equity returns in each country separately.

In order to get an idea of the magnitude and the time-varying nature of the variance premiums, Figure 1 displays the (benchmark) time series for all countries considered. The main statistics of these series are summarized in Table 1. This table also displays the IV indices and their underlying equity market indices for each country. The volatility premiums $[volp_{j,t} = iv_t - \sqrt{\widehat{rv}_{j,t+1}}]$ are also included in the table in order to visualize the magnitude of the premiums in annual percentages. The average volatility premium ranges between 1.7% for Belgium to 3.8% for Japan. In order to get an intuitive idea of these magnitudes in terms of one month maturity at-the-money put options, the 3.8% volatility premium in Japan translates into a price difference of 18% in a Black Scholes world. That is, one month at-the-money put options priced at 26.75% implied volatility, which is the average IV index for Japan, are 18% more expensive than the same options priced at 22.87% implied volatility, which is the average realized volatility for this country in this sample.

The information in Table 1 and Figure 1 suggests that the variance premiums display significant time variation. In particular, the premiums show several episodes of high volatility and notorious spikes around the same periods of time which translate into large Kurtosis for all series. The first high-variance-premiums episode occurs around the end of the technological boom in 2000. A second episode occurs at the end of 2002. This second episode coincides with the high macroeconomic uncertainty reported in the second semester of 2002 in the US (first semester of 2003 for Germany. An episode also related to the corporate accounting scandals around those years). Finally, the most notorious variance premium spikes occur around the recent subprime crisis. Not surprisingly, the minimum and maximum values for all series, except for Germany, occur in the last quarter of 2008. For Japan, for example, the variance premium reached 3,398.2 (annual percentage squared) in October 2008.[7]

Now, in order to assess the positive nature of the average variance premiums, Figure 2 summarizes the results for a test on the significance of the mean variance premium for all countries. This figure displays the average variance premiums and their respective confidence intervals for the four alternative measures introduced in Section 2. The evidence suggests that the average variance premium is positive and significant for all countries analyzed and all alternative measures, except perhaps when the martingale measure is used. This evidence supports the idea that agents also price market volatility in countries other than the US. These results are new evidence that extends that found for the US by Britten-Jones and Neuberger (2000), Jiang and Tian (2005), Bakshi and Madan (2006),

[7] See Bollerslev, Gibson and Zhou (2010), and Corradi, et. al. (2009) for a more detailed analysis of the relation between the variance premium and the business cycle in the US.

Carr and Wu (2009), Todorov (2010), Bollerslev, Gibson and Zhou (2010), Bekaert and Engstrom (2010), and BTZ, among others.[8] This paper is, to the best of my knowledge, the first to show that these stylized facts also hold in other developed markets.

I now test another US-based stylized fact, namely that the local variance premium predicts local equity returns.[9] Given the new evidence presented above on the existence of a volatility premium in all countries analyzed, I investigate the role of the variance premium in predicting returns for all countries in the sample. To do so, Figure 3 reports the estimation results for the following regressions:

$$(r - r_f)_{j,t,t+h} = \gamma_{0,,j,h} + \gamma_{1,,j,h} vp_{j,t} + \gamma_{2,,j,h} dy_{j,t} + \gamma_{3,,j,h} ts_{j,t} + \epsilon_{j,h,t},$$

where $(r - r_f)_{j,t,t+h}$ represents future compounded annualized excess returns h-months ahead, $dy_{j,t}$ is the local dividend yield, and $ts_{j,t}$ is the local term spread.

The evidence in Figure 3 confirms most of the results previously found in the literature for the US. That is, the US variance premium predicts returns specially for horizons between 3 to 6 months. In fact, the evidence shows that the US variance premium explains up 15% of the total variation in future equity returns at the quarterly frequency. The predictive power, as well as the coefficient of the variance premium in these regressions, follows a hump-shaped pattern and becomes null for horizons around one year.

However, the evidence suggests that the local variance premium plays a modest or insignificant role in predicting returns in any other country analyzed. For example, the results show that for Germany, Japan, the UK and the Netherlands, the R^2 is modest and hardly ever above 1%. Not surprisingly, for these countries, the variance premium does not predict equity returns for any horizon considered. Now, for Belgium the R^2 is as high as 10% for the one-month horizon; and the predictive power of the variance premium follows a linearly decreasing as the horizon increases. Actually, the variance premium in Belgium plays a significant role in predicting returns for horizons up to 10 months.[10] Finally, for France, although the R^2 are also modest, the predictability follows a pattern similar to that found for the US. That is, both the R^2 and the variance premium coefficient are higher for horizons between 3 and 6 months.

In sum, although this is, to the best of my knowledge, the first paper to present evidence on the role of the variance premium in predicting returns for countries other than the US, the single-country evidence is puzzling. My findings are on the one hand consistent with the existence of time-varying variance premiums for a large sample of countries. On the other hand, they suggests that the variance premium does not predict

[8] A group of papers have also provided preliminary evidence of this regularity using Black–Scholes-based implied volatility. See, for instance, Bakshi, Cao and Chen (2000), Christoffersen, Heston and Jacobs (2006), and Bollerslev and Zhou (2006).

[9] See for instance BTZ, Zhou (2010) and Drechsler and Yaron (2010).

[10] It is worth pointing out that the variance premium in Belgium shows the lowest Sharpe ratio (almost half that for the rest of the countries). This could preliminary suggest that the variance premium is particularly volatile in Belgium. This in turn implies a noisier measure in this country, potentially driven by the liquidity of the Belgian option market.

returns in countries other than the US. The concurrence of these two findings cannot be explained by the existing domestic models where the variance premium implicitly explains the variation in the local equity premium. This puzzling evidence is nonetheless the motivation for the international general equilibrium model introduced in the following section. The model proposed is able to qualitatively explain the poor evidence for the role of the local variance premium in predicting returns outside the US. This model suggests that the variance premium of a leader country plays a dominant role in predicting returns for all other countries; a key implication for which I provide empirical evidence in the subsequent section.

4 A Two-Country Model for the role of the Variance Premium in International Equity Markets

The domestic nature of the existing models in the literature restricts the analysis of the variance premium in an international setting. These models cannot provide an explanation for the poor role of the local variance premium in predicting returns in countries other than the US as shown in the previous section. Therefore, I propose an international consumption-based general equilibrium (GE) model where the variance risk is priced in the global as well as in the local portfolios. My model yields several new qualitative implications for the role of the variance premium in international markets. The most relevant implication of the model is that the variance premium of a leader economy plays a dominant role in predicting equity returns in all portfolios. In addition, the model implies that the leader country variance premium also plays a role in explaining equity and option markets correlations across countries.

In this section, I present the basic setup of the model as well as its main implications.[11] I do not attempt to estimate nor to test my model but rather to use its qualitative implications to investigate the inability of the variance premium to predict local equity returns in countries other than the US. Therefore, I propose a numerical simulation of the model in order to understand its implications and illustrate the mechanism behind it. These numerical simulations provide the link between the single-country evidence, the implications of the model and the empirical evidence presented in the following section.

4.1 Model Setup and Assumptions

The model presented here is a two-country extension of that in BTZ. It preserves two key ingredients in BTZ's model: the use of recursive preferences, and the time-varying nature of macroeconomic uncertainty characterized by the volatility of consumption. However, my model adds to the literature by extending the intuition that financial markets dislike macroeconomic uncertainty (BY and Bansal, et al., 2005) to an international setting. Therefore, I include the additional sources of risk embedded in the consumption process

[11] In order to save space, the detailed solution of my model is presented in Appendix A

of each country, namely the country-specific time-varying volatility and the volatility of volatility (VoV) of consumption.[12] The setup of the model requires several additional assumptions. First, the two countries are assumed to be of a "considerable" size. That is, they both play a role in determining the global consumption growth which is a weighted average of the two countries' consumption growth. Second, one of the countries is assumed to be "the leader". The consumption process for the leader country is assumed to be entirely driven by local shocks, while the consumption process for the second country, "the follower", is also affected by the shocks generated in the leader country. Finally, I assume fully integrated equity markets. That is, there exists a unique representative agent holding a global portfolio with positions in the two equity markets. The assumptions of fully integrated equity markets and potentially integrated economies seem adequate given the particular characteristics of the sample considered in this paper.

Formally, each country consumption process is modeled similar to BTZ. The log of the consumption growth $g_{j,t}$ for the leader country (labeled as 1) follows

$$g_{1,t+1} = \mu_{1,g} + \sigma_{1,t} z_{g_1,t+1}, \tag{1}$$

$$\sigma^2_{1,t+1} = a_\sigma + \rho_\sigma \sigma^2_{1,t} + \sqrt{q_{1,t}} z_{\sigma_1,t+1},$$

$$q_{1,t+1} = a_q + \rho_q q_{1,t} + \varphi_q \sqrt{q_{1,t}} z_{q_1,t+1},$$

whereas the consumption process for the follower country (labeled as 2) follows

$$g_{2,t+1} = \mu_{2,g} + \phi_g \mu_{1,g} + \phi_\sigma \sigma_{1,t} z_{g_1,t+1} + \sigma_{2,t} z_{g_2,t+1}, \tag{2}$$

$$\sigma^2_{2,t+1} = a_\sigma + \rho_\sigma \sigma^2_{2,t} + \sqrt{q_{2,t}} z_{\sigma_2,t+1},$$

$$q_{2,t+1} = a_q + \rho_q q_{2,t} + \varphi_q \sqrt{q_{2,t}} z_{q_2,t+1}.$$

The global consumption growth is a weighted average of the two countries' consumption process as in

$$g_{w,t} = \omega g_{1,t} + (1-\omega) g_{2,t},$$

where ω is the weight of the leader country in the global economy.

In order to simplify the model, the parameters in the volatility and VoV processes in Eqs. (1) and (2) are assumed to be the same across countries. I also assume that there are neither within nor cross-country statistical correlations in the shocks. The only

[12] Bekaert, Engstrom and Xing (2009) survey the evidence on time-varying volatility of consumption for the US. Bansal, et. al. (2005) provide empirical evidence of time-varying macroeconomic uncertainty for the US, Germany, Japan, and the UK. Now, BTZ also find preliminary empirical evidence on the existence of time-varying VoV for the US.

correlations assumed in my model are those implied by the parameters ϕ_g (level) and ϕ_σ (volatility) in Eq. (2). These two parameters control the extent to which the follower country is affected by the shocks generated in the leader country. In particular, ϕ_σ implies that the consumption process of the follower country is affected not only by the local macroeconomic uncertainty, but also by that generated in the leader economy. More importantly, the fact that both economies are exposed to the same sources of macroeconomic uncertainty yields the systematic component in both countries' variance premiums.[13]

Now, the unique world representative agent is endowed with Epstein Zin Weil preferences (Epstein and Zin, 1989; and Weil, 1989). That is, her life-time utility function is given by the following equation:

$$U_t = [(1-\delta)C_t^{\frac{1-\gamma}{\theta}} + \delta(E_t[U_{t+1}^{1-\gamma}])^{\frac{1}{\theta}}]^{\frac{\theta}{1-\gamma}}, \tag{3}$$

where $0 < \delta < 1$ is the time discount rate, $\gamma \geq 0$ is the risk aversion parameter, and $\theta = \frac{1-\gamma}{1-\frac{1}{\psi}}$ for $\psi \geq 1$ is the intertemporal elasticity of substitution (IES).[14] These preferences have the property of assigning non-zero market prices to shocks not directly related to aggregate consumption. This property is crutial to investigate other risk factors such as news related to volatility which is the main objective of this paper.

4.2 Model-Implied Variance Premiums

Given the solution of the model in Appendix A, it can be shown that the two countries' VoV isolate the variance premium in the global and the local portfolios. The expression for the global portfolio's variance premium is given by[15]

$$VP_{w,t} = E_t^Q[Var_{r_j,t+1}] - E_t^P[Var_{r_j,t+1}],$$

where $Var_{r_j,t}$ is the conditional variation of returns between time t and $t+1$ for portfolio j for $j = 1, 2, w$ (see appendix A). The variance premium can be approximated as[16]

[13] The parameters ϕ_g, and ϕ_σ can of course be set to 0, a case that I will also analyze in the numerical simulation of the model. Now, although ϕ_g turns out to have an insignifcant effect on the role of international variance premium, it is kept to maintain the possibility of a common level component in consumption. Alternative ways of characterizing the systematic component of the variance premiums outside the simplifications of a two-country model are being explored in my current research agenda.

[14] To be coherent with the idea of agents that fear an increase in macroeconomic uncertainty ψ is assumed to be higher than 1. This assumption accomodates some empirical asset pricing regularities, among them: (i) a positive variance premium; (ii) the feedback effect between PD ratios and consumption volatility; and (iii) a low risk-free rate (BY and BTZ). See also Mehra and Prescott (1985) for reasonable values of γ.

[15] It is important to keep in mind that this is actually the drift difference of the conditional variance between the two measures. In the case of Gaussian shocks, the level difference $(Var^Q(r_{t+1}) - Var^P(r_{t+1}))$ would be zero (see Drechsler and Yaron, 2010).

[16] The risk neutral probability is replaced by its log-linear approximation:

$$E_t^Q(\sigma_{r,t+1}^2) \approx \log[e^{-rt,t}E_t(e^{m_{t=1}+\sigma_{r,t+1}^2)}] - \frac{1}{2}Var_t(\sigma_{r,t+1}^2).$$

Bear in mind that a closed form solution to the risk neutral variance cannot be obtained in this setting.

$$VP_{w,t} \approx (\theta - 1)\kappa_{w,1}(V_{w,1}q_{1,t} + V_{w,2}q_{2,t}), \tag{4}$$

where $(\theta - 1)\kappa_{w,1}V_{j,k}$ represents the load of $q_{k,t}$ on $VP_{j,t}$. For the global portfolio, these loads are characterized by the following expressions:

$$V_{w,1} = (\omega + (1-\omega)\phi_\sigma)^2 A_{w,1} + (A_{w,1}^2 + A_{w,2}^2\varphi_q^2)\kappa_1^2\varphi_q^2 A_{w,2},$$

$$V_{w,2} = (1-\omega)^2 A_{w,3} + (A_{w,3}^2 + A_{w,4}^2\varphi_q^2)\kappa_1^2\varphi_q^2 A_{w,4},$$

where $A_{j,1}$, $A_{j,2}$, $A_{j,3}$ and $A_{j,4}$ are respectively the loads of the risk factors $\sigma_{1,t+1}^2$, $q_{1,t+1}$, $\sigma_{2,t+1}^2$, $q_{2,t+1}$ on the wealth-consumption ratio of each portfolio. These loads are derived in detail in Appendix A.

For the leader country, the variance premium is given by

$$\begin{aligned} VP_{1,t} &= E_t^Q[Var_{r_1,t+1}] - E_t^P[Var_{r_1,t+1}] \\ &\approx (\theta - 1)k_{w,1}(V_{1,1}q_{1,t} + V_{1,2}q_{2,t}), \end{aligned} \tag{5}$$

$$V_{1,1} = A_{w,1} + (A_{1,1}^2 + A_{1,2}^2\varphi_q^2)\kappa_{1,1}^2{\varphi_q}^2 A_2,$$

$$V_{1,2} = A_{1,3}^2 + (A_{1,4}^2\varphi_q^2)\kappa_{1,1}^2\varphi_q^2 A_{w,4},$$

while for the follower country

$$\begin{aligned} VP_{2,t} &= E_t^Q[Var_{r_2,t+1}] - E_t^P[Var_{r_2,t+1}] \\ &\approx (\theta - 1)\kappa_{w,1}(V_{2,1}q_{1,t} + V_{2,2}q_{2,t}), \end{aligned} \tag{6}$$

$$V_{2,1} = \phi_\sigma^2 A_{w,1} + (A_{2,1}^2 + A_{2,2}^2\varphi_q^2)\kappa_{2,1}^2\varphi_q^2 A_{w,2},$$

$$V_{2,2} = A_{w,3} + (A_{2,3}^2 + A_{2,4}^2\varphi_q^2)\kappa_{2,1}^2\varphi_q^2 A_{w,4}.$$

Eqs. (4) to (6) imply that the VoV of both countries are the unique sources of the variance premiums in all portfolios. Actually, for $\theta < 1$, the two countries' VoV load positively on the variance premiums. That is, $V_{j,k} \leq 0$ for $j, k = 1, 2, w$ (see appendix A). Consequently, the global and local variance premiums are positive if $\theta < 1$. While the load of foreign VoV in the leader country variance premium is explained by the recursive nature of the utility function given fully integrated equity markets, the leader country VoV load on the follower country variance premium has the following two sources: the recursive nature of the preferences, and the implied sensitivity to the leader country macroeconomic uncertainty (Eq. (2)).

As an immediate consequence of the common components in the variance premium of all portfolios, the variance premium covariance across countries is uniquely characterized by the two countries' VoV. The expression for the variance premium covariance derived from Eqs. (5) and (6) can be written as follows:

$$Cov_t(VP^1_{t+1}, VP^2_{t+1}) = (\theta - 1)^2 k^2_{w,1} \varphi^2_q (V_{1,1} V_{2,1} q_{1,t} + V_{1,2} V_{2,2} q_{2,t}) \tag{7}$$

where the VoV of both countries loads positively on the variance premium covariance across countries if $\theta < 1$.

4.3 Model-Implied Equity Premiums

In order to understand the relation between the variance premiums and the dynamics of returns, in this section, I find the expressions for the equity premiums.

The global equity premium is characterized by the following expression:

$$\begin{aligned} EP_{w,t} &= E_t(r_{w,t+1} - r_{f,t}) \\ &= \gamma \sigma^2_{w,t} - \frac{1}{2}\sigma^2_{w,t} \\ &\quad + (1-\theta) k_{w,1} (P_{w,1} q_{1,t} + P_{w,2} q_{2,t}), \end{aligned} \tag{8}$$

where $r_{j,t+1}$ is the (log) gross return for portfolio j ($j = 1, 2, w$), $r_{f,t}$ is the global risk-free rate, $\sigma^2_{w,t} = \omega \sigma^2_{1,t} + (1-\omega)\sigma^2_{2,t}$ is the volatility of the world consumption, and $(-\frac{1}{2}\sigma^2_{r_w t})$ is the geometric adjustment term. The term $(1-\theta)k_{w,j}P_{j,k}$ represents the load of $q_{k,t}$ on $EP_{j,t}$. For the global portfolio these loads are given by

$$\begin{aligned} P_{w,1} &= k_{w,1}(A^2_{w,1} + A^2_{w,2}\varphi^2_q), \\ P_{w,2} &= k_{w,1}(A^2_{w,3} + A^2_{w,4}\varphi^2_q). \end{aligned}$$

Equation (8) shows the three model-implied components of the global risk premium. The first component is the classic risk-return trade-off $\gamma\sigma^2_{w,t}$. This first component is also present when the agents are endowed with CRRA preferences. Now, there are two additional components, one for the VoV generated in each country. The VoV components of the equity premium represent the true premium for variance risk since they are driven by the shocks to the volatility and the volatility of volatility of consumption in both countries. In the case of the global portfolio, the VoV of both countries load positively on the equity premium if $\theta < 1$. That is, $(1-\theta)k_{w,1}P_{w,j} \geq 0$, for $j = 1, 2$ (see Appendix A). These positive loads are in line with the concept that, at least for the global portfolio, agents are positively compensated for the risk generated by the time-varying nature of the VoV.

The expressions for the equity premiums for each country are given by

$$\begin{aligned} EP_{1,t} &= E_t(r_{1,t+1} - r_{f,t}) \\ &= \gamma(\omega + (1-\omega)\phi_\sigma)\sigma^2_{1,t} - \frac{1}{2}\sigma^2_{r_1,t} \\ &\quad +(1-\theta)k_{w,1}(P_{1,1}q_{1,t} + P_{1,2}q_{2,t}), \end{aligned} \tag{9}$$

and

$$\begin{aligned} EP_{2,t} &= E_t(r_{2,t+1} - r_{f,t}) \\ &= \gamma\phi_\sigma(\omega + (1-\omega)\phi_\sigma)\sigma^2_{1,t} + \gamma(1-\omega)\sigma^2_{2,t} - \frac{1}{2}\sigma^2_{r_2,t} \\ &\quad +(1-\theta)k_{w,1}(P_{2,1}q_{1,t} + P_{2,2}q_{2,t}), \end{aligned} \tag{10}$$

where

$$\begin{aligned} P_{j,1} &= k_{j,1}(A_{w,1}A_{j,1} + A_{w,2}A_{j,2}\varphi_q^2), \\ P_{j,2} &= k_{j,1}(A_{w,3}A_{j,3} + A_{w,4}A_{j,4}\varphi_q^2), \text{ for } j = 1, 2. \end{aligned}$$

As for the global portfolio, the equity premium in each country is characterized by a volatility of consumption component, and two VoV components, one for each country. In particular, the VoV components in Eqs. (9) and (10) represent the true premium for local and foreign variance risk. Now, comparing the expresssions for the Variance premium (Eqs. 5 and 6) with those for the equity premiums (Eqs. 9 and 10) yields the basic intuition for the role of local and foreign variance premium in predicting equity returns in any country. The intuition is as follows: the VPs reveal the VoV in both countries which in turn drive (in part) the time variation in the equity premiums. It is important to bear in mind that although the VoV is not a necessary condition to generate a variance risk premium, introducing the VoV isolates the risk premium on volatility and differentiate it from the consumption risk premium.

It seems natural from Eqs. (8) to (10) to expect that the VoV also explains the time variation in the covariance of returns across countries. The expression for the covariance of returns is given by

$$Cov_t(r_{1,t+1}, r_{2,t+1}) = \phi_\sigma\sigma^2_{1,t} + CO_1 q_{1,t} + CO_2 q_{2,t}, \tag{11}$$

where CO_j is the load of $q_{j,t}$ on the covariance of returns. These loads are given by

$$\begin{aligned} CO_1 &= \kappa_{1,1}\kappa_{2,1}(A_{1,1}A_{2,1} + A_{1,2}A_{2,2}\varphi_q^2), \\ CO_2 &= \kappa_{1,1}\kappa_{2,1}(A_{1,3}A_{2,3} + A_{1,4}A_{2,4}\varphi_q^2). \end{aligned}$$

4.4 Numerical Implications of the Two-Country Model

In this section, I present some numerical simulations of my model in order to investigate the mechanism of transmission of VoV shocks across countries. The purpose of these simulations is to analyze the qualitative implications of my model for the variance premiums and for the interaction between the variance premiums and the equity returns. I believe that understanding the qualitative implications of the model provides a natural step between the model and the empirical evidence presented in the next section.

The base scenario for the numerical simulations is displayed in Table 2. In this scenario, the parameters in the preference function are calibrated as in BTZ. Now, in order to simplify the interpretation of results, I consider the hypothetical case where the world is composed of only two countries: the US (leader), and Germany (follower). For these two countries I calibrate the parameters in Eqs. (1) and (2) as follows: $\mu_{j,g}$ is estimated as the average IP growth in each country during the period 1973-2009; $\mu_{j,\sigma}$ is estimated as the IP growth unconditional variance for the same period; and the rest of the parameters are calibrated as in BTZ (homogeneous parameters). Now, the Campbell and Shiller constants k_o and k_1 are estimated using data for the Price-Dividend (PD) ratio for each country as well as for the Datastream world portfolio. The log-linearization constants are estimated as $k_1 = \frac{e^{E(PD)}}{1+e^{E(PD)}}$, where $E(PD)$ is the unconditional mean of the (log) PD ratio, and $k_0 = -k_1 \ln(1-k_1) - (1-k_1)\ln(1-k_1)$ (Campbell and Cochrane, 1999). Bear in mind that k_o and k_1 should actually be made dependent of the theoretical wealth-consumption ratio (see Appendix A). However, I use the unconditionally expected PD ratio, to make these two parameters independent from the set of parameters considered in each case.

4.4.1 Variance Premium Dynamics

According to the first main implication of my model, both countries' VoV load positively on all portfolios' variance premiums (see Eqs. (4) to (6)). In order to show so, Figure 4 displays the (unconditionally expected) VoV loads on the variance premium for all portfolios. The figure shows the components of the variance premiums for alternative values of the risk aversion (γ), the weight of the leader country (ω), and the correlation of consumption (ϕ_σ). The simulations show that the implied size of the US VoV load dominates that of Germany in all cases considered. The dominance of the US VoV increases with the relative size of the leader economy (ω), and with the relative dependence of the follower economy (ϕ_σ). The contribution of the follower economy VoV in the variance premiums, on the other hand, is almost insignificant no matter the size nor the independence of the consumption process in this economy.

The simulations also suggest that the magnitude of the expected variance premiums monotonously increases with the risk aversion, and decreases with the relative size of the riskiest market.[17] The riskiest market is assumed, for coherence, to be that in the follower country. However, for all cases considered, the average variance premium is quantitatively

[17] It is easy to show the same monotonous relation for the IES ψ. Results for the relation between ψ and the model implications are available upon request.

far from that empirically observed for these two countries (see Table 1). The limitation to quantitatively reflect the observed premium in models with recursive preferences has been previously documented by Drechsler and Yaron (2010) in a single-country setting.

In unreported results, I show that the model-implied variance premium correlation across the two countries is above 0.98 for all simulations. This results is to be expected given the high common component of the leader country VoV in all variance premiums. Actually, for all cases considered, the model implies that the leader country VoV accounts for more than 99% of the total cross-country variance premium covariance. Surprisingly, the result on the dominant role of the US VoV holds no matter the relative size of the follower economy ($(1-\omega) < 0.5$) or its implied correlation with the leader economy.

In sum, the numerical simulations show that the VoV generated in the leader economy accounts for most of the systematic component of the variance premiums. Therefore, the VoV generated in the leader economy plays the key role in explaining the variance premium for all portfolios. This in turn implies that the leader country VoV is also the key driver of the expected variance premium correlation across countries.

4.4.2 Return Dynamics

According to the second main implication of my model, the two countries' VoV that uniquely characterize the variance premiums also drive the time variation in equity premiums. Figure 5 displays the model-implied components of the equity premium for the global and the local portfolios for alternative sets of parameters. The simulations show that the leader country VoV load dominates that of the follower country in all portfolios' equity premiums for all cases considered. In some cases, the VoV of the leader country loads negatively on the follower country's equity premium. This case only occurs when economies are poorly correlated as can be seen in Panel J and K. However, the follower country VoV loads negatively on the leader country's equity premium for all cases considered, except of course for the extreme case where the size of the German economy is insignificant (Panels C,F,I, and L).

The possibility of VoV loading negatively on the equity premiums can actually be explained by the mechanism of transmission of shocks to VoV implied by the model. According to this mechanism, a positive shock to VoV in the follower country has a negative impact on the leader country's equity premium. This effect can be interpreted as a macroeconomic uncertainty induced flight-to-safety from the follower to the leader economy. The possibility of an uncertainty flight-to-safety in this direction is actually generated by the fact that the leader country consumption process is, by construction, not sensitive to the shocks generated in the follower country (Eq. (1)). Investing in equities in the leader country is then expected to become a more attractive investment alternative with respect to this foreign source of risk. In contrast, an uncertainty flight-to-safety in the other direction (leader to follower) is not always possible. This is due to the fact that the follower country consumption process is affected by the shocks in the leader economy (Eq. (2)). Therefore, a flight-to-safety in this direction is only possible if the economies are assumed to be quite independent. For example, in the case of totally

independent economies in Panel J, any equity market is free from the uncertainty risk generated in the foreign economy. Thus, in this extreme case, the VoV of one country will always load negatively on the other country's equity premium.

As a consequence of the second main implication of my model, both countries' VoV also play a role in explaining the covariance of equity returns across countries. As expected, even if the follower economy has a large (relative) size the, VoV of the leader country dominates. The dominance of the leader country VoV increases with the relative size of the leader economy (ω), and the degree of dependence across the two economies (ϕ_σ). In line with the simulations in Figure 5, the VoV generated in the follower country may even load negatively on the covariance of returns. Actually, in the case of totally independent or mildly correlated economies, the simulations confirm that even VoV generated in the leader economy might load negatively on the covariance of returns.[18]

Finally, the simulations in Figure 6 show the relation between the correlation of the economies and the model-implied correlation across equity markets. The simulations reflect the documented disparity between the correlation of equity markets and the correlation of economies. They show that the equity return correlation is in some cases higher than the implied correlation of consumption. In particular, the simulations suggest that for moderately risk averse agents ($\gamma > 2$) and moderately correlated economies, the implied correlation across equity markets is larger than that implied by the correlation of consumption. This result arrives as a direct consequence of the recursive nature of the representative agent's preferences.

In sum, the numerical simulations show that the VoV generated in the leader economy plays the key role in explaining the time variation in the equity premium of all portfolios. As a consequence of this implication, the leader economy VoV also plays a dominant role in explaining the time variation in equity return correlations across countries. The simulations also show some consequences derived from the model setup. In particular, from the assumptions of integrated markets where the representative agent is endowed with recursive preferences and one economy behaves as a follower. For example, the model introduces the possibility of a macroeconomic uncertainty induced flight-to safety, which in turn introduces the possibility that the VoV of one country covaries negatively with the equity premium of another country.

5 The Variance Premium and International Equity and Option Markets: Empirical Evidence

In this section, I present the empirical evidence based on the qualitative implications of the GE model analyzed in Section 4. First, using the variance premiums for all countries in the sample, I investigate the dominant role of the US variance premium in (i) explaining the time variation in the variance premium for all other countries, (ii) predicting the variance premium correlations across countries, (iii) predicting not only the local equity

[18] These simulations are left unreported.

returns, but also those in other countries, and (iv) predicting the correlation of equity returns across countries. Then, I investigate the empirical evidence when the effects of country-specific shocks to VoV are separated using the model. Finally, I propose an extension of the empirical evidence to analyze the potential role of the variance premium in explaining excessive comovements across equity and option markets. The excessive comovements analysis seems a natural extension to understand equity and option markets linkages around episodes of extreme macroeconomic uncertainty beyond the implications of the model.

5.1 Cross-country Variance Premium Correlations

A first implication of my model is that the variance premiums are highly correlated across countries. The high variance premium correlation is due to the common load of the leader country VoV in all variance premiums (leader, follower, and global portfolio). This in turn implies that the leader country variance premium plays a key role in predicting the variance premium correlations across countries. In order to analyze this implication, I first provide evidence for the variance premium correlations across countries. Then, I analyze the role of the US variance premium in explaining the time variation in the variance premium of all other countries in the sample. Finally, I investigate the role of the US variance premium in predicting the variance premium correlations between any country and the US.

Table 3 displays the variance premium correlations across all countries in the sample. In line with the first implication of my model, all countries but Japan show correlations above 0.5. In particular, the US and the UK show a high correlation coefficient of 0.73. Among European markets, France and The Netherlands show the highest correlation coefficient in the sample: 0.89. However, Japan's variance premium shows a relatively low, or even negative, correlation with the variance premium in any other market excepts perhaps with Switzerland.[19] The evidence for Japan stands in sharp contrast to the implications of the model. In fact, my model can only accommodate positive variance premium correlations. This is derived from the ability of my model to characterize only positive variance premiums.

The results on the high variance premium correlations has been previously documented in the literature for a shorter sample of countries. For example, Bekaert, Hoerova and Scheicher (2009) find evidence of high risk aversion and uncertainty correlation between Germany and the US. Although their measures are not directly the variance premiums, their empirical methodology uncovers the risk aversion and uncertainty time series using the observed IV and realized volatilities for these two countries. Sugihara (2010) also finds evidence of strong linkages in volatility premiums between the US, Germany and Japan. He actually finds empirical evidence that the correlation between these three markets is stronger around certain episodes. In particular, after the subprime crisis. However, in this

[19] The highly idiosyncratic dynamic of the variance premium in Japan has been previously documented in the literature (see, for instance, Driessen and Maenhout, 2006).

paper, I do not only extend the evidence for a larger sample of countries; I also provide a fundamental explanation for the dynamics of the variance premium correlation across countries. In particular, my model relates the high variance premium correlation across countries to a systematic component which is mainly driven by the leader country variance premium.

The results in Table 4 relate the evidence on the high cross-country variance premium correlation to the systematic component of the variance premiums implied by my model. The table shows the role of the US variance premium in explaining the time variation in all other countries' variance premiums. The evidence suggests that the US variance premium can explain a large portion of the changes in the variance premium of all other countries except perhaps for Japan. In fact, the average R^2 in the regressions is as high as 42,6% when Japan is excluded. Actually, only for Japan, the estimated coefficient for the US variance premium is not significant. It is important to bear in mind that the divergence in the explanatory role of the US variance premium in all other countries' variance premiums is linked in my model to the relative size and the degree of dependence among economies (see Figure 4).

A direct consequence of the common component in all variance premiums is that the variance premium correlations are predicted by the leader country's variance premium. In order to test this consequence, Table 5 reports the estimated coefficients $\gamma_{1,jk}$ for the following regressions:

$$\rho_t(vp_{j,t,t+1}, vp_{k,t,t+1}) = \gamma_{0,jk} + \gamma_{1,jk} vp_{k,t} + \epsilon_{jk,t},$$

where the correlation coefficient for the period t to $t+1$ is calculated using daily data for the variance premiums of the two countries for the month starting immediately after the realization of $vp_{k,t-1}$.[20,21] The evidence suggests that the US variance premium predicts the one-month-ahead variance premium correlation between the US, Germany, and Japan (first horizontal block of results).[22] However, the results show that the US variance premium does not outperform all other countries' variance premium. For example, the first vertical block of results in the table suggests that the variance premiums in Germany, Japan, the UK, Switzerland and The Netherlands can also forecast the variance premium correlation between these countries and the US.[23]

[20] The following month $(t, t+1)$ is assumed to be the period 22 days after the realization of $vp_{k,t}$.

[21] Equation (7) actually has an implication on the variance premium covariance. To avoid a potential scale problem, and make results easier to interpret, I only report cross-country correlations. An expression for the variance premium correlation fom Eq. (7) is direct, although not necessarily linear in VoV.

[22] In unreported results, I actually show that, except for the martingale assumption, the predictive role of the US variance premium over its correlation with Germany and Japan holds for all alternative variance premium specifications considered.

[23] Given the high correlation in vp_t across countries, it would be hard to disentangle the simultaneous role of $vp_{US,t}$ with any other $vp_{j,t}$ since multiple regressions will be highly affected by multicolinearity. In Subsection 5.3, I explore the separate role of the country-specific VoV shocks and perform a test with the simultaneous role of the two countries VoV.

In sum, the evidence in this section suggests that the variance premium correlations across countries increase following episodes of increasing variance premiums. It also suggests that the model-implied dominant role of the leader country variance premium restricts the potential ability of other countries in predicting one-month ahead variance premium correlations. In order to explore higher frequency correlation patterns, in section 5.4, I investigate the role of the US variance premium in explaining excessive variance premium comovements at the daily frequency.

5.2 Cross-Country Equity Return Correlations

The second main implication of my model is that the variance premiums covary with the equity premiums (Eqs. (9) and (10)). This is due to the fact that the VoV shocks that uniquely characterize the variance premiums also load on both countries' equity premiums. In particular, the model implies that the leader country's VoV dominates that of the follower country in all equity premiums. As a consequence, the leader country variance premium should outperform the follower country in predicting local and foreign returns. In this section, I provide evidence for the role of the US variance premium in predicting equity returns for all countries in the sample.

Figure 7 reports the estimation results for the following regressions:

$$(r - r_f)_{j,t,t+h} = \gamma_{0,j,h} + \gamma_{1,j,h} vp_{US,t} + \gamma_{1,j,h} dy_{j,t} + \gamma_{1,j,h} ts_{j,t} + \epsilon_{j,h,t},$$

where $(r - r_f)_{j,t,t+h}$ represents future compounded annualized excess returns h-months ahead, $dy_{j,t}$ is the local dividend yield, and $ts_{j,t}$ is the local term spread. The results suggest that the US variance premium predicts not only the US equity returns, but also those for all other countries in the sample. The predictive power of the US variance premium for all countries resembles the hump-shaped pattern found by BTZ for the US (local return predictability). This pattern reflects the fact that the variance premium should be a dominant predictor for horizons where the VoV is the main source of variation in equity returns. The extension of this evidence for other countries indicates that the US VoV is the dominant source of variation in all countries' equity returns for horizons between 3 and 6 months. The figure also suggests that the predictive power of the US variance premium is complementary to that of local term spreads and dividend yields.[24] Now, when compared to Figure 3, the evidence also suggest that the US variance premium outperforms the local variance premiums in predicting equity returns for all countries considered. In unreported results, I show that the ability of the US variance premium to

[24] The hump-shaped predictability pattern, as well as the significance of the US variance premium in predicting foreign equity returns is robust to considering the US term spread and dividend yield. Results for these regressions are available upon request.

predict foreign returns holds for all alternative variance premium specifications considered, except perhaps for the range-based estimation.[25,26]

As a consequence of the systematic component of equity premiums, the leader country variance premium should also be a useful predictor of equity return correlations across countries (Eq. (11)). In order to test this consequence, Figure 8 reports the estimation results for the following regressions:

$$\rho_t(r_{j,t,t+h}, r_{US,t,t+h}) = \gamma_{0,jk} + \gamma_{1,j,US} vp_t^{US} + \epsilon_{jk,t},$$

where $\rho_t(r_{j,t,t+h}, r_{US,t,t+h})$ is the h-months ahead equity return correlation between any country and the US. The results suggest that the US variance premium predicts equity return correlations between the US and any other country in the sample except for Japan and Belgium. As for the equity returns, the ability of the US variance premium to forecast return correlations holds for horizons between 3 and 6 months for most of the countries. Actually, for the equity correlation between the US and Germany, the US variance premium has predictive power for horizons up to 12 months. In unreported results, I also show that the US variance premium outperforms all other countries in the sample in predicting equity return correlations.

In sum, the evidence in this section supports the implications of my model for the role of the variance premium in predicting equity returns. It confirms the predominant role of the US variance premium in predicting foreign equity returns and return correlations across countries. Therefore, the evidence supports the theoretical solution implied by the model in Section 4 to the local return predictability puzzle in Section 3. That is, the local variance premium cannot predict returns in countries other than the US because the role of the variance premium in those countries is dominated by the variance premium in a leader country: the US.

5.3 Model Implications and Country-specific VoV

In this section, I investigate the implications of my model when each country's VoV ($q_{j,t}$) is identified separately. The identification of the VoV is done by means of the model in Section 4. The procedure is as follows: using Equations (5) and (6), and the benchmark calibration presented in Table 2, the monthly values of $q_{US,t}$ and $q_{GER,t}$ are obtained from $vp_{US,t}$ and $vp_{GER,t}$. It is important to keep in mind that the results in this section are merely an exploration of the empirical evidence, since they are, in any case, dependent on the model as well as on the parameters considered in the base scenario.

Similar to Table 5, Table 6 displays the role of both countries' VoV in forecasting the variance premium correlation between Germany and the US. The evidence confirms

[25] When the range based forecast of realized volatility is used, the US variance premium predicts returns only for the UK, Belgium and France.

[26] Results for the robustness tests are left unreported in order to save space and center the discussion. The results for the alternative variance premium specifications, samples, currencies, as well as for alternative variance covariance matrix approximations (Hodrick, 1992) are available upon request.

the dominant role of the US VoV in forecasting the one-month-ahead variance premium correlations. The estimated VoV in Germany, on the other hand, plays an insignificant role in forecasting the one-month ahead variance premium correlation.

Now, Table 7 shows the role of the estimated VoV in predicting excess returns for Germany and the US. The results in this table confirm those in Figure 7. That is, on the one hand, the excess returns in the US and Germany are predicted by the US VoV for horizons between 3 to 6 months. On the other hand, the estimated coefficient for $q_{GER,t}$ is negative for these horizons, which confirms the uncertainty induced flight-to-safety argument explained in Section 4 (see Figure 5). However, the negative $q_{GER,t}$ estimated coefficient for the equity returns in Germany stands in contrast to the implications of the model, and not in line with the idea that agents fear macroeconomic uncertainty. In particular, macroeconomic uncertainty generated locally. Nonetheless, this result supports the idea that the representative agent is mainly concerned about the macroeconomic uncertainty generated in the leader economy.[27]

Finally, Table 8 confirms the evidence in Figure 8. That is, the equity return correlation between these markets increases following positive shocks to the US VoV. The results show that as it is implied by my model, the role of the US VoV dominates that of Germany for all horizons considered.

In sum, the results in this section confirm those obtained when the variance premiums are used to test the main implications of my model. That is, that the US VoV plays the key role in explaining the time variation in variance premiums and equity premiums. Although these results depend on the model and the parameters considered, the dominant role of the US VoV is robust to alternative values of γ and ω. The results are even robust to the assumption that the US and Germany economies are poorly correlated (low values of ϕ_σ). These results are available upon request.

5.4 Exploring the role of the Variance Premium in Explaining Excessive comovements

In this section, I extend the analysis of the model implications to understand the potential role of the variance premium in explaining excessive comovements across international equity and option markets. Although a natural extension, the excessive comovement analysis does not have an immediate linkage with the model in Section 4. Therefore, the evidence presented in this section is merely an investigation of the impact of unusual events from an empirical perspective. As in the previous sections, I investigate both the variance premium and the equity return correlations. The procedure to test for excessive comovements is done at the daily as well as at the monthly frequency, though only the results for the daily frequency are reported.

The analysis of the excessive comovements in the variance premium dynamics requires the estimation of the following system of equations:

[27] Multicolineality still plays an important role in this prediction results. The regression coefficients change substantially when the two estimated $q_{j,t}$ are considered simultaneously in the regressions.

$$vp_{j,t+h} = \gamma_{0,,j,h} + \gamma_{1,,j,h,t} vp_{US,t} + \epsilon_{t,h}, \tag{12}$$

where h are the alternative horizons considered and the time varying coefficient $\gamma_{1,,j,h,t}$ follows

$$\gamma_{1,j,h,t} = v_{o,,j,h} + v_{1,,j,h} D_{US,t},$$

where the dummy $D_{US,t}$ characterizes extreme values of $vp_{US,t}$. This variable takes the value 1 when $vp_{US,t}$ is above the 5^{th} percentile.[28] The estimated $v_{1,,j,h}$ are displayed in Figure 9 for horizons between 1 and 22 days. The evidence suggests that episodes of unusually high US variance premium generate unusual variance premium correlations between the US and most of the countries in the sample. As can be seen from the figure, this effect is significant only in the very short term, usually up to 10 days. For all countries, except France, the significance of $v_{1,j,h}$ follows a decreasing pattern as the horizon increases, which in turn suggests that it could be hard to identify unusual variance premium comovements at the monthly frequency. In sum, the empirical evidence suggests that the variance premium correlations tend to intensify following episodes of extremely high US variance premium.

In order to investigate the excessive comovement of returns, I follow the literature on contagion. In particular, the procedures in Bekaert, Harvey and Ng (2005) and Baele and Inghelbrecht (2010). In this case, the test is performed on the residuals from a single-factor model. Therefore, excessive return comovements can be interpreted as cross-country equity return correlation beyond what is expected from the exposition of all returns to a common factor. To maintain the coherence with the rest of the paper, I assume that the common factor is the US equity returns. The procedure for this test is explained in detail in Appendix B, and its results are displayed in Figure 10. The evidence shows that, in contrast to the evidence for the variance premium dynamics, there is no clear effect of extreme variance premium episodes over the equity returns. Therefore, the evidence suggests that, for the return correlations, only the fundamental relation implied by the model is supported by the empirical evidence.[29]

6 Conclusions

This paper presents several new findings related to the variance risk premium for a total of eight countries. First, I provide new evidence that the variance premiums display significant time variation and are, on average, positive for all countries analyzed. However, I also provide evidence that except for the US, the local variance premiums do not predict local equity returns. This evidence is in sharp contrast to the existing theoretical models where the variance premium explains the time variation in equity returns.

[28] The results for alternative percentiles as well as for two-sided extreme events are available upon request.

[29] The insignificant effect of extreme variance premium episodes holds at the monthly frequency. These esults are available upon request.

Motivated by the puzzling single-country evidence, I propose an international model to understand the role of the variance premium in explaining international equity returns. The model is a two-country general equilibrium model which extends that in Bollerslev, Tauchen and Zhou (2009). My model yields relevant qualitative implications that explain the inability of the variance premium in predicting local returns in countries other than the US. In particular, my model implies that the variance premium generated in a leader economy plays a key role in explaining the time variation in equity returns in the two countries. Therefore, the leader country variance premium outperforms the follower country variance premium in predicting not only equity returns, but also equity return correlations across countries. The dominant role of the leader country variance is a consequence of the common components in the variance premiums of all countries. In particular, a consequence of the dominant load of macroeconomic uncertainty shocks generated in the leader economy in the variance premiums of both countries.

Finally, I provide new empirical evidence for the qualitative implications of my model for the eight countries in the sample. I show that the US variance premium has predictive power over the equity returns for all countries in the sample. The predictive power of the US variance premium over international equity returns is (i) stronger for horizons between 3 and 6 months, (ii) additional to that of traditional local (or US) variables, and (iii) clearly outperforms the local variance premium themselves. Finally, I also show that the US variance premium predicts the correlation of equity returns between the US and all countries in the sample, except for Japan and Belgium.

Given the new findings presented in this paper, exploring the dynamics of the variance premium in an international setting remains a very interesting topic in my research agenda. I am currently working in disentangling the systematic and country-specific components of the variance premiums. In future research, I will also investigate in depth the short-term dynamics of the variance premiums. In particular, the contagion patterns across countries.

APPENDIX

A Detailed Solution of the Two-country Model

This appendix explains in detail the solution to the model in Section 4.

Each country return process is assumed to be a claim on the local consumption growth, while the global portfolio return is a claim on the weighted global consumption $g_t^w = \omega g_t^1 + (1-\omega) g_t^2$, where ω is the weight of the leader country. Following Campbell and Shiller (1988), the returns are linearized as

$$r_{j,t+1} = \kappa_{j,0} + \kappa_{j,1} z_{j,t+1} - z_{j,t} + g_{j,t+1}, \text{ for } j = 1, 2, w, \tag{13}$$

where $z_{j,t}$ denotes the log of the wealth-consumption ratio of the asset that pays the consumption endowment $\{C_{j,t+i}\}_{i=1}^{\infty}$. As it is standard in the asset pricing literature, I conjecture a solution for $z_{j,t}$ as a function of the state variables of both countries as follows:

$$z_{j,t+1} = A_{j,0} + A_{j,1}\sigma_{1,t+1}^2 + A_{j,2} q_{1,t+1} + A_{j,3}\sigma_{2,t+1}^2 + A_{j,4} q_{2,t+1}. \tag{14}$$

Based on this solution, the basic asset pricing equation is imposed in order to determine the components of $z_{j,t+1}$. The basic asset pricing equation is the first order condition from the agent maximization problem given by

$$E_t[(\exp(m_{t+1} + r_{j,t+1})] = 1,$$

where m_{t+1} is the (log of) intertemporal marginal rate of substitution. For the case of Epstein-Zin-Weil preferences, and given that markets are assumed to be perfectly integrated, the unique marginal rate of substitution is given by

$$\begin{aligned} m_{t+1} &= \theta \log \delta - \frac{\theta}{\psi} g_{t+1} + (\theta - 1) r_{t+1} \\ &= b_{mo} + b_{mg} g_{w,t+1} + b_{mr} r_{w,t+1}, \end{aligned}$$

where $0 < \delta < 1$ is the time discount rate, $\gamma \geq 0$ is the risk aversion parameter, and $\theta = \frac{1-\gamma}{1-\frac{1}{\psi}}$ for $\psi \geq 1$ is the intertemporal elasticity of substitution (IES).

Solving for the world portfolio yields the following expressions for the components of $z_{j,t+1}$:

$$\begin{aligned} A_{w,0} &= \frac{\theta \log \delta + (1-\gamma)(\omega \mu_{1,g} + (1-\omega)(\mu_{2,g} + \phi_g \mu_{1,g}))}{\theta(1 - \kappa_{w,1})} \\ &\quad + \frac{\kappa_{w,0} + \kappa_{w,1} A_{w,1} a_\sigma + \kappa_{w,1} A_{w,2} a_q + \kappa_{w,1} A_{w,3} a_\sigma + \kappa_{w,1} A_{w,4} a_q}{(1 - \kappa_{w,1})}, \end{aligned}$$

$$A_1 = \frac{(1-\gamma)^2(\omega+(1-\omega)\phi_\sigma)^2}{2\theta(1-\kappa_{w,1}\rho_\sigma)},$$

$$A_{w,2}^{+,-} = \frac{(1-\kappa_{w,1}\rho_q) \pm \sqrt{(1-\kappa_{w,1}\rho_q)^2 - \theta^2\kappa_{w,1}^2\varphi_q^2 A_{w,1}^2}}{\theta\kappa_{w,1}^2\varphi_q^2},$$

$$A_{w,3} = \frac{(1-\gamma)^2(1-\omega)^2}{2\theta(1-\kappa_{w,1}\rho_\sigma)},$$

and

$$A_{w,4}^{+,-} = \frac{(1-\kappa_{w,1}\rho_q) \pm \sqrt{(1-\kappa_{w,1}\rho_q)^2 - \theta^2\kappa_{w,1}^2\varphi_q^2 A_{w,3}^2}}{\theta\kappa_{w,1}^2\varphi_q^2}.$$

To avoid the load of time-varying volatilities $\sigma_{1,t}$, and $\sigma_{2,t}$ from growing without bounds, I only keep $A_{w,2}^-$ ($A_{w,4}^-$). The positive root discarded is explosive in φ_q, i.e., $\lim_{\varphi_q\to 0} A_{w,2}^+\varphi_q \neq 0$ ($\lim_{\varphi_q\to 0} A_{w,4}^+\varphi_q \neq 0$). Now $A_{w,2}^-$ ($A_{w,4}^-$) will be a solution to the model as long as $(1-\kappa_{w,1}\rho_q)^2 \geq \theta^2\kappa_{w,1}^2\varphi_q^2 A_{w,1}^2$ ($(1-\kappa_{w,1}\rho_q)^2 \geq \theta^2\kappa_{w,1}^2\varphi_q^2 A_{w,3}^2$). It is easy to show from these expressions that all state variables load negatively on the global wealth-consumption ratio. That is, $A_{w,1}$, $A_{w,2}$, $A_{w,3}$, $A_{w,4} \leq 0$ as long as $\theta < 1$.

Solving for the leader country 1 yields the following expressions:

$$\begin{aligned} A_{1,0} &= \frac{\kappa_{1,0} + \kappa_{1,1}A_{1,1}a_\sigma + \kappa_{1,1}A_{1,2}a_q + \kappa_{1,1}A_{1,3}a_\sigma^2 + \kappa_{1,1}A_{1,4}a_q + \mu_{1,g}}{(1-\kappa_{1,1})} \\ &\quad - \frac{\begin{array}{c}\kappa_{w,0} + (\kappa_{w,1}-1)A_{w,0} + \kappa_{w,1}A_{w,1}a_\sigma + \kappa_{w,1}A_{w,2}a_q + \\ +\kappa_{w,1}A_{w,3}a_\sigma + \kappa_{w,1}A_{w,4}a_q + \omega\mu_{1,g} + (1-\omega)(\mu_{2,g} + \phi_g\mu_{1,g})\end{array}}{(1-\kappa_{1,1})}, \end{aligned}$$

$$A_{1,1} = \frac{(1-\theta)(1-\gamma)^2(\omega+(1-\omega)\phi_\sigma)^2 + \theta(1-\gamma(\omega+(1-\omega)\phi_\sigma))^2}{2\theta(1-\kappa_{1,1}\rho_\sigma)},$$

$$\begin{aligned} A_{1,2}^{+,-} &= \frac{(1-\kappa_{1,1}\rho_q) + (1-\theta)\kappa_{1,1}\kappa_{w,1}A_{w,2}\varphi_q^2}{\kappa_{1,1}^2\varphi_q^2} \\ &\quad \pm \frac{\sqrt{\begin{array}{c}((1-\kappa_{1,1}\rho_q) + (1-\theta)\kappa_{1,1}\kappa_{w,1}A_{w,2}\varphi_q^2)^2 - \kappa_{1,1}^2\varphi_q^2((\theta-1)^2\kappa_1^2A_{w,2}^2\varphi_q^2 + \\ +2(\kappa_{w,1}\rho_q - 1)(\theta-1)A_{w,2} + (\kappa_{1,1}A_{1,1} + (\theta-1)\kappa_{w,1}A_{w,1})^2)\end{array}}}{\kappa_{1,1}^2\varphi_q^2}, \end{aligned}$$

$$A_{1,3} = \frac{(1-\theta)(1-\kappa_{w,1}\rho_\sigma)A_{w,3} + \frac{1}{2}\gamma^2(1-\omega)^2}{(1-\kappa_{1,1}\rho_\sigma)},$$

and

$$A_{1,4}^{+,-} = \frac{(1-\kappa_{1,1}\rho_q)+(1-\theta)\kappa_{1,1}\kappa_{w,1}A_{w,4}\varphi_q^2}{\kappa_{1,1}^2\varphi_q^2} \pm \frac{\sqrt{\begin{array}{c}((1-\kappa_{1,1}\rho_q)+(1-\theta)\kappa_{1,1}\kappa_{w,1}A_{w,4}\varphi_q^2)^2-\kappa_{1,1}^2\varphi_q^2[(\theta-1)^2\kappa_{w,1}^2\varphi_q^2A_{w,4}^2+\\ +2(\kappa_{w,1}\rho_q-1)(\theta-1)A_{w,4}+(\kappa_{1,1}A_{1,3}+(\theta-1)\kappa_{w,1}A_{w,3})^2]\end{array}}}{\kappa_{1,1}^2\varphi_q^2}.$$

Finally, for the follower country 2, solving the basic asset pricing equation yields

$$A_{2,0} = \frac{\kappa_{2,0}+\kappa_{2,1}A_{2,1}a_\sigma+\kappa_{2,1}A_{2,2}a_q+\kappa_{2,1}A_{2,3}a_\sigma+\kappa_{2,1}A_{2,4}a_q+\mu_{2,g}+\phi_g\mu_{1,g}}{(1-\kappa_{2,1})} - \frac{\begin{array}{c}\kappa_{w,0}+\kappa_{w,1}A_{w,0}+\kappa_{w,1}A_{w,1}a_\sigma+\kappa_{w,1}A_{w,2}a_q+\\ +\kappa_{w,1}A_{w,3}a_\sigma+\kappa_{w,1}A_{w,4}a_q-A_{w,0}+\omega\mu_{1g}+(1-\omega)(\mu_{2,g}+\phi_g\mu_{1,g})\end{array}}{(1-\kappa_{2,1})},$$

$$A_{2,1} = \frac{(1-\theta)(1-\gamma)^2(\omega+(1-\omega)\phi_\sigma)^2+\theta(\phi_\sigma-\gamma(\omega+(1-\omega)\phi_\sigma))^2}{2\theta(1-\kappa_{2,1}\rho_\sigma)},$$

$$A_{2,2}^{+,-} = \frac{(1-\kappa_{2,1}\rho_q)+(1-\theta)\kappa_{w,1}\kappa_{2,1}A_{w,2}\varphi_q^2}{\kappa_{2,1}^2\varphi_q^2} \pm \frac{\sqrt{\begin{array}{c}((1-\kappa_{2,1}\rho_q)+(1-\theta)\kappa_{w,1}\kappa_{2,1}A_{w2}\varphi_q^2)^2-2\varphi_q^2\kappa_{2,1}^2((\theta-1)(\kappa_{w,1}\rho_q-1)A_{w,2}+\\ +\frac{1}{2}((\theta-1)\kappa_{w,1}A_{w,1}+\kappa_{2,1}A_{2,1})^2+\frac{1}{2}\varphi_q^2(\theta-1)^2\kappa_{w,1}^2A_{w,2}^2)\end{array}}}{(\kappa_1^2)^2\varphi_q^2},$$

$$A_{2,3} = \frac{(1-\theta)(1-\kappa_{w,1}\rho_\sigma^2)A_{w,3}+\frac{1}{2}(1-\gamma(1-\omega))^2}{(1-\kappa_{2,1}\rho_\sigma^2)},$$

and

$$A_{2,4}^{+,-} = \frac{(1-\kappa_{2,1}\rho_q)+(1-\theta)\kappa_{w,1}\kappa_{2,1}A_{w,4}\varphi_q^2}{\kappa_{2,1}^2\varphi_q^2} \pm \frac{\sqrt{\begin{array}{c}((1-\kappa_{2,1}\rho_q)+(1-\theta)\kappa_1\kappa_{2,1}A_{w,4}\varphi_q^2)^2-2\varphi_q^2\kappa_{2,1}^2[2(\kappa_{w,1}\rho_q-1)(\theta-1)A_{w,4}+\\ +[(\theta-1)\kappa_{w,1}A_{w,3}+\kappa_{2,1}A_{w,3}]^2+\varphi_q^2(\theta-1)^2\kappa_{w,1}^2A_{w,4}^2]\end{array}}}{\kappa_{2,1}^2\varphi_q^2}.$$

Again, following the same reasoning as for the world portfolio, it only makes sense to keep $A_{j,2}^-$ and $A_{j,4}^-$.

B Excessive Return Comovements

The test for the excessive return comovements in this paper is a simplified version of the contagion tests in Bekaert, Harvey and Ng (2005), and Baele and Inghelbrecht (2010). I assume that the only fundamental factor to which all countries are exposed is the US equity return. This assumption is coherent with the assumption of a leader economy throughout the paper. It is also consistent with the fact that except for the Euro-zone, not enough countries for any region are considered in the sample.[30]

The excess US returns (global factor) are modeled as follows:

$$r_{US,t} - r_{f,t} = \delta'_{US} Z_{US,t-1} + e_{US,t}, \tag{15}$$

where $e_{US,t} \mid Z_{US,t-1} \sim N(0, \sigma^2_{US,t})$, where $Z_{US,t-1}$ contains the so-called global variables. The global variables considered are the world Datastream dividend yield, the Eurodollar spread, the 10 years US T-bill spread and the change in the 90 days US t-bill rate. Now, $\sigma^2_{US,t}$ follows a (potentially) asymmetrical GARCH process such as

$$\sigma^2_{US,t} = a_{US} + b_{US}\sigma^2_{US,t-1} + c_{US}e^2_{US,t-1} + d_{US}\eta^2_{US,t-1},$$

where $\eta_{US,t}$ is the negative return shock ($\eta_{US,t} = \min\{o, e_{US,t}\}$).

The local returns for all other countries are also assumed to follow GARCH (1,1) processes such as

$$r_{j,t} - r_{f,t} = \delta_j Z_{j,t-1} + \beta^{US}_{j,t-1}\mu_{US,t-1} + \beta^{US}_{j,t-1}e_{US,t} + e_{j,t}, \tag{16}$$

where $\mu_{us,t-1} = E[r_{US,t} - r_{f,t} \mid Z_{US,t-1}]$. The local information set $Z_{j,t-1}$ contains the local dividend yield. Now, the residuals in Eq. (16) follow $e_{j,t} \mid Z_{j,t-1} \sim N(0, \sigma^2_{j,t})$, where $\sigma^2_{j,t}$ follows a (potentially) asymmetrical GARCH process such as

$$\sigma^2_{j,t} = a_j + b_j\sigma^2_{j,t-1} + c_j e^2_{j,t-1} + d_j\eta^2_{j,t-1}.$$

Finally, the time varying sensitivity to the US (global) factor follows

$$\beta^{US}_{j,t-1} = \beta_{j,0} + \beta_{j,1}ts_{j,t-1} + \beta_j X^{US}_{j,t-1}, \tag{17}$$

where $X^{us}_{j,t-1}$ is the percentage of trade over GDP (sum of exports and imports over local GDP. Only for the monthly frequency), and $ts_{j,t-1}$ is the 1-year term spread for each country. Controlling by $X^{us}_{j,t-1}$ allows the betas to be impacted by trade as proposed by Bekaert, Harvey and Ng (2005), while the term spread is included to account for the possible cyclicality of betas as suggested by Baele and Inghelbrecht (2010).

Following the literature of contagion, in a first stage, I estimate the model in Eqs. (15) to (17). In a second stage, the residuals from this regression are used to test for

[30] A single-factor model is considered in Tang (2001). However, it has been shown that models including a regional factor outperform those with only a global factor (see for instance Bekaert, Hodrick and Zhang, 2005).

unusual return comovements across countries. The excessive comovement test requires the estimation of the following regression:

$$\begin{aligned} \widehat{e}_{j,t} &= w_j + v_{j,t}\widehat{e}_{us,t} + u_{j,t}, \\ v_{j,t} &= v_o + v_1 D_{US,jt-1}, \end{aligned}$$

where $D_{US,j,t-1}$ are the dummy variables controlling for extreme realizations of the variance premium.[31] The estimated parameters for this tests are available upon request.

[31] All the attention is focused on the estimated parameter v_1. See Baele and Inghelbrecht (2010) for a discussion on the difference between the test for the correct specification of the model and the contagion test itself.

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Table 1: Summary Statistics. Variance (and Volatility) Premiums

The table reports the average volatility premiums (in annual percentages) calculated monthly as $volp_{j,t} = iv_{j,t} - E_t(rv_{j,t+1})$ for the eight countries for the sample period 2000 to 2009. It also reports the summary statistics for the variance premiums (in annual squared percentages). The variance premium in each country is estimated as $vp_{j,t} = iv_{j,t}^2 - (\widehat{rv}_{jt+1})^2$,where the benchmark specification for the expected realized variance is its first order autoregressive forecast. AR(1) is the estimated first-order autoregressive coefficient of the variance premium. Now, *,** and *** represent significance at the standard 1, 5 and 10% confidence levels, both for the significance of the mean and the AR(1) coefficient. For the average volatility and variance premium, I perform a standard mean test and correct the standard deviations using Newey-West with 12 lags (given the evidence on the significance of the autoregressive coefficient). For the AR(1) coefficient, I correct the standard errors using the Newey-West HAC (Heteroskedasticity and autocorrelation correction) with 12 monthly lags (Newey and West, 1987).

			Volatility Premium	Variance Premium						
Country	IV Index	Index	Mean (%)	Mean (sq. %)	Min.	Max.	St. Dev.	Kurt.	Skew.	AR(1)
US	VIX	S&P 500	3.18***	124.32***	−1265.35	1155.62	257.55	11.90	−0.45	0.38***
GER	VDAX	DAX 30	2.42***	142.25***	−653.94	1612.70	288.28	10.56	2.10	0.28**
JAP	VXI	NIKKEI 225	3.87***	257.35***	−243.46	3398.24	485.43	21.64	3.91	0.74***
UK	VFTSE	FTSE 100	3.40***	152.68***	−810.06	1023.58	232.17	8.28	1.08	0.55***
SWI	VSMI	SMI	2.72***	140.48***	−284.18	1154.08	248.90	7.70	2.12	0.71***
NL	VAEX	AEX 25	3.24***	164.95***	−1357.79	1420.36	329.72	10.04	0.76	0.43***
BE	VBEL	BEL 20	1.71***	67.84**	−1491.42	1180.34	260.39	16.26	−0.72	0.22**
FR	VCAC	CAC 100	2.31***	115.87**	−1741.72	1805.45	322.28	18.31	0.36	0.27***

Table 2: Base Scenario for the Numerical Implications of the Two-Country Model
The table reports the values for the two-country model parameters considered as the base scenario to test its numerical implications. In this scenario, all parameters in the preference function (Eq. (3)) are calibrated as in BTZ. The country-specific parameters in Eqs. (1) and (2) are calibrated as follows: $\mu_{j,g}$ is estimated as the average IP growth for the sample 1973-2009; $\mu_{j,\sigma}$ is estimated as the IP growth unconditional variance for the sample 1973-2009; the rest of the parameters are calibrated as in BTZ. Finally, the parameters k_o and k_1 in the log-linearization of returns (Eq. (13)) are estimated using data for the Price-Dividend (PD) ratio for each country as well as for the Datastream world portfolio. The log-linearization constants are estimated as $k_1 = \frac{e^{E(PD)}}{1+e^{E(PD)}}$, where $E(PD)$ is the unconditional mean of the (log) PD ratio, and $k_0 = -k_1 \ln(1-k_1) - (1-k_1)\ln(1-k_1)$ (Campbell and Cochrane, 1999).

	Value			
Param.	Global	US	GER	Description
μ_g		1.6×10^{-3}	8.3×10^{-4}	Mean consumption growth
a_σ		1.2×10^{-6}	6.6×10^{-6}	Long-run consumption volatility
ρ_σ		0.98	0.98	Speed of reversion consumption volatility
a_q		2.0×10^{-7}	2.0×10^{-7}	Long-run VoV
ρ_q		0.80	0.80	Speed of reversion VoV
k_0	0.12	0.13	0.12	Campbell-Shiller k_0
k_1	0.97	0.97	0.97	Campbell-Shiller k_1
ψ	2.50			Intertemporal elasticity of substitution
$\log \delta$	1.00			Discount factor

Table 3: Variance Premium Correlations across countries

The table reports the correlation coefficients among the monthly variance premiums for all countries for the sample period 2000 to 2009.

	US	GER	JAP	UK	SWI	NL	BE	FR
US	1.00	0.56	−0.08	0.74	0.37	0.76	0.62	0.78
GER		1.00	0.24	0.74	0.79	0.82	0.42	0.78
JAP			1.00	0.18	0.61	0.07	0.07	−0.14
UK				1.00	0.70	0.85	0.64	0.77
SWI					1.00	0.67	0.48	0.51
NL						1.00	0.72	0.89
BE							1.00	0.57
FR								1.00

Table 4: The role of the US Variance Premium in explaining foreign Variance Premiums

The table reports the estimated coefficients $\gamma_{1,j}$ in the following regression:

$$vp_{j\neq US,t} = \gamma_{0,j} + \gamma_{1,j} vp_{US,t} + \epsilon_{j,t}.$$

The standard errors are corrected by Newey-West HAC with 12 lags. *,** and *** represent significance at the standard 1, 5 and 10% confidence levels.

	$vp_{j,t}$							
	GER	JAP	UK	SWI	NL	BE	FR	Avg. R^2
$vp_{US,t}$	0.63**	−0.15	0.66***	0.36*	0.98***	0.63***	0.97***	
	(2.41)	(−0.32)	(10.14)	(1.73)	(7.10)	(6.01)	(6.83)	
R^2	31.47	0.60	54.27	13.54	58.12	38.29	60.26	36.65

Table 5: Predicting Variance Premium Correlations across Countries

The table reports the estimated coefficients $\gamma_{1,j,k}$ in the following regression:

$$\rho_t(vp_{j,t,t+1}, vp_{k,t,t+1}) = \gamma_{0,jk} + \gamma_{1,j,k} vp_{k,t-1} + \epsilon_{j,k,t},$$

where j are the countries in the columns and k, the countries in the rows. For example, the information under the column JAP shows how the variance premium correlation between Japan (j) and any other country in the rows (k) is forecasted by the latter country variance premium. The correlation coefficient for the period t to $t+1$ is calculated using daily data for the variance premiums of the two countries for the month starting immediately after the realization of $vp_{k,t-1}$. The standard errors in all regressions are corrected by Newey-West with 12 lags. In order to make the coefficients easier to interpret, the variance premiums are taken in monthly squared percentages.

	$\rho(vp_{j,t,t+1}, vp_{k,t,t+1})$								
$vp_{k,t-1}$	US	GER	JAP	UK	SWI	NL	BE	FR	Avg. R^2
US		50.52**	45.53**	28.62	26.54	30.34	46.40	8.22	
		(2.05)	(2.03)	(1.58)	(1.42)	(1.61)	(1.48)	(0.41)	
R^2		4.57	2.50	1.88	1.16	2.04	2.30	0.14	2.08
GER	38.23***		22.16	31.31***	6.52	19.22*	24.32	10.32	
	(3.52)		(1.40)	(2.58)	(0.62)	(1.84)	(1.07)	(0.89)	
R^2	4.40		0.96	3.51	0.17	1.91	1.29	0.53	1.82
JAP	37.45**	30.90***		46.63***	55.76***	36.99***	47.99***	37.84***	
	(2.31)	(2.77)		(3.51)	(4.21)	(2.67)	(3.08)	(2.98)	
R^2	4.52	2.95		6.46	7.98	4.24	5.71	4.04	5.13
UK	39.45***	27.25*	66.80***		3.24	24.88*	−0.23	−8.33	
	(3.28)	(1.77)	(2.94)		(0.25)	(1.84)	(−0.01)	(−0.57)	
R^2	4.32	1.91	6.00		0.03	2.15	0.00	0.23	2.09
SWI	21.49**	16.95	42.14**	15.16*		18.70*	2.23	8.79	
	(2.31)	(1.60)	(2.09)	(1.78)		(1.74)	(0.07)	(0.93)	
R^2	1.12	1.02	2.52	0.83		1.22	0.01	0.26	1.00
NL	21.32**	21.08**	14.66	22.71**	15.80		29.42	5.20	
	(2.13)	(2.21)	(0.58)	(1.97)	(1.18)		(1.55)	(0.58)	
R^2	1.63	2.22	0.40	2.40	0.95		1.84	0.17	1.37
BE	−6.40	−6.08	−14.92	−13.84	−18.32	−34.07		−25.70	
	(−0.17)	(−0.13)	(−0.33)	(−0.36)	(−0.50)	(−0.64)		(−0.60)	
R^2	0.03	0.03	0.15	0.18	0.31	1.09		0.58	0.34
FR	−0.59	−1.99	19.24	−6.72	−21.20	−5.95	−2.48		
	(−0.04)	(−0.18)	(0.87)	(−0.48)	(−1.33)	(−0.52)	(−0.12)		
R^2	0.00	0.01	0.49	0.15	1.28	0.18	0.01		0.30

Table 6: Predicting Variance Premium Correlations across Countries using the estimated VoV

Similar to Table 5, this table reports the results of monthly regressions for the one-month ahead correlation of vp_t between Germany and the US as in

$$\rho_t(vp_{US,t,t+1}, vp_{GER,t,t+1}) = \gamma_0 + \gamma_1 q_{US,t-1} + \gamma_2 q_{GER,t-1} + \epsilon_t,$$

where the explanatory variables are in this case the country-specific estimated $q_{t,j}$ for these two countries. The identification of $q_{j,t}$ is done by means of the model in Section 4. The procedure is as follows: using Equations (5) and (6), and the benchmark calibration presented in Table 2, the monthly values of $q_{US,t}$ and $q_{GER,t}$ are obtained from the variance premiums of Germany and the US.

	$\rho(vp_{US,t,t+1}, vp_{GER,t,t+1})$
$q_{US,t-1}$	0.21^{***}
	(3.10)
$q_{GER,t-1}$	0.00
	(1.93)
R^2	3.57

Table 7: Predicting Equity Returns using the estimated VoV

The table reports the results for the monthly regressions of h-months ahead (compounded annualized) returns for the US and GER as in

$$(r - r_f)_{j,t,t+h} = \gamma_{0,j,k} + \gamma_{1,j,k} q_{k,t} + \epsilon_{j,k,t},$$

where the explanatory variables are the estimated $q_{k,t}$ for the two countries. The forecasting horizons considered are 1, 3, 6 and 12 months. The standard errors are corrected by Newey-West HAC with $max\{2h, 12\}$ monthly lags (Newey and West, 1987). The identification of $q_{j,t}$ is done by means of the model in Section 4. The procedure is as follows: using Equations (5) and (6), and the benchmark calibration presented in Table 2, the monthly values of $q_{US,t}$ and $q_{GER,t}$ are obtained from the variance premiums of Germany and the US.

	$(r - r_f)_{j,t,t+h}$							
	h=1		*h=3*		*h=6*		*h=12*	
	US	GER	US	GER	US	GER	US	GER
$q_{US,t}$	238.92***	156.84	189.42***	185.18***	102.61***	87.41**	−13.59	−45.86
	(3.04)	(1.64)	(3.87)	(2.96)	(2.62)	(2.01)	(−0.37)	(−0.96)
R^2	7.96	1.63	15.08	7.02	7.31	2.79	0.23	1.33
$q_{GER,t}$	−3.03***	−2.38***	−1.91***	−2.28***	−0.72	−0.81*	0.81***	1.01**
	(−3.62)	(−2.62)	(−3.39)	(−4.00)	(−1.58)	(−1.88)	(4.99)	(2.28)
R^2	9.73	2.85	11.71	8.17	2.80	1.83	6.61	5.11

Table 8: Predicting Equity return Correlations across Countries using the estimated VoV
The table reports the results for the monthly regressions of h-months ahead equity return correlations between the US and GER as in

$$\rho_t(r_{US,t,t+1}, r_{GER,t,t+1}) = \gamma_0 + \gamma_1 q_{US,t-1} + \gamma_2 q_{GER,t-1} + \epsilon_t,$$

where the explanatory variables are the estimated $q_{j,t}$ for the two countries. The forecasting horizons considered are 1, 3, 6 and 12 months. The standard errors are corrected by Newey-West HAC with $max\{2h, 12\}$ monthly lags (Newey and West, 1987). The identification of $q_{j,t}$ is done by means of the model in Section 4. The procedure is as follows: using Equations (5) and (6), and the benchmark calibration presented in Table 2, the monthly values of $q_{US,t}$ and $q_{GER,t}$ are obtained from the variance premiums of Germany and the US.

	$\rho(r_{US,t,t+h}, r_{GER,t,t+h})$			
	h=1	*h=3*	*h=6*	*h=12*
$q_{US,t-1}$	0.12^{*}	0.15^{***}	0.14^{***}	0.10^{***}
	(1.83)	(3.07)	(3.56)	(2.96)
$q_{GER,t-1}$	0.00	0.00^{**}	0.00^{**}	0.00^{**}
	(1.70)	(2.14)	(2.38)	(2.22)
R^2	2.85	8.77	10.17	6.44

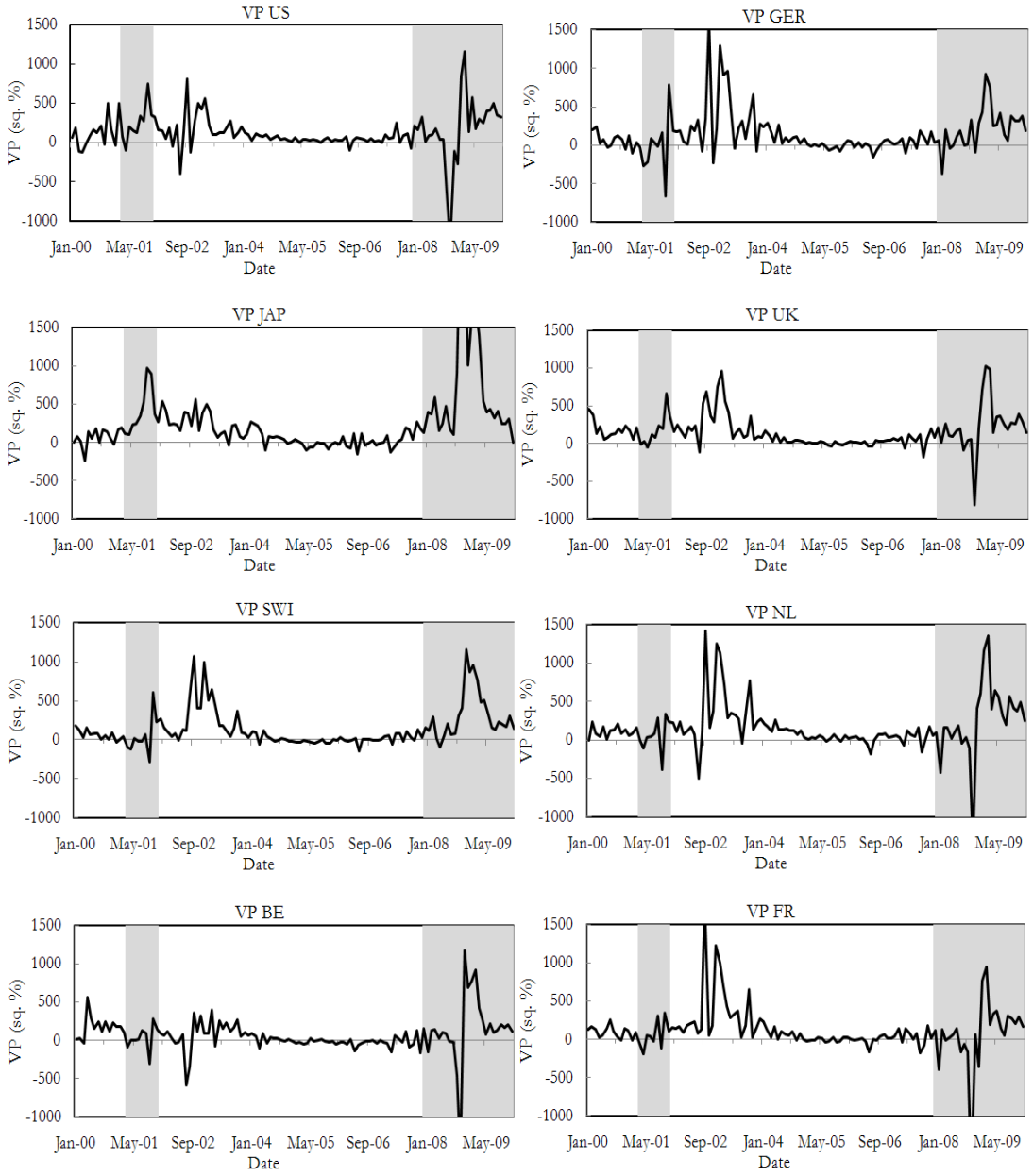


Figure 1: Estimated (model-free) Variance premiums

The figure shows the Variance Premiums vp_t in annual squared percentages for the eight countries the sample (see Table 1) for the sample period 2000 to 2009. The variance premium in each country is estimated as $vp_{j,t} = iv_{j,t}^2 - (\widehat{rv}_{jt+1})^2$,where the benchmark specification for the expected realized variance is its first order autoregressive forecast. The shaded areas represent NBER recession episodes for the US.

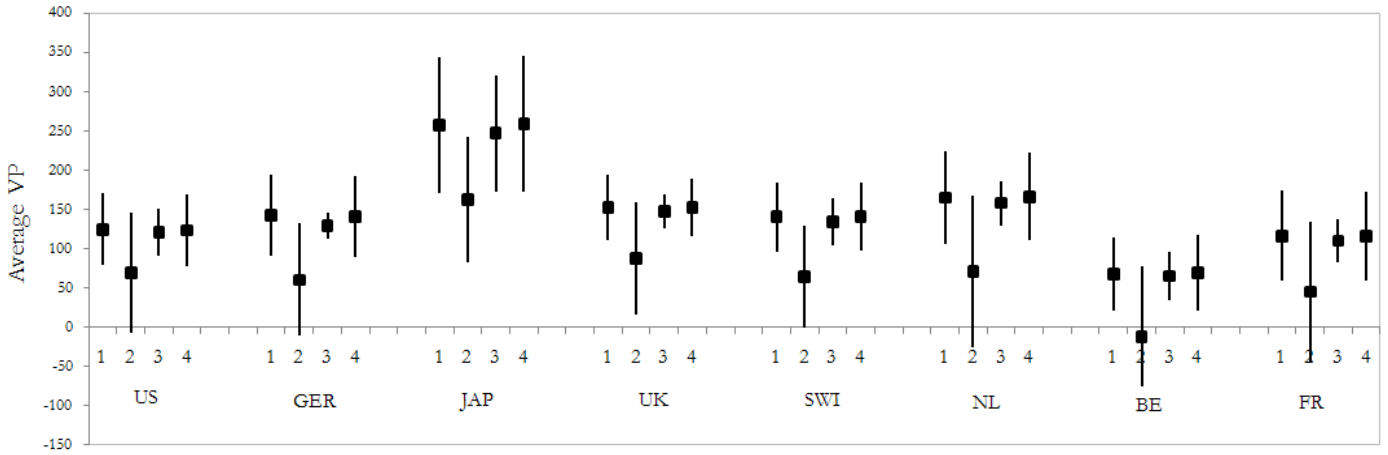


Figure 2: Significance of the average Variance Premiums. Alternative specifications

The figure reports the average variance premiums for each country for 4 alternative specifications (in bold squares) for the sample period 2000 to 2009. For each measure and each country, I also report the 95% confidence intervals for the significance of the average variance premium. Measure 1 is the benchmark measure (AR(1)) where the expected realized variance is estimated as its first order autoregressive forecast. Measure 2, assumes that the expectation of the volatility under the physical measure is well-proxied by rv_t or martingale assumption. In measure 3, the expected realized variance is estimated from a regression that includes the IV indices as in $rv_{j,t+1}= \gamma_o+\gamma_1 rv_{j,t} + \gamma_2 iv_{j,t}+\epsilon_t$. Finally, in measure 4, the expected realized variance is estimated from a regression that includes the monthly range-based variance for each country as in $rv_{j,t+1}= \gamma_o+\gamma_1 rv_{j,t} + \gamma_2 RangeV_{j,t}+\epsilon_t$, where $RangeV_{j,t}$ is the range based variance calculated as $RangeV_{j,t} = \frac{1}{4\ln 2}\sum_{t_i=1}^{N_t} range_{t_i}^2$, where $range_{t_i}$ is the daily difference between the highest and the lowest price of the index.

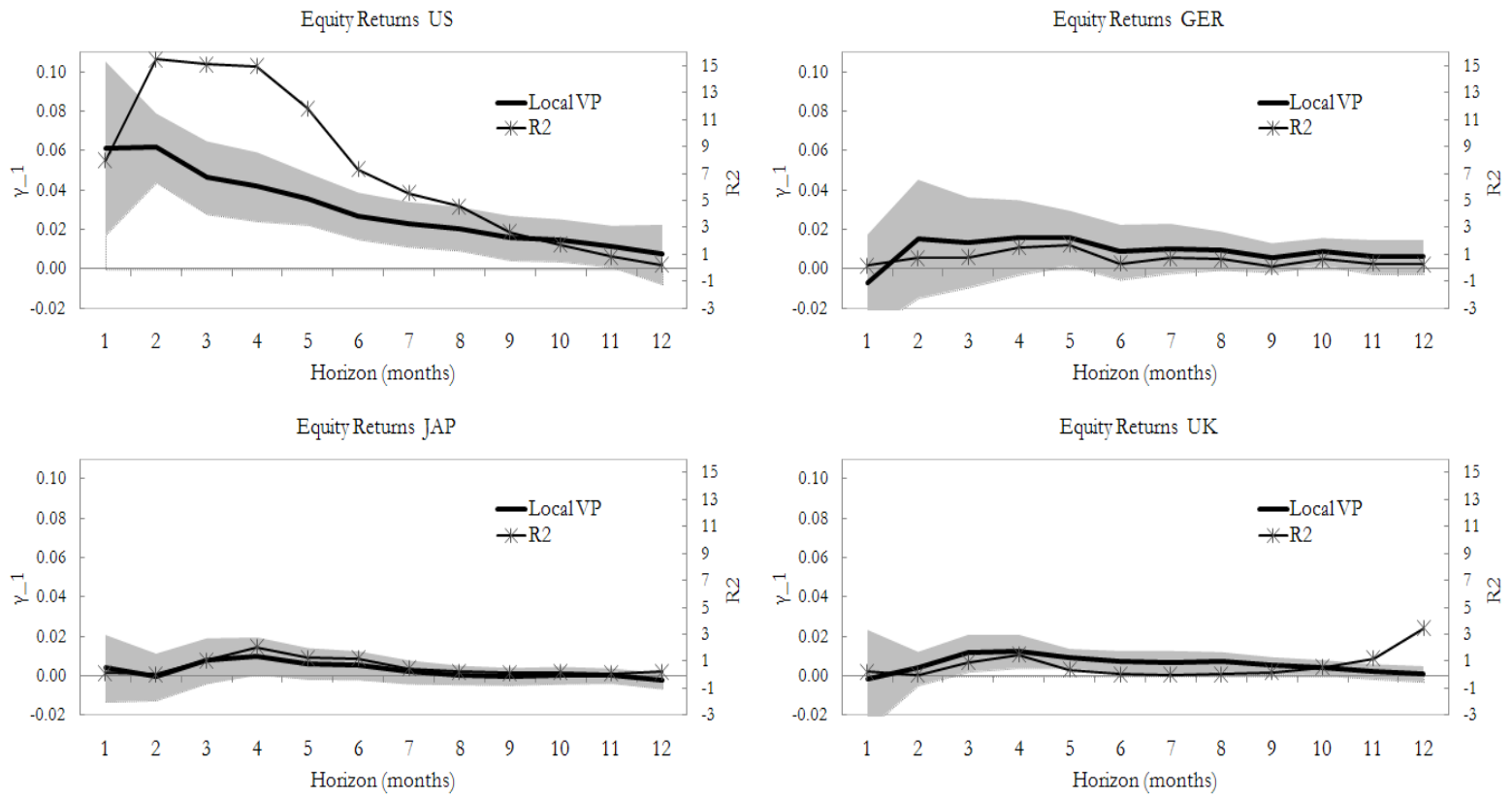


Figure 3: The role of the Local Variance Premium in Predicting Local Equity Returns

The Figure reports the estimated coefficients $\gamma_{1,j,h}$ in the following regressions:

$$(r - r_f)_{j,t,t+h} = \gamma_{0,,j,h} + \gamma_{1,,j,h} vp_{j,t} + \gamma_{2,,j,h} dy_{j,t} + \gamma_{3,,j,h} ts_{j,t} + \epsilon_{j,h,t},$$

where $(r - r_f)_{j,t,t+h}$ are h-months (compounded annualized) excess returns, $dy_{j,t}$ are the local dividend yields and $ts_{j,t}$ are the local term spreads calculated as the difference between the 1 year T-bill and the 3 months t-bill rate. I consider monthly forecasting horizons up to 12 months. The shaded areas represent the 95% confidence intervals for the Newey-West corrected standard errors with a number of lags $l = max\{2h, 12\}$. The figure also reports in the secondary axis the R^2 for each regression. In order to separately identify the predictive power of the variance premium, the R^2 are reported for regressions in which only the variance premiums are considered as in $(r - rf)_{j,t,t+h} = \gamma_{0,j,h} + \gamma_{1,j,h} vp_{j,t} + \epsilon_{j,h,t}$.

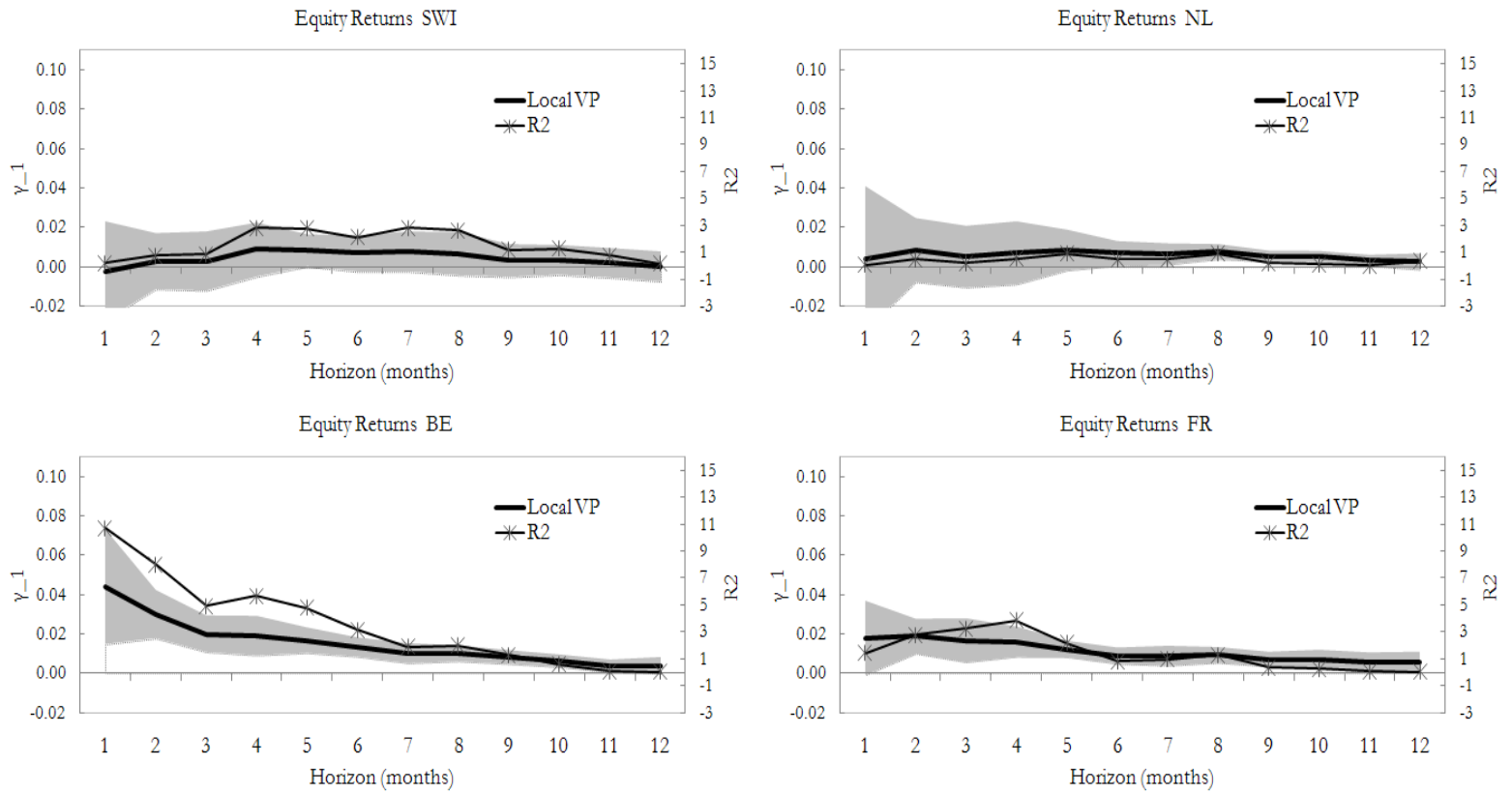


Figure 3: The role of the Local Variance Premium in Predicting Local Equity Returns. Continued

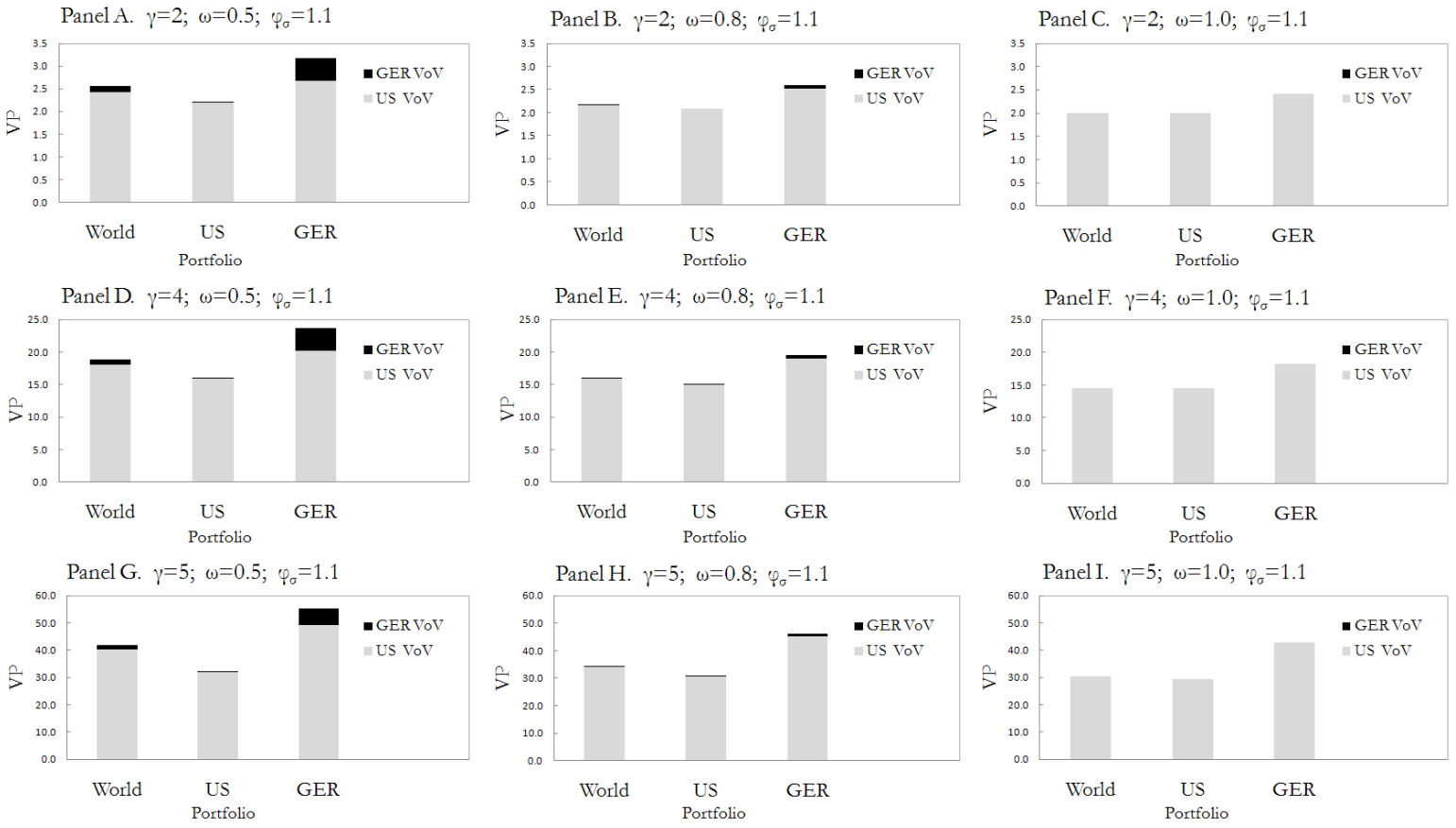


Figure 4: loads of VoV on the Variance Premiums. Alternative Parameters

The figure reports the total unconditional loads of the two countries' volatility of volatility VoV on the variance premium of each portfolio as implied by Eqs. (4) to (6) for alternative values of the parameters γ, ω, ϕ_σ. The unconditional loads are calculated as $(\theta-1)\kappa_{w,1}V_{j,k}E(q_{US,t})$ and $(\theta-1)\kappa_{w,1}V_{j,k}E(q_{GER,t})$, for $k = US, GER$, and j each one of the three possible portfolios: US, GER, and the global portfolio. Given the parameters in the base scenario (Table 2), the average VoV is given by $E(q_{US,t}) = E(q_{GER,t}) = \frac{a_q}{1-\rho_q} = 1.0 \times 10^{-6}$.

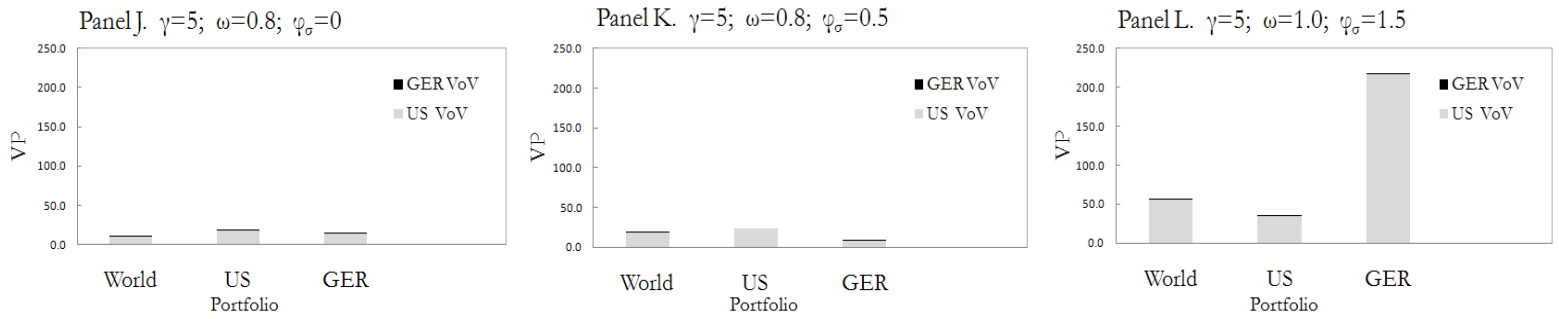


Figure 4: loads of VoV on the Variance Premiums. Alternative Parameters. Continued

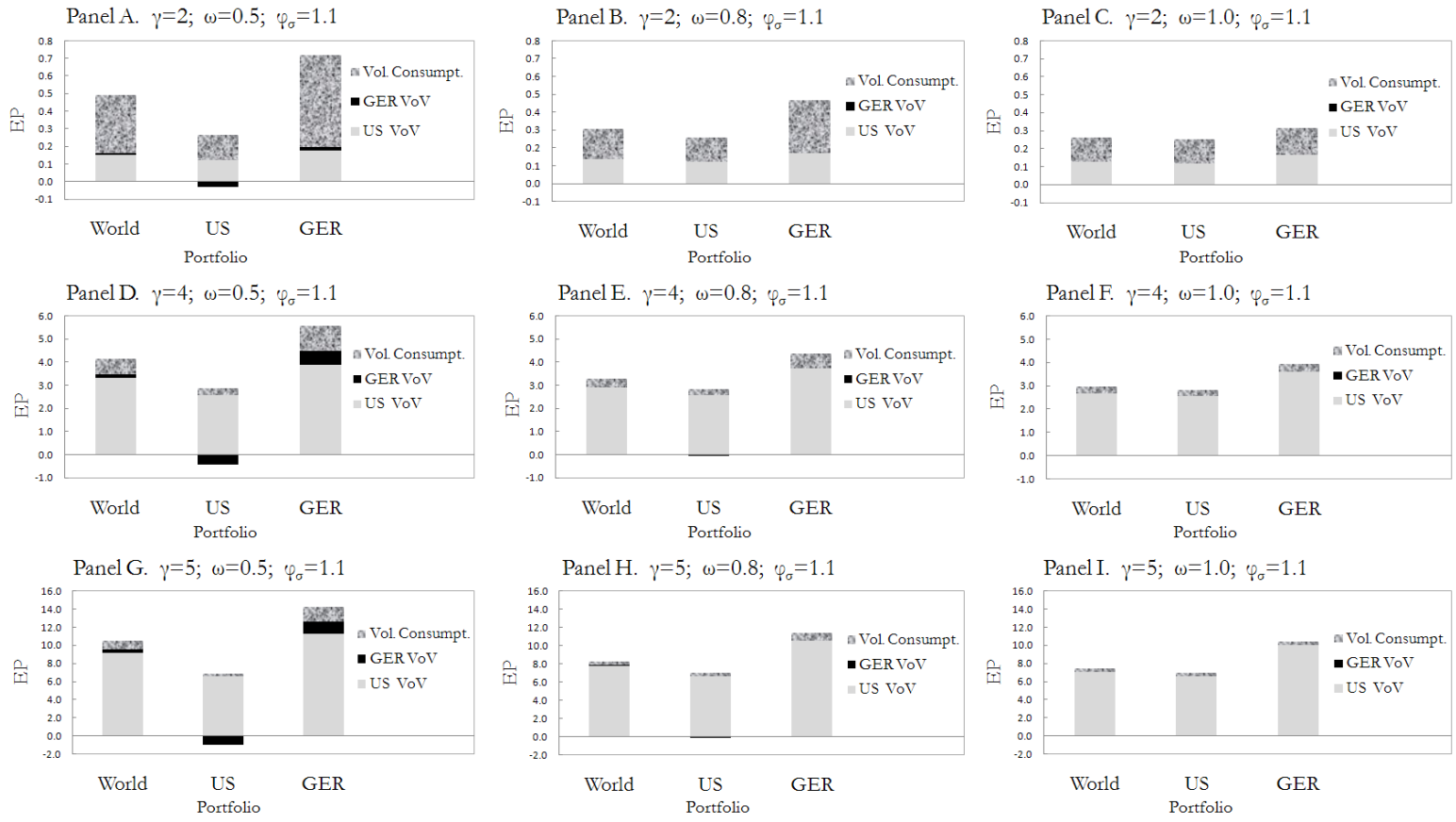


Figure 5: Consumption Volatility and VoV loads on Equity Premiums. Alternative Parameters

The figure reports the total unconditional components of all possible portfolio's equity premiums as implied by Eqs. (8) to (10) for alternative values of the parameters γ, ω, ϕ_σ. Only the exponential adjustment term $(-\frac{1}{2}\sigma^2_{r_1,t})$ is not considered in the figure. Given the parameters in the base scenario (Table 2), the loads of the volatility of consumption are calculated by assuming that the average volatility of consumption $E(\sigma_{US,t}) = E(\sigma_{GER,t}) = \frac{a_{\sigma,US}}{1-\rho_\sigma} = 6.0 \times 10^{-5}$. The loads of VoV are calculated by assuming that the average VoV $E(q_{US,t}) = E(q_{GER,t}) = \frac{a_q}{1-\rho_q} = 1.0 \times 10^{-6}$.

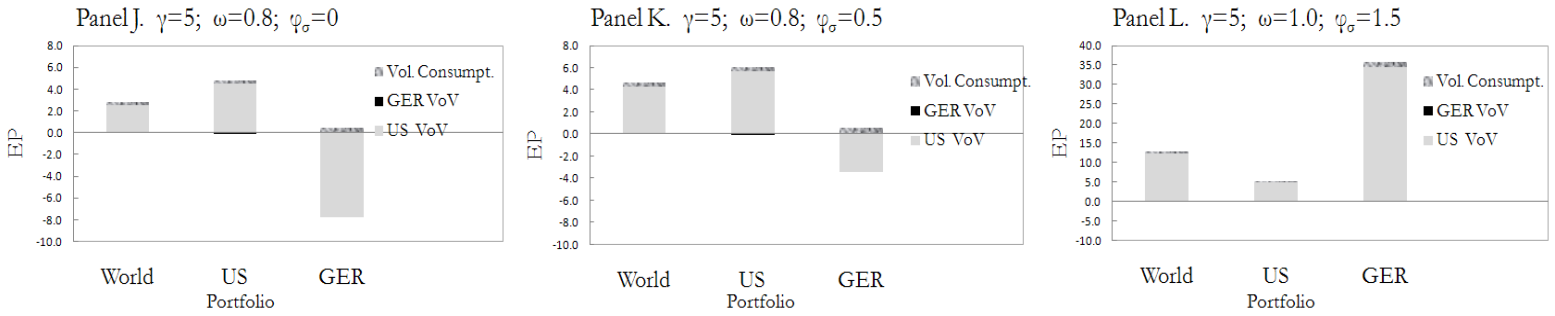


Figure 5: Consumption Volatility and VoV loads on Equity Premiums. Alternative Parameters. Continued

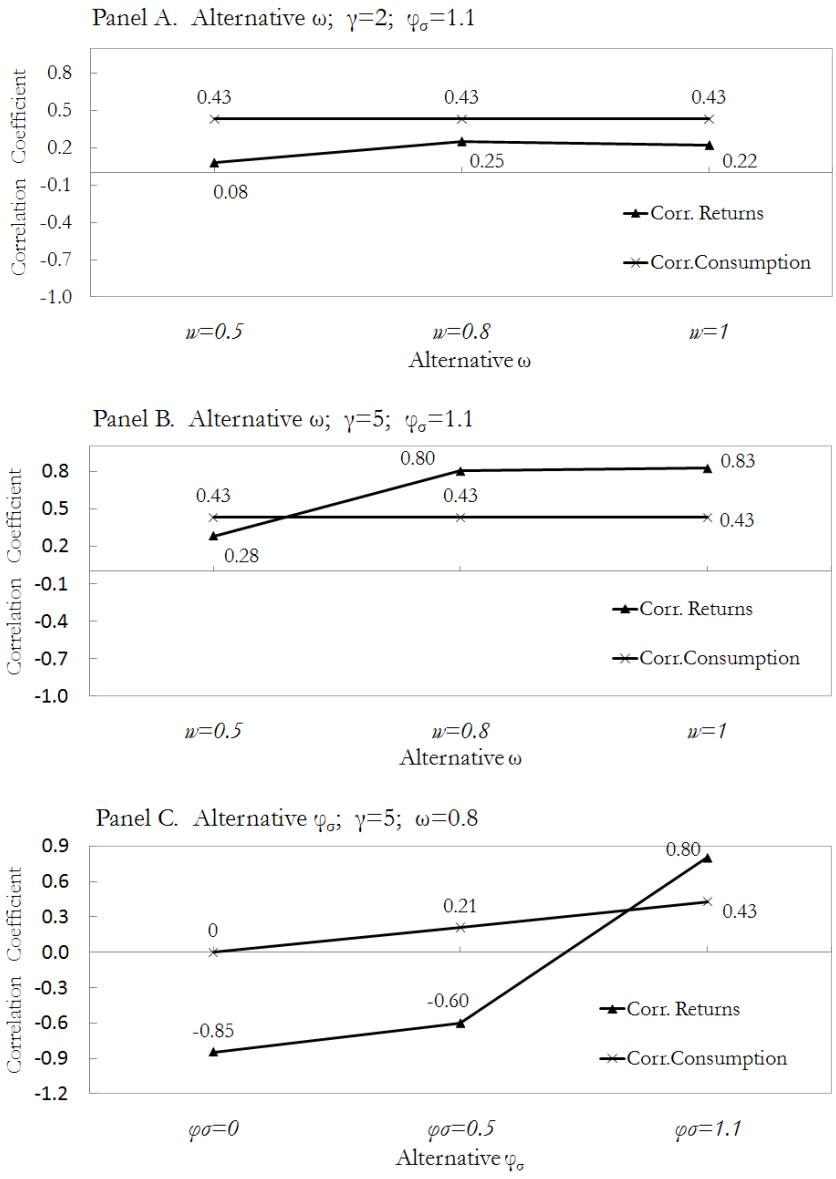


Figure 6: Cross-Country Return Correlations and Model-implied correlation of consumption

The figure shows the model-implied unconditional correlation of consumption ($\rho(g_{US,t}, g_{GER,t})$) and the model-implied equity return correlation ($\rho(r_{US,t}, r_{GER,t})$) between Germany and the US for several alternative values of the parameters γ, ω, ϕ_σ.

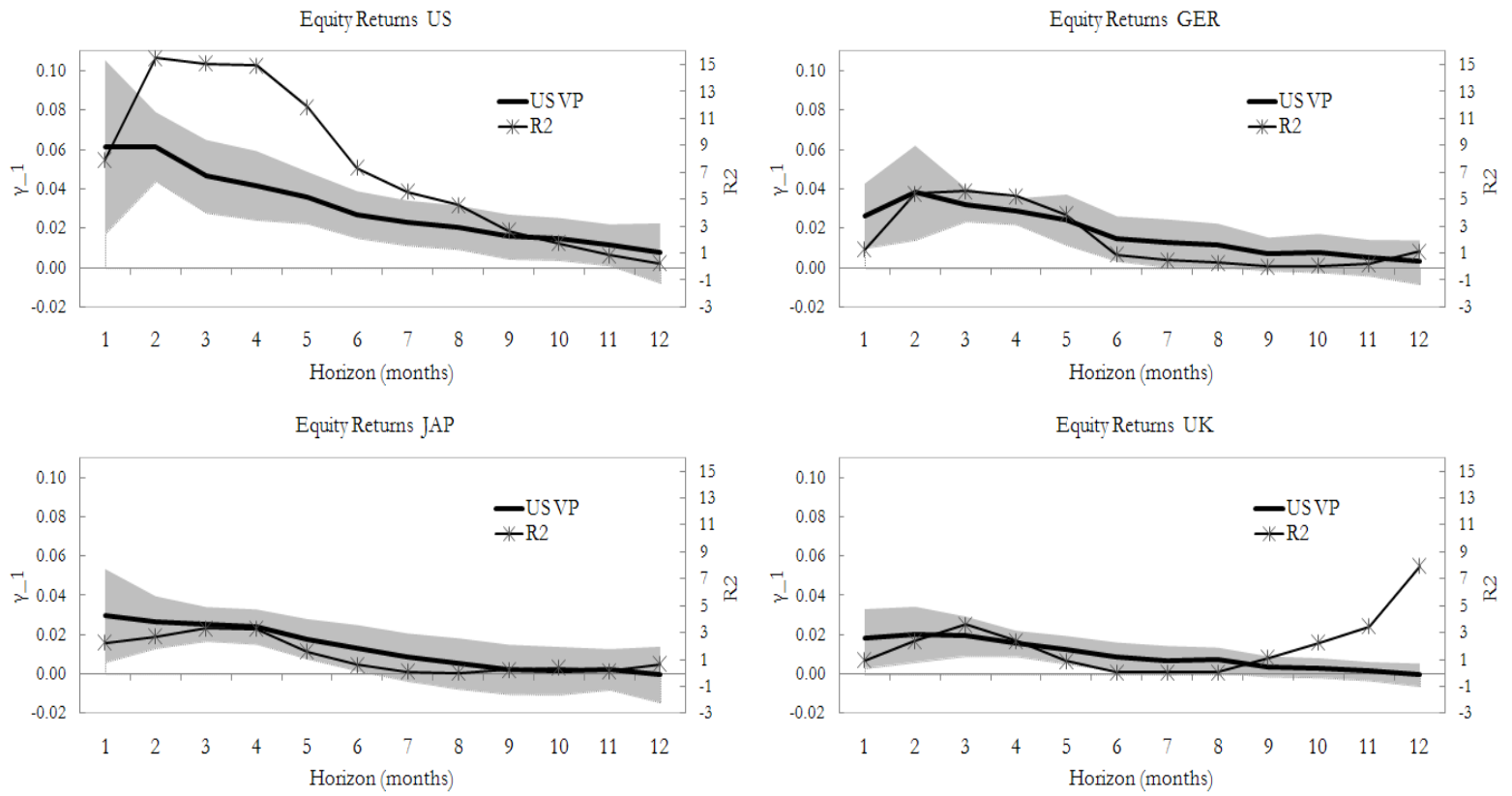


Figure 7: The role of the US Variance Premium in Predicting International Equity Returns

The Figure reports the estimated coefficient $\gamma_{1,j,h}$ in the following regressions:

$$(r - r_f)_{j,t,t+h} = \gamma_{0,j} + \gamma_{1,j,h} vp_{US,t} + \gamma_{1,j,h} dy_{j,t} + \gamma_{1,j,h} ts_{j,t} + \epsilon_{j,h,t},$$

where $(r - r_f)_{j,t,t+h}$ are h-months (compounded annualized) excess returns, $dy_{j,t}$ are the local dividend yields and $ts_{j,t}$ are the local term spreads calculated as the difference between the 1 year T-bill and the 3 months t-bill rate. I consider monthly forecasting horizons up to 12 months. The shaded areas represent the 95% confidence intervals for the Newey-West corrected standard errors with a number of lags $l = max\{2h, 12\}$. The figure also reports in the secondary axis the R^2 for each regression. In order to separately identify the predictive power of the variance premium, the R^2 are reported for regressions in which only the US variance premium is considered as in $(r - rf)_{j,t,t+h} = \gamma_{0,j,h} + \gamma_{1,j,h} vp_{j,US} + \epsilon_{j,h,t}$.

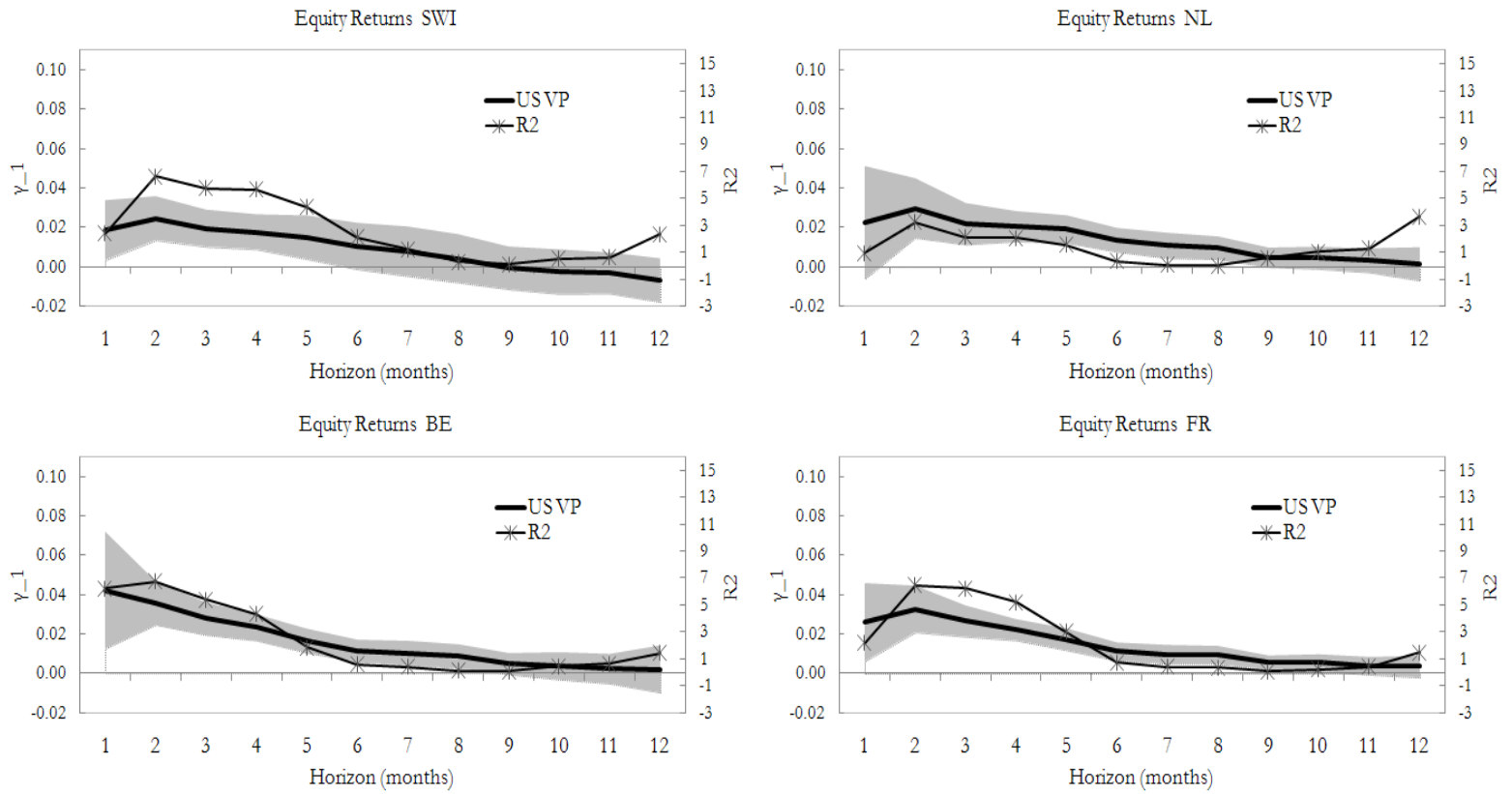


Figure 7: The role of the US Variance Premium in Predicting International Equity Returns. Continued

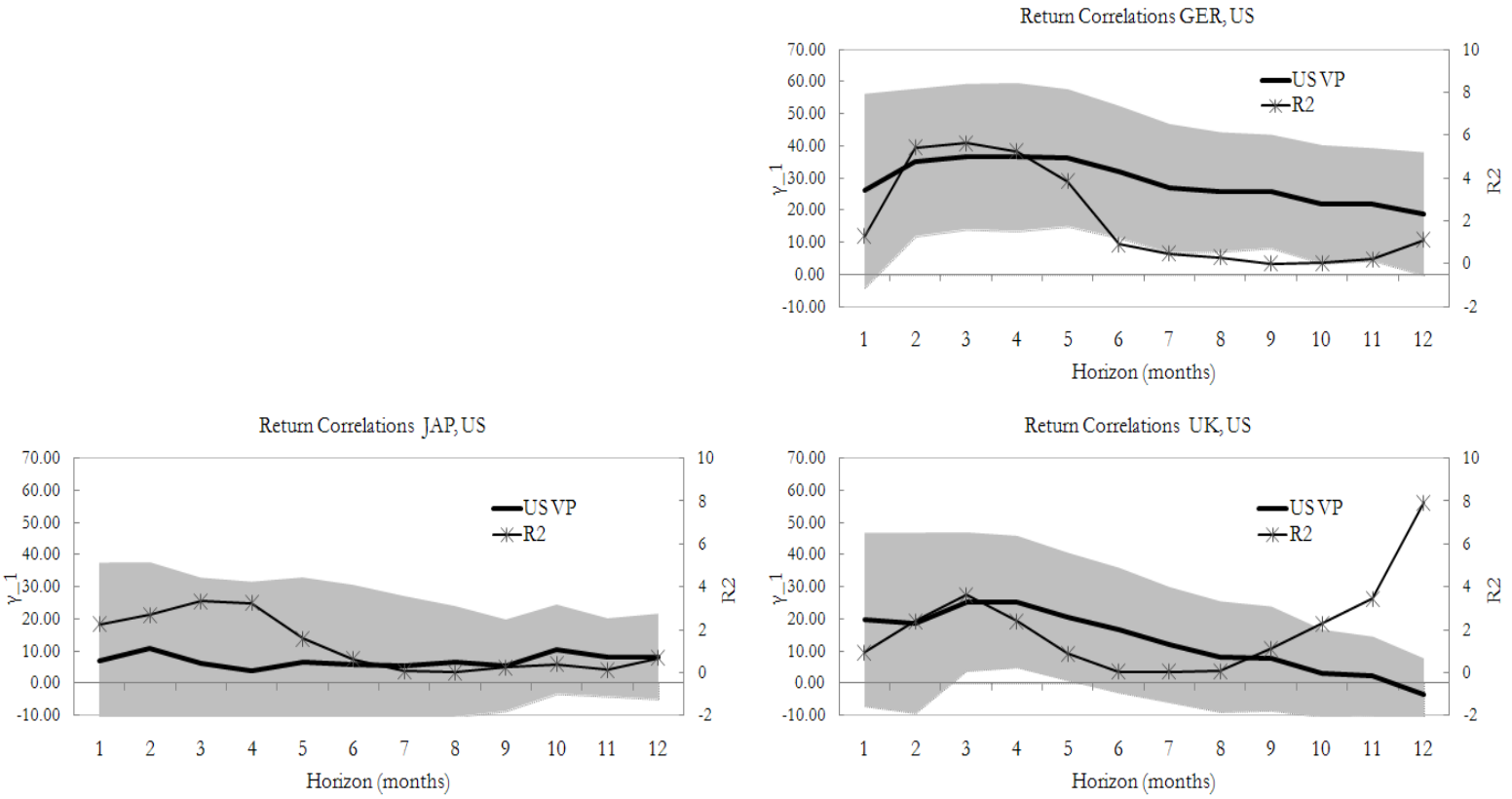


Figure 8: The role of the US Variance Premium in Predicting Equity Return Correlations across countries
The table shows the estimated coefficients $\gamma_{1,j,US}$ in the following regression:

$$\rho_t(r_{j,t,t+h}, r_{US,t,t+h}) = \gamma_{0,jk} + \gamma_{1,j,US} vp_{US,t-1} + \epsilon_{jk,t},$$

where $\rho_t(r_{j,t,t+h}, r_{US,t,t+h})$ is the h-months ahead equity return correlation between any country and the US. The correlation coefficient for the period t to $t+1$ is calculated using daily equity returns for the two countries for the month starting immediately after the realization of $vp_{k,t-1}$. The shaded areas represent the 95% confidence intervals for the Newey-West corrected standard errors with a number of lags $l = max\{2h, 12\}$. The figure also reports in the secondary axis the R^2 for each regression.

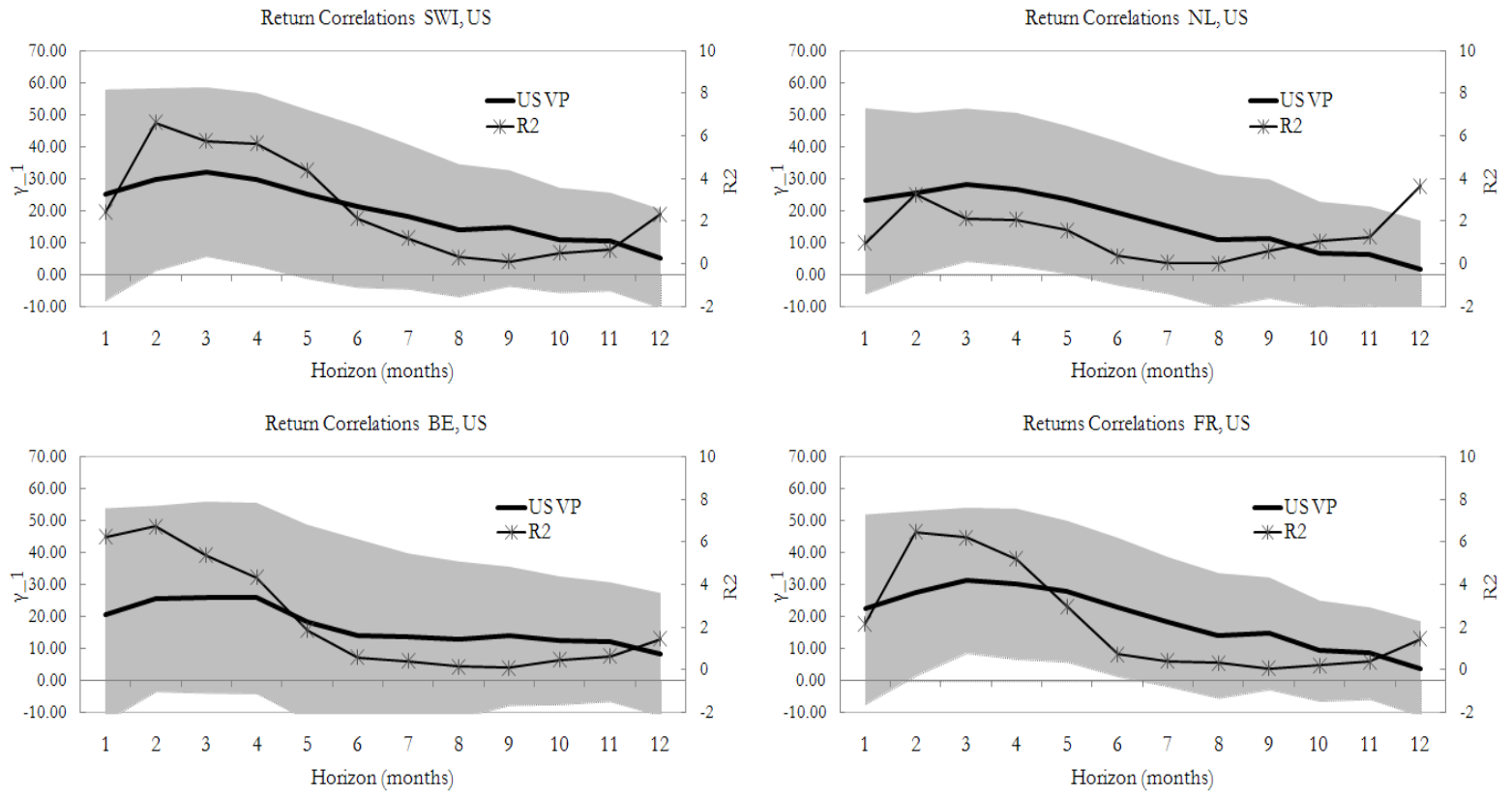


Figure 8: The role of the US Variance Premium in Predicting Equity Return Correlations across countries. Continued

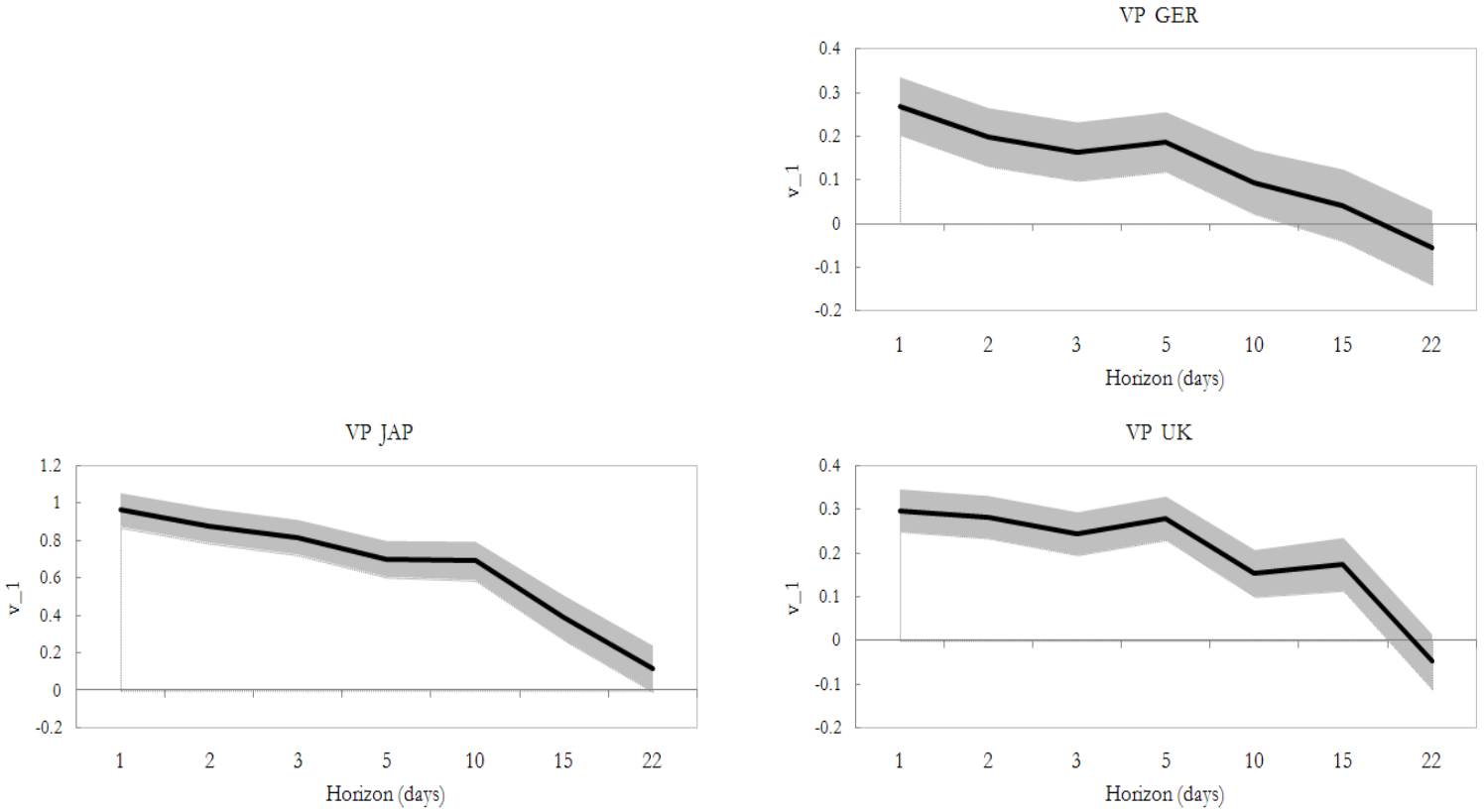


Figure 9: The role of the US Variance Premium in explaining Excessive Variance Premium Comovements
The figure reports the estimated coefficient $v_{1,j,h}$ in the following regressions:

$$vp_{j,t+h} = \gamma_{0,j,h} + \gamma_{1,,j,h,t} vp_{US,t} + \epsilon_{t,h}, \tag{18}$$

where $vp_{j,t+h}$ is the h-days ahead variance premium for country j. The time-varying coefficient $\gamma_{1,,j,h,t}$ follows the process $\gamma_{1,j,h,t} = v_{o,j,h} + v_{1,,j,h} D_{US,t}$, where the dummy $D_{US,t}$ characterizes the extreme values of the US variance premiums. The shaded areas represent the 95% confidence intervals.

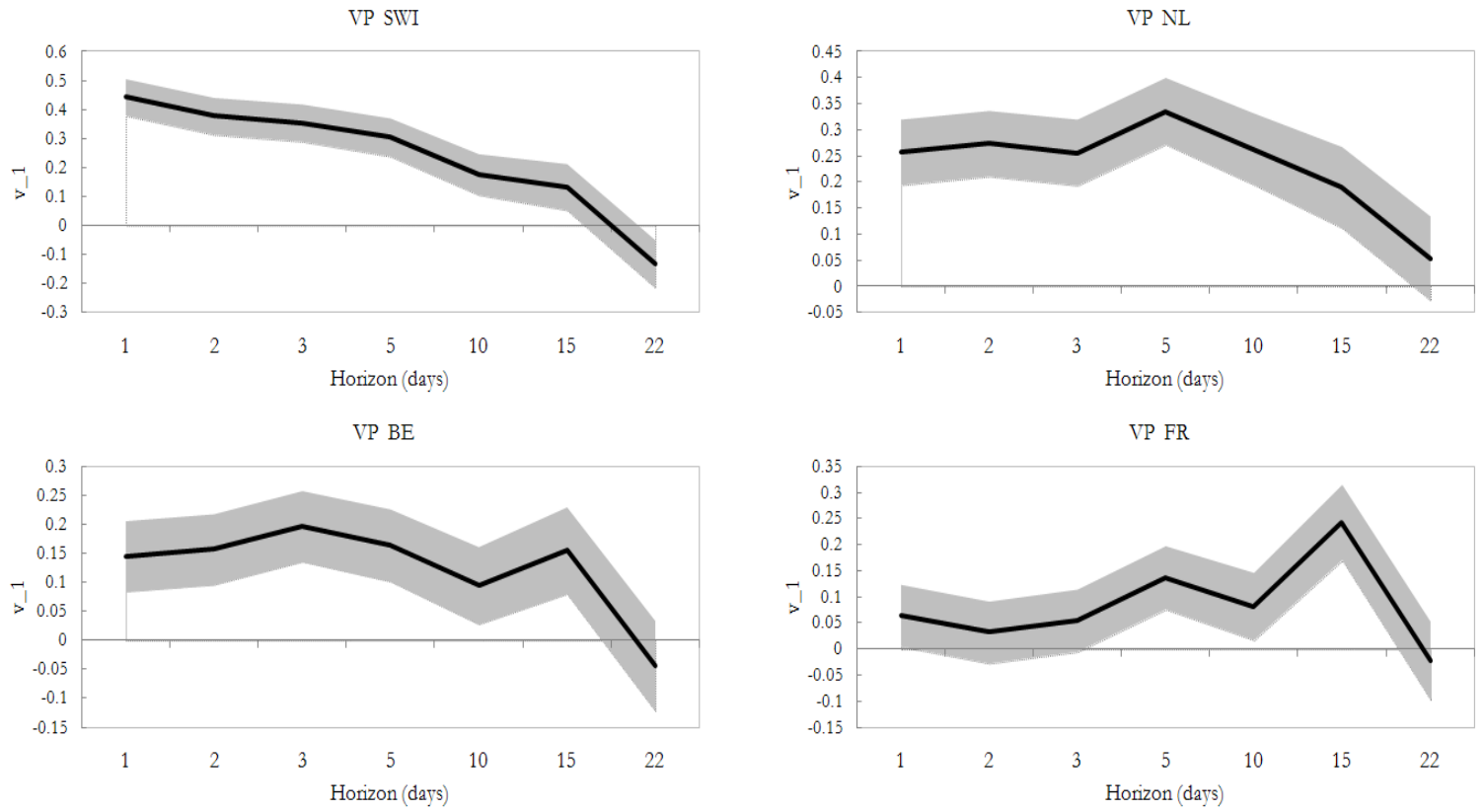


Figure 9: The role of the US Variance Premium in explaining Excessive Variance Premium Comovements. Continued

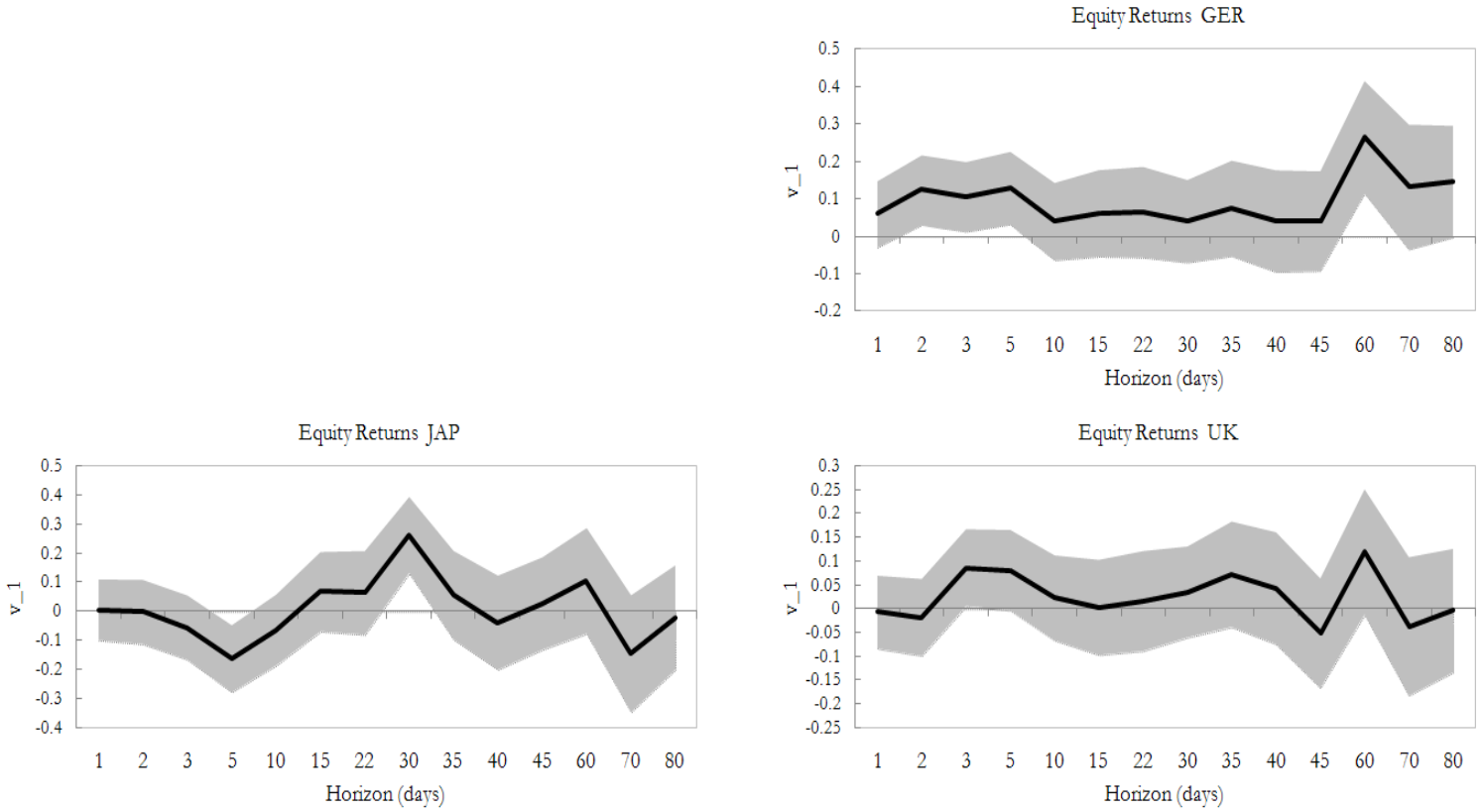


Figure 10: The role of the US Variance Premium in explaining Excessive Return Comovements

The figure reports the estimated coefficient $v_{1,j,h}$ in the following regressions:

$$e_{j,t+h} = \gamma_{0,j,h} + \gamma_{1,j,h} e_{US,t} + \epsilon_{,j,h,t},$$

where $e_{j,t+h}$, $e_{US,i}$ are the residuals from a standard contagion procedure as explained in Appendix B, for alternative $h-$days ahead considered. The time-varying coefficient $\gamma_{1,,j,h,t}$ follows the process $\gamma_{1,j,h,t} = v_{o,,j,h} + v_{1,j,h} D_{US,t}$, where the dummy $D_{US,t}$ characterizes the extreme values of the US variance premiums. The shaded areas represent the 95% confidence intervals.

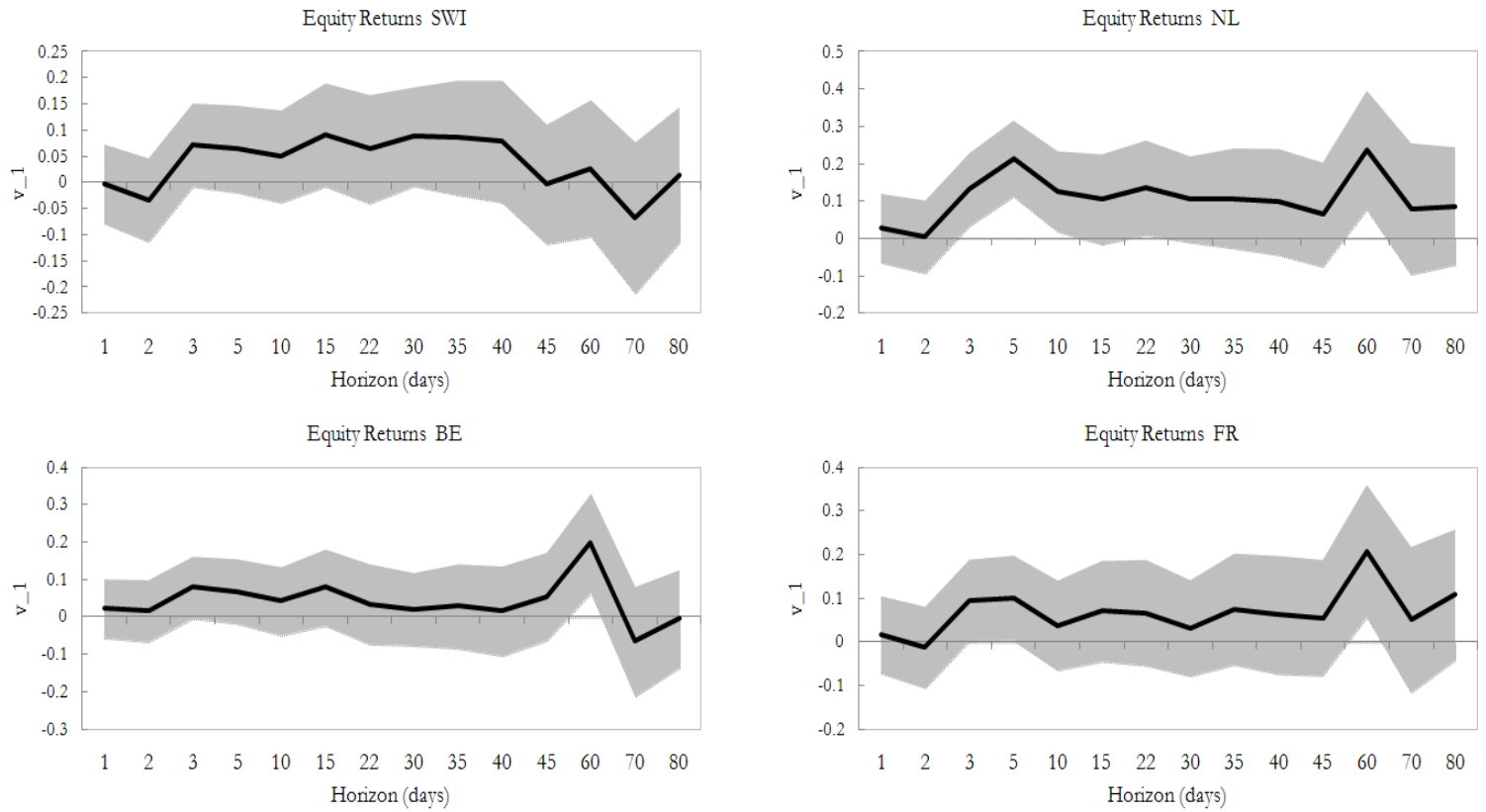


Figure 10: The role of the US Variance Premium in explaining Excessive Return Comovements. Continued