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Abstract

Previous studies document the existence of long-run trends in comovements in the stock and bond markets. Following these findings, this paper examines possible trends in stock-bond return correlations. To this end, we introduce a trend component into a smooth transition regression (STR) model including the multiple transition variables of Aslanidis and Christiansen (2012). The results indicate the existence of significant decreasing trends in stock-bond correlations for many advanced safer countries. In addition, although stock market volatility continues to be an important factor in stock-bond correlations, the short rate and yield spread become only marginally significant once we introduce the trend component. Our out-of-sample analysis also demonstrates that the STR model including the CBOE Volatility Index (VIX) and time trend as the transition variables dominates other models. Furthermore, we find a significant increase in stock-bond correlations for riskier Eurozone countries around the beginning of the Euro crisis. Our findings of decreasing and increasing trends in stock-bond correlations can be considered as a consequence of the decreasing effects of diversification and more intensive flight-to-quality behavior that have taken place in recent years and after the Euro crisis.

Keywords: Comovement, Flight-to-quality, Diversification effect, Smooth transition
JEL classification: C22, G15, G17

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1 Introduction

Understanding time variations in stock-bond return correlations is one of the most important issues in finance due to its profound implications for asset allocation and risk management. Naturally, a number of studies have examined the dynamics of stock-bond correlations and identified the economic factors driving their time-series behavior. For instance, Li (2002) conducts a regression analysis to investigate the relationship between stock-bond correlations and macroeconomic variables, showing that unexpected inflation is the most important determinant of stock-bond correlations. Similarly, Ilmanen (2003) argues that stock-bond correlations are more likely to be negative when inflation is low and stock market volatility is high. Yang, Zhou, and Wang (2009) examine stock-bond correlations over the past 150 years, using the smooth transition conditional correlation (STCC) model, and find that higher stock-bond correlations tend to follow higher short rates and (to a lesser extent) higher inflation rates. In addition, Connolly, Stivers, and Sun (2005, 2007) identify the VIX stock market volatility index as an important determinant of stock-bond correlations. Furthermore, Aslanidis and Christiansen (2012, 2014) demonstrate that stock-bond correlations are explained mostly by short rates, yield spreads between long- and short-term bonds, and the VIX. On the other hand, Pastor and Stambaugh (2003) note that changes in stock-bond correlations depend on liquidity. Similarly, Baele, Bekaert, and Inghelbrecht (2010) find that macroeconomic fundamentals contribute little to explaining stock-bond correlations, but liquidity plays a more important role. Finally, Baur and Lucey (2009) examine the flights between stocks and bonds, defined as negative stock-bond correlations, in eight developed countries. They show that flights exist and occur frequently in crises periods; moreover, flights occur at the same time in many countries. Other related studies include Guidolin and Timmermann (2006); Bansal, Connolly, and Stivers (2010); and Viceira (2012).

A number of recent studies also investigate long-run trends in international financial markets. For instance, Christoffersen, Errunza, Jacobs, and Langloiset (2012) examine copula correlations in international stock markets and find a significant increasing trend that can be explained by neither volatility nor other financial and macroeconomic variables. Similarly, Berben and Jansen (2005) and Okimoto (2014) report the increasing dependence in major equity markets. In international bond markets, Kumar and Okimoto (2011) find an increasing trend in correlations among international long-term government bonds and a decreasing trend in correlations between short- and long-term government bonds within single countries. Existing trends in comovements are also documented in commodities markets. For example, Tang and Xiong (2012) show that the prices of non-energy commodity futures in the US have become increasingly correlated with oil prices after 2004. In addition, Ohashi and Okimoto (2013) find increasing trends in the excess comovements of commodities prices. Other related studies include Longin and Solnik (1995), Silvennoinen and Teräsvirta (2009), and Silvennoinen and Thorp (2013).

Regarding the long-run trends in stock-bond correlations, few studies examine the existence of trends with statistical significance although many previous studies recognize negative trends in stock-bond correlations. For instance, Kim, Moshirian, and Wu (2006) document the downward trends in time-varying conditional correlations between stock and bond market returns in European countries, Japan, and the US. They further show that the introduction of the European monetary union has Granger caused the decreasing trend in stock-bond correlations within Europe but not outside. Similarly, Baur (2010) finds a negative trend in stock-bond comovements for eight developed countries, based on the rolling window estimation. He argues that the decreasing comovement is due to more frequent portfolio rebalancing, in which investors change the weights of stocks and bonds to compensate for the decreased benefits of international diversification caused by the increased cross-country stock and bond comovements. In addition, using the smooth transition regression (STR) models, Aslanidis and Christiansen (2012) suggest that a decreasing trend in stock-bond correlations can be captured well by short rates, yield spread, and the VIX.

Our study contributes to the literature in several aspects. First, we examine the existence of long-run nonlinear trends in stock-bond correlations with statistical significance by extending the STR model of Aslanidis and Christiansen (2012). This could be an important contribution since none of the previously mentioned studies confirms the existence of a decreasing trend in stock-bond correlations with statistical significance. Indeed, our results strongly indicate a significant decreasing trend in stock-bond correlations for the US, Germany, and the UK. Second, we investigate whether this time trend can be explained by financial variables, as suggested by Aslanidis and Christiansen (2012). Our results demonstrate that although stock market volatility continues to be an essential factor for stock-bond correlations, other important financial variables, namely, short rates and yield spreads, become only marginally significant once we introduce the decreasing trend. Our out-of-sample analysis also indicates that the STR model including the VIX and time trend as the transition variables dominates other models. In other words, the decreasing trend cannot be explained by short rates or yield spreads; rather it has more explanatory power than these variables. Thus, we find a corresponding negative trend in stock-bond correlations with a positive trend in stock market correlations reported by Christoffersen, Errunza, Jacobs, and Langloiset (2012). Third, we also apply our preferred model to eight other countries, including those with more credit risks such as Italy and Spain. Our results reveal an interesting contrast. Although relatively safer countries share a similar decreasing trend in stock-bond correlations, the stock-bond correlations for the riskier countries, namely, Italy, Portugal, and Spain have increased significantly and suddenly around the beginning of the Euro crisis, which has not been reported by any of the previously mentioned studies. Our findings of decreasing and increasing trends in stock-bond correlations are consistent with the more intensive flight-to-quality behavior in recent years, as documented by Kim, Moshirian, and Wu (2006) and Baur (2010), among others, but provide additional evidence of flight-to-quality behavior after the Euro crisis.

The remainder of the paper is organized as follows: Section 2 presents the model, while Section 3 conducts the empirical analysis and Section 4 provides the conclusion.

2 Smooth Transition Regression Model

The main purpose of this paper is to examine possible long-run trends in realized stock-bond return correlations. To this end, we employ the smooth-transition model that is developed by Teräsvirta (1994) in the AR model framework and later used to analyze the determinants of stock-bond correlations by, among others, Yang, Zhou, and Wang (2009) and Aslanidis and Christiansen (2012). The former authors model correlations as latent variables and analyze them using the STCC model, whereas the latter authors investigate the realized correlation based on the smooth transition regression (STR) model with multiple transition variables. We employ the latter approach in this paper because it considerably facilitates the examination of the determinants of the time series behavior of stock-bond correlations, as emphasized by Aslanidis and Christiansen (2012). In addition, many other studies, including Ilmanen (2003) and Connolly, Stivers and Sun (2005, 2007), have examined the realized correlations. Therefore, we apply the STR model with multiple transition variables to the realized correlations, following Aslanidis and Christiansen (2012).

The STR model used by Aslanidis and Christiansen (2012) is given by

$$FRC_t = \rho_1\{1 - F(s_{t-1})\} + \rho_2 F(s_{t-1}) + \varepsilon_t \tag{1}$$

where FRC_t is the Fisher transformation of the realized correlation, RC_t, namely

$$FRC_t = \frac{1}{2}\log\left(\frac{1 + RC_t}{1 - RC_t}\right), \tag{2}$$

converting the realized correlation into a continuous variable not bounded between -1 and 1.[1] $F(s_{t-1})$ in (1) is the logistic transition function, taking values between 0 and 1. If $F(s_{t-1}) = 0$, the average value of FRC would be ρ_1 and if $F(s_{t-1}) = 1$, the average value of FRC would be ρ_2. In this sense, ρ_1 and ρ_2 in (1) can be considered the average correlations in regimes 1 and 2,

[1] As a realized correlation, Aslanidis and Christiansen (2012) use the weekly sample correlation calculated from five-minute high frequency stock and bond returns without demeaning, whereas we use monthly sample correlations based on daily data with demeaning.

respectively.[2] Thus, the conditional mean of FRC_t is modeled as the weighted average of the two correlation extremes; the weight is decided by $F(s_{t-1})$. $s_{t-1} = (s_{1,t-1}\ s_{2,t-1}\ \cdots\ s_{K,t-1})'$ is a $K \times 1$ vector of transition variables,[3] governing the transition between regimes 1 and 2. Specifically, $F(s_{t-1})$ is expressed as

$$\begin{aligned} F(s_{t-1}) &= \frac{1}{1+\exp[-\gamma'(s_{t-1}-c)]} \\ &= \frac{1}{1+\exp[-\gamma_1(s_{1,t-1}-c)+\cdots-\gamma_K(s_{K,t-1}-c)]}, \end{aligned} \tag{3}$$

where γ_k is assumed to be positive for at least one k to identify the STR model with multiple transition variables.[4] The location parameter c decides the center of the transition, while the smoothness parameter vector $\gamma = (\gamma_1, \gamma_2, \ldots, \gamma_K)'$ specifies the speed of the transition. More precisely, the transition caused by the transition variable $s_{k,t-1}$ is abrupt for large values of γ_k and gradual for small values of γ_k. One of the main advantages of the STR model is that it can detect, from the data, when and how any transitions occur in stock-bond correlations. In addition, the STR model can describe a wide variety of change patterns, depending on the parameters c and γ, which can be estimated from the data. Thus, by estimating the STR model, we can estimate the best transition patterns in stock-bond correlations.

In contrast to Aslanidis and Christiansen (2012), we use time trends as one of the transition variables to capture long-run trends in stock-bond correlations, following Lin and Teräsvirta (1994). In this framework, the time-varying correlation FRC_t changes smoothly from ρ_1 to ρ_2 with time, assuming that γ_k for the time trend is positive. Thus, we can interpret ρ_1 as a correlation around the beginning of the sample and ρ_2 as correlation around the end of the sample. A similar model is applied to conditional correlations by, among others, Berben and Jansen (2005) and Kumar and Okimoto (2011), who examine trends in correlation in international equity market and international bond market, respectively. This paper differs from these studies by investigating possible trends in stock-bond return correlations.

One concern about STR model (1) is possible serial correlation in FRC_t. Aslanidis and Christiansen (2012) address the serial correlation of the error term by calculating the Newey-West standard errors. However, if FRC_t itself has a serial correlation, this results in the inconsistent estimates of the correlation parameters. Indeed, a number of studies based on the dynamic conditional correlation (DCC) model of Engle (2002) suggest that the conditional correlations among

[2]More precisely, ρ_1 is the average 'Fisher-transformed correlation." In what follows, we simply refer to this as 'correlation".

[3]In practice, all transition variables are standardized to have a mean of 0 and a variance of 1 as Aslanidis and Christiansen (2012).

[4]Specifically, we assume γ_1 associated with VIX is positive for all estimated models.

financial returns are typically highly serially correlated. To address possible serial correlations in FRC_t, we modify STR model (1) by including the AR(1) term as follows:

$$FRC_t = \rho_1\{1 - F(s_{t-1})\} + \rho_2 F(s_{t-1}) + \phi FRC_{t-1} + \varepsilon_t. \tag{4}$$

In this STR model, FRC_t can be expressed as the weighted sum of the correlations expected by the economic variables and the previous correlation level. Theoretically, this model is also relevant because economic conditions may not be reflected immediately due, in part, to slow reactions by and imperfect information available to market participants. Therefore, the correlation may be adjusted slowly from the previous level, as in STR model (4).

We estimate STR model (4) using the maximum likelihood estimation (MLE) method, assuming that ε_t follows independently and is identically normally distributed. If the normal distribution assumption is inappropriate, the estimation can be considered to follow the nonlinear least squares method.

3 Empirical Analysis

3.1 Data

Our main empirical analysis is based on monthly data for the United States (US), Germany (GE), and the United Kingdom (UK), with the sample period lasting from January 1991 to May 2012. All data used in the analysis are obtained from DataStream. Initially, we obtain daily data on futures contracts in the stock and bond markets of these three countries. Using the daily data, we obtain the realized stock-bond return correlations in each country for each month. We use futures on the S&P 500 (US), DAX (GE), and FTSE (UK) stock indices to calculate stock returns and each country's ten-year bond futures to calculate bond returns.

We also obtain the VIX, short rate, and yield spread as transition variables, following Aslanidis and Christiansen (2012), who demonstrate that these three variables are the most important transition variables for determining stock-bond correlation regimes. These three variables are also documented as important determinants of stock-bond correlations by many previous studies. For instance, Aslanidis and Christiansen (2014) find that these three variables are by far the most critical predictors of stock-bond correlations at their low and high quantiles. In addition, Connolly, Stivers, and Sun (2005, 2007) identify the VIX as a factor that influences stock-bond correlations, while Baele, Bekaert, and Inghelbrecht (2010) use the short rate as an important explanatory variable for stock-bond correlations. Furthermore, Viceira (2012) finds that short rates and yield spreads are the two most important predictors of the realized bond CAPM beta and the bond C-CAPM beta.

The VIX (VIX) is the volatility index for the Chicago Board of Options Exchange (CBOE) and is based on the volatility of options on the S&P 500 index. We use the US VIX for all countries due to the limited availability of VIX data for the two other examined countries.[5] The short rate (R) is the three-month Treasury bill rate from the secondary market for the US and the three-month LIBOR rate for Germany and UK, while the yield spread (SPR) is defined as the ten-year constant maturity Treasury bond yield minus the short-rate for each country.

3.2 Benchmark Model Results

Our benchmark model is Aslanidis and Christiansen's (2012) preferred model, namely STR model (4), with $s_{t-1} = (VIX_{t-1}, R_{t-1}, SPR_{t-1})'$. We refer to this model Model 1 and its estimation results are presented in Table 1, in which several items are worth noting. First, the last two rows of the table report the results of a version of Teräsvirta's (1994) linearity test and Eitrheim and Teräsvirta's (1996) additive nonlinearity test. As can be seen, the linearity test rejects the null of linearity in favor of the STR alternative at the 1% significance level for all countries. In contrast, the additive nonlinearity test is not significant, meaning that the proposed model adequately captures all smooth transition regime-switching behavior in the data without additional regimes for all countries.

Second, the AR parameters ϕ are highly significant, with estimated values of 0.38, 0.34, and 0.25 for US, GE, and UK, respectively. In other words, our results indicate that stock-bond correlations change from the previous level toward the correlation level expected by economic variables with some serial correlation, which is not captured by Aslanidis and Christiansen's (2012) original model.

Third, the correlation parameters for regime 1 are significantly positive, with estimated values of 0.30, 0.38, and 0.44 for US, GE, and UK, respectively, while those for regime 2 are significantly negative, with respective values of -0.32, -0.40, and -0.36. In other words, there are two distinct regimes, one with positive average correlations and the other with negative average correlations. Thus, correlations change smoothly or rapidly from positive to negative or from negative to positive, depending on the transition variables.

Finally, all three transition variables, the VIX, short rate, and yield spread, have statistically significant effects on the regime transition at the 5% significance level for all countries. These results are fairly consistent with those of Aslanidis and Christiansen (2012), who demonstrate that stock-bond correlations are explained mostly by these three variables using STR model (1)

[5]We confirm that the German and UK VIX indices are highly correlated with the US VIX, with a correlation that is greater than 0.8. We also confirm that we can obtain quantitatively similar results even if we use each country's VIX data with a shorter sample period.

without the AR term. These three variables are also reported to be important determinants of stock-bond correlations by other studies. For instance, the VIX is identified as a predominant factor for stock-bond correlations by Connoly, Stivers and Sun (2005, 2007) and Bansal, Connolly and Stivers (2010). In addition, Baele, Bekaert and Inghelbrecht (2010) use the short rate as an important explanatory variable for stock-bond correlations, while Yang, Zhou, and Wang (2009) find that higher stock-bond correlations tend to follow higher short rates. Furthermore, Viceira (2012) finds that the yield spread and the short rate are important predictors for the realized bond CAPM beta and bond C-CAPM beta, which can be regarded as a transformation of the stock-bond correlation.

To see more detailed information on the regime transitions for each variable, the transition functions (3) of each variable are plotted in Figure 1, holding the other variables constant at their mean values of zero. As can be seen, there is little difference across countries in terms of short rates and yield spreads, and the correlation regime changes rather rapidly from the negative regime to the positive regime as these variables get larger. For instance, if the short rate is lower than the average by one standard deviation, the transition function takes a value greater than 0.97, meaning that the weight of the negative correlation regime is greater than 97%. More specifically, if the short rate is lower than the average value by one standard deviation, the average correlation is less than -0.30, -0.39, and -0.35 for US, GE, and UK, respectively. On the other hand, if the short rate is higher than the average value plus one standard deviation, the weight of negative regime becomes less than 0.04, making the average correlation more than 0.28 for all countries. Similarly, if the yield spread is lower (larger) than the average value by one standard deviation, the transition function is greater (less) than 0.90 (0.11), with an average correlation of less than -0.26 (greater than 0.18) for all countries. Since larger yield spreads and short rates are usually associated with better macroeconomic conditions, the results indicate that stock-bond correlations tend to be positive when the economy is booming. In other words, when the economy is in recession, stock-bond correlations have a tendency to be negative. This is arguably consistent with flight-to-quality behavior because investors do not want to take many risks when economic conditions are not good.

The VIX transition function also demonstrates flight-to-quality behavior. For US and GE, the VIX transition function indicates that the correlation regime changes relatively smoothly from the negative regime to the positive regime as the standardized VIX changes from -3 to 3. The UK VIX transition function indicates slower changes in the correlation regime but still suggests that a higher VIX tends to be associated with negative stock-bond correlations. Thus, the results demonstrate that when the VIX is high or there is much uncertainty in the market, investors try to escape from risks, making stock-bond correlations negative.

Finally, the time series of the estimated correlations for Model 1 together with the actual realized correlations for each country are plotted in Panel (a) of Figures 2-4 to indicate goodness of fit. As can be seen, the estimated correlation fits the actual correlation quite well for all countries. More specifically, Model 1 successfully captures the tendency for there to be positive correlations before 2000 and negative correlations after 2000 because the correlation regimes tend to be identified as the positive regime before 2000 and the negative regime after 2000.

In sum, the results of Model 1 indicate that the VIX, short rate, and yield spread are important determinants of stock-bond correlation regimes for all countries, which is consistent with previous studies such as Aslanidis and Christiansen (2012), who estimate a similar model for US. In addition, we demonstrate the significance of including the AR(1) to allow for smooth adjustments in correlation regimes, in contrast with Aslanidis and Christiansen (2012). Although the performance of Model 1 is quite satisfactory, it is possible to improve Model 1 by including other variables. In particular, recent studies have found long-run correlation trends in international financial markets, suggesting that we can modify Model 1 by introducing a time trend component; this is examined in next subsection.

3.3 Introduction of a Time Trend Component

The results of Model 1 are fairly consistent with previous studies examining the dynamics of stock-bond correlations. On the other hand, another previous studies have suggested the existence of long-run trends in correlation in international financial markets. For instance, Christoffersen, Errunza, Jacobs, and Langloiset (2012) examine copula correlations in international stock markets and find a significant increasing trend in the comovements of international stock returns that can be explained by neither volatility nor other financial and macroeconomic variables. In addition, Kumar and Okimoto (2011) find an increasing trend in correlations between international long-term government bonds and decreasing trends in correlations between the short- and long-term government bonds within single countries. It is therefore of interest to analyze possible trends in stock-bond correlations by estimating STR model (4) with a time trend component (T) as well as the VIX, short-rate, and spread as transition variables (Model 2). Thus, the vector of transition variables for Model 2 is defined as $s_{t-1} = (VIX_{t-1}, R_{t-1}, SPR_{t-1}, T_{t-1})'$.

Table 2 reports the estimation results for Model 2. As can be seen, the results suggest that the basic structure of Model 2 is reasonably similar to that of Model 1. Specifically, the linearity and additive nonlinearity tests documented in the last two rows of Table 2 show that the two-state STR model is preferred to the linear model without regime changes and the three-state STR model with an additional correlation regime. In addition, Model 2 indicates the existence of two distinct correlation regimes, with a negative average correlation for one regime and a positive average correlation for the other, as in Model 1. Furthermore, the AR term is significant at least at the 10% significance level for US and GE, suggesting smooth adjustments in stock-bond correlations in these countries.

Although the basic structures of Models 1 and 2 are quite similar, there are important differences in the determinants of their stock-bond correlation regimes. In particular, the estimation results of Model 2 indicate that the time trend component is highly significant for all countries, suggesting that Model 1 omits an important factor of stock-bond correlations. More specifically, the time trend component coefficient estimates are significantly positive for all countries, meaning that there is a decreasing trend in stock-bond correlations. To see this more clearly, we plot the time trend for the correlations estimated through Model 2 in Panel (a) of Figure 5.[6] As can be seen, the stock-bond correlations for all countries have clear decreasing trends, with a rapid decrease between the late 1990s and the early 2000s, reaching an average of -0.54 by the end of sample period in May 2012. Our finding of negative trend is consistent with the previous studies such as Baur (2010), but few studies confirm it with statistical significance. Our finding of the existence of a time trend in correlations between financial assets is also in line with recent studies. For instance, Christoffersen, Errunza, Jacobs, and Langloiset (2012) and Okimoto (2014) document increasing correlations or dependences in the major equity markets. Similarly, Kumar and Okimoto (2011) find an increasing trend in correlations between international long-term government bonds and decreasing trends in correlations between a single country's short- and long-term government bonds.

Another important difference between Models 1 and 2 is the significance of the short rate and yield spread in determining the stock-bond correlation regime. Although the VIX remains an important factor in determining stock-bond correlations, the short rate and yield spread become less important in Model 2. Specifically, neither of these measures are significant for US, while only one of them is significant for GE and UK. In addition, the short rate coefficient for GE is significantly positive instead of negative, making interpretation of the result rather difficult. The results are in contrast with the findings of the previously mentioned studies examining the determinants of stock-bond correlations without a time trend component. Thus, our results demonstrate that some

[6] Time trend for the correlations is calculated as follows. First we calculate the time trend in FRC as

$$TTFRC_t = \frac{\hat{\rho}_1\{1-\hat{F}(s_{t-1})\} + \hat{\rho}_2\hat{F}(s_{t-1})}{1-\hat{\phi}},$$

holding the all transition variables other than a time trend variable constant at their mean values of zero. Then, we applied the inverse of Fisher transformation (2) to $TTFRC_t$ to obtain the time trend component for the correlation.

of the important factors suggested by previous studies have become less relevant once we consider possible decreasing trends in stock-bond correlations.

To compare the goodness of fit of Models 1 and 2, we plot the time series of the correlations estimated through Model 2 together with the actual realized correlations for each country in Panel (b) of Figures 2-4. As can be seen, the correlations estimated through Models 1 and 2 are similar to each other and do not differ much over the sample. Thus, they qualitatively have the same power in illustrating the time series behavior of stock-bond correlations.

We can compare the goodness of fit of Models 1 and 2 more formally using the information criteria reported in Table 3, namely the Schwartz information criterion (SIC) and Akaike information criterion (AIC). Although the AIC favors Model 2 for GE and UK, the SIC prefers Model 1 to Model 2 for all countries. Thus, in terms of the in-sample fit, our results are somewhat inconclusive.

To make a more comprehensive comparison between Models 1 and 2, we conduct an out-of-sample forecast evaluation as follows. First, we estimate both Models 1 and 2 using data from February 1991 to January 2001 and evaluate the terminal one-month-ahead forecast error based on the estimation results. The data are then updated by one month, and the terminal one-month-ahead forecast error is re-calculated from the updated sample (specifically, from March 1991 to February 2001). This procedure is repeated until reaching one month before the end of the sample period, namely April 2012. Finally, we calculate the root-mean-squared forecast error (RMSE) and mean absolute error (MAE) using the obtained time series of one-month-ahead forecast errors. The third and fourth rows of Table 4 report the RMSE and MAE values for Models 1 and 2. As can be seen, the RMSE and MAE values of Model 2 are smaller than those of Model 1 for GE, while Model 1 exhibits better out-of-sample performance than Model 2 for other two countries.

Overall, our model comparison results show that Model 2 is not necessarily a better model than Model 1, although the time trend component is highly significant. One possible explanation for this result is the weak significance of the short rate and yield spread in Model 2, as mentioned. Indeed, neither of these factors are significant for US, while only one of them is significant for GE and UK. Thus, we might be able to improve the model by excluding these variables. To examine this possibility, we will consider a more parsimonious model in next subsection.

3.4 Results with Selected Transition Variables

Our results for Model 2 indicate that the short rate and yield spread become less important determinants of stock-bond correlations if decreasing trends in stock-bond correlations are taken into consideration. To illustrate this point more clearly, we estimate a more parsimonious STR model (4) that includes only VIX and time as the transition variables (Model 3).

The estimation results for Model 3 are shown in Table 5. As can be seen, the estimation results are essentially same as those of Model 2. The two-state STR model with a negative average correlation for one regime and a positive average correlation for the other regime is preferred to the linear model without regime changes and the three-state STR model. In addition, the AR term is highly significant for US and GE, suggesting that the stock-bond correlations of these countries change slowly from the previous level toward the correlation level expected by economic variables. Furthermore, the VIX is significantly positive for all countries. Thus, the correlation regime changes from a positive to a negative regime when the VIX is high. Finally, the estimated time trend component is also significantly positive for all countries, meaning that stock-bond correlations tend to be in the negative regime in more recent periods. The decreasing trend can be confirmed visually from the estimated time trend component of stock-bond correlation depicted in Panel (b) of Figure 5. As can be seen from the figure, time trend components of stock-bond correlation for all countries exhibit similarly with clear decreasing trends. Specifically, they have decreased rapidly from an average correlation of over 0.4 in the beginning of 1999 to an average correlation of -0.30 at the end of 2003, reaching an average of -0.53 in May 2012.

We also plot the time series of the estimated correlation for Model 3 together with the actual realized correlation for each country in Panel (c) of Figures 2-4 to graphically illustrate the performance of Model 3. As can be seen, the estimated correlations of Model 3 are quite similar to those of other models and do not differ much over the sample, suggesting that all models have the same qualitative explanatory power over stock-bond correlation behavior. Given that Model 3 has only two transition variables, this arguably indicates the superiority of Model 3 over the other two models. We can confirm this point more formally using the SIC and AIC reported in Table 3. As can be seen, Model 3 has the smallest SIC and AIC values for all countries, meaning that Model 3 is the best among the three models in terms of in-sample fit.

We additionally compare the out-of-sample performance of Model 3 and the other two models by conducting the same out-of-sample forecast evaluation as before. The results reported in Table 4 indicate that Model 3 exhibits the best out-of-sample performance for all countries, regardless of the employed performance measure.

In sum, our results are clear: Model 3 is the best among the three models, meaning that transitions between correlation regimes can be described sufficiently well by the VIX and time trend components. In other words, we demonstrate the possibility that the short rate and yield spread are not important factors in relation to stock-bond correlation regimes, in great contrast to previous studies such as Aslanidis and Christiansen (2012). Thus, flight-to-quality behavior is not strongly related with economic conditions, measured by short rates and yield spreads, but is associated with market uncertainty, as captured by the VIX. In addition, flight-to-quality behavior has become stronger in more recent years, resulting in decreasing trends in stock-bond correlations.

As discussed Baur (2010), a possible explanation for this trend in flight-to-quality behavior is the recent increasing trend in correlations or dependences in international equity markets, which is documented by Christoffersen, Errunza, Jacobs, and Langloiset (2012) and Okimoto (2014), among others. Specifically, Christoffersen, Errunza, Jacobs, and Langloiset (2012) emphasize that benefits from international diversification have decreased over time and this decrease has been especially drastic among developed markets, such as those examined in this study. Similarly, Okimoto (2014) demonstrates that when we invest in two major equity markets, the 99% Value at Risk and expected shortfall have increased by about 20% between 1973 and 2008 due to the diminishing benefits from international diversification to decrease risk in major equity markets. In addition, Berben and Jansen (2005) show that correlations among the GE, UK, and US stock markets have doubled between 1980 and 2000, implying decreasing diversification effects. Finally, Silvennoinen and Teräsvirta (2009) show that stock returns within and across European and Asian markets exhibit a clear upward shift in the level of correlations between 1998 and 2003, which corresponds to the timing of the rapid decrease in the estimated time trend of stock-bond correlations from our models. Thus, benefits from international diversification seem to have been disappearing in more recent years. In this case, the investors who allocated their money into the equity markets of those countries have been exposed to higher risks of simultaneous drops in stock prices in recent years. As a consequence, they have more recently needed to make greater use of bond markets to control their risk exposure, producing the decreasing trend in stock-bond correlations. Indeed, the beginning of the integration of international equity markets and the beginning of decreases in stock-bond correlations appear to occur around the same time.

In addition to integration in equity markets, increasing correlations are observed in other markets as well. For instance, Kumar and Okimoto (2011) show that long-term government bond markets have become more integrated since the late 1990s, while Silvennoinen and Thorp (2013) find that correlations among stock, bond, and commodity future returns greatly increased around the early 2000s. Similarly, Tang and Xiong (2012) document increasing correlations of non-energy commodity with crude oil after 2004. These phenomena further diminish the effects of diversification in international financial markets, making investors diversify risks through bond markets. This phenomenon induces a rebalancing, particularly with from stocks to bonds.

Fleming, Kirby, and Ostdiek (1998) and Kodres and Pritsker (2002) study how cross-market hedging theoretically influences asset pricing. Specifically, Fleming, Kriby, and Ostdiek (1998) demonstrate that information linkages in stock and bond markets may be greater if cross-market hedging effects are considered within daily returns. In addition, Kodres and Pritsker (2002) show that a shock in one asset market may generate cross-market rebalancing, which influences prices in non-shocked asset markets. Since the disappearance of diversification effects produces investment behavior involving rebalancing from stocks to bonds, correlations between stocks and bonds tend to be negative, which can be captured by a trend variable, as indicated by our results.

Lastly, there have been a number of studies focusing on the relation between the cross market hedging and time varying stock market uncertainty. For instance, David and Veronesi (2002) examine the relation between economic uncertainty and implied volatility in equity markets. It is consistent with our empirical result that stock-bond correlation turns negative along with the increase in the VIX.

In sum, integration of international equity markets and market uncertainty induce the negative stock-bond correlation. Our empirical results demonstrate that two transition variables, trend and VIX, can capture these factors sufficiently well.

3.5 Results for other countries

In this subsection, we examine other countries, in addition to the three that have been analyzed so far, to obtain further evidence of significant trends in stock-bond correlations. To this end, with reference to Baur and Lucey (2009) and Baur (2010), we investigate Australia (AU), Canada (CA), France (FR), Switzerland (SW), Japan (JP), Italy (IT), Portugal (PO), and Spain (SP). We use futures returns from the JGB futures and TOPIX futures for JP. Due to the limited availability of futures price data for other countries, we use returns from the WGBI 7-10 year total return index as bond returns,[7] and returns from the market value-weighted stock total return index as stock returns.[8] The sample period for this analysis is from June 1993 to May 2012 for AU, CA, FR, JP, and SW, and from October 2001 to May 2012 for SP, IT, and PO.

We estimate Model 3 for each country, and the estimation results are presented in Table 6.[9] As can be observed, the results for AU, CA, FR, and SW are essentially the same as those of US, GE, and UK. The estimated correlation parameters for regime 1 are significantly positive, with estimated values of 0.403, 0.265, 0.483, and 0.234 for AU, CA, FR, and SW, respectively, while

[7]Since the WGBI 7-10 year total return index for PO is not available, we use the WGBI all maturities index.

[8]Specifically, we use stock index returns from ASX 200 (AU), SPTSX 60 (CA), CAC 40 (FR), SMI (SW), MIB (IT), PSI (PO), and IBEX 35 (SP).

[9]If the transition function looks like a step function, γ_2 associated with time trend becomes very large and is not well determined, since the log-likelihood becomes insensitive with γ_2. In these cases (for JP, IT, PO, and SP), we have fixed γ_2 at an upper bound equal to 300 and have re-estimated the model. Additionally, if γ_1 related to VIX reaches its lower limit of 0, specifically for PO and SP, we have fixed γ_1 at 0 and have re-estimated the model. For these cases, the parameter's standard errors are denoted by NA.

those for regime 2 are significantly negative, with respective values of -0.511, -0.291, -0.346, and -0.427. In addition, the AR term is highly significant for these four countries, suggesting that their stock-bond correlations change slowly from the previous level toward the correlation level expected by the economic variables.

As for transition variables, the VIX and time trend are significantly positive for these four countries, which are also consistent with the results of US, GE, and UK. Thus, the correlation regime changes from a positive to a negative regime when the VIX is high, and the correlation tends to be in the negative regime in more recent periods. The decreasing trend can be confirmed visually from the estimated time trend component of stock-bond correlations, as depicted in Panel (a) of Figure 6. A significant decrease in stock-bond correlations is observed in the 1999-2005 period. As for JP, the stock-bond correlations had already been negative from the first half of the 1990s, which had been further reduced from around June 2003. Despite some differences in the levels of stock-bond correlations for AU, CA, FR, JP, and SW, particularly in the first half of the sample, stock-bond correlations have reached a similar level of about -0.4 in 2012, which is also comparable to US, GE, and UK.

On the other hand, the results for IT, PO, and SP, which are considered the countries with more credit risks, show a complete contrast. As presented in Table 6, the estimated correlation parameters for regime 1 are significantly negative (except for PO), with estimated values of -0.193, -0.162, and -0.222 for IT, PO, and SP, respectively, while those for regime 2 are significantly positive, with respective values of 0.206, 0.232, and 0.229. Additionally, Figure 6 demonstrates that although IT PO, and SP had negative stock-bond correlations from the early 2000s up to the Euro crisis, these had become positive from the inception of the Euro crisis. More precisely, the change points are estimated as December 2009 for PO and SP, and January 2010 for IT. Interestingly, they happened immediately after the beginning of the Euro crisis by the revelation of the public finances, with the accounting fraud caused by the change of the Greek government in October 2009. Stock-bond correlations for these riskier countries have suddenly risen from that time. After the Euro crisis, since the bonds of these three countries are considered risky assets, these results are deemed consistent with the flight-to-quality movement.

In sum, our analysis of other countries further provides the evidence of significant trends in stock-bond correlations, with a remarkable contrast between safer and riskier countries. Although relatively safer countries share a similar decreasing trend in stock-bond correlations, the stock-bond correlations for the riskier countries (IT, PO, and SP) have increased significantly and suddenly around the beginning of the Euro crisis. Our findings of decreasing and increasing trends in stock-bond correlations are consistent with the more intensive flight-to-quality behavior in recent years as documented by Kim, Moshirian, and Wu (2006) and Baur (2010), among others, but provide additional evidence of flight-to-quality behavior after the Euro crisis.

4 Conclusion

In this paper, we investigate the existence of long-run trends with statistical significance in realized stock-bond return correlations. To this end, we introduce a trend component into the smooth transition regression (STR) model with the multiple transition variables of Aslanidis and Christiansen (2012). In addition, we analyze in detail the case of not only the US, but also Germany and the UK, to conduct a more comprehensive examination. The results indicate the existence of a significant decreasing trend in stock-bond correlations for all three countries.

Since a number of studies based on the dynamic conditional correlation (DCC) model of Engle (2002) have suggested that conditional correlations between financial returns are typically highly serially correlated, we extend the STR model of Aslanidis and Christiansen (2012) by including the AR(1) term. The AR parameter estimates are highly significant for all countries. Thus, our results demonstrate that stock-bond correlations change slowly from the previous level toward the correlation level expected by the economic variables, which is not captured by the Aslanidis and Christiansen's (2012) original model.

Regarding transition variables, we examine the VIX, short rate, and yield spread, which have been identified by previous studies as arguably three of the most important factors. All three transition variables have statistically significant effects on regime transitions for all countries in our extended model. The results are fairly consistent with those of previous studies, particularly that of Aslanidis and Christiansen (2012). However, once we introduce the trend component, although the VIX remains an important factor for stock-bond correlations, the short rate and yield spread become only marginally significant. Indeed, our in-sample analysis suggests that the STR model including the VIX and time trend as the transition variables is the best model based on the SIC and AIC, meaning that the transition of stock-bond correlation regimes can be described sufficiently well by the VIX and time trend components. In addition, our out-of-sample analysis also demonstrates that the STR model with the VIX and time trend as the transition variables dominates other models. Thus, the decreasing trend cannot be explained by short rates or yield spreads; rather, it has more explanatory power than these variables, which is fairly consistent with the positive trend in stock market correlations reported by Christoffersen, Errunza, Jacobs, and Langloiset (2012).

Finally, we apply our preferred model to eight other advanced countries to provide further evidence of significant trends in stock-bond correlations. Our results document an interesting contrast. Although relatively safer countries share a similar decreasing trend in stock-bond correlations, the stock-bond correlations for the riskier countries, namely, IT, PO, and SP have increased significantly and rapidly around the beginning of the Euro crisis.

Previous studies document the existence of long-run trends in comovements in the stock and bond markets, suggesting that benefits from international diversification have recently been disappearing. Therefore, investors have been exposed to higher risks of simultaneous drops in stock prices in recent years. Consequently, they have needed to make greater use of bond markets to control their risk exposure, producing the decreasing trend in stock-bond correlations. Interestingly, the beginning of the integration of international equity markets suggested by several previous studies and the beginning of decreases in stock-bond correlations appear to occur around the same time. In addition, stock-bond correlations for riskier Euro countries have significantly and suddenly increased around the beginning of the Euro crisis. Our findings of decreasing and increasing trends in stock-bond correlations can be considered a consequence of the decreasing effects of diversification and more intensive flight-to-quality behavior that have taken place in recent years and after the Euro crisis.

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Table 1: Estimation results of the benchmark model (Model 1)

	US		GE		UK	
	Coef	St. err	Coef	St. err	Coef	St. err
ρ_1	0.298***	0.101	0.378**	0.164	0.437***	0.055
ρ_2	-0.321***	0.129	-0.404***	0.147	-0.360***	0.038
ϕ	0.380***	0.090	0.342**	0.134	0.249***	0.080
VIX	1.370***	0.206	1.308***	0.099	0.537***	0.103
R	-3.414***	1.018	-3.968***	0.528	-3.824***	0.097
SPR	-2.201***	0.673	-2.839***	0.610	-2.476***	0.219
c	0.046	0.095	0.062	0.208	-0.007	0.077
Log-likelihood	-248.86		-250.95		-248.34	
Linearity test	12.3***		24.44***		16.55***	
Additive nonlinearity test	0.22		0.73		0.20	

Note: The table shows the estimation results of the STR Model 1 with transition variables; VIX index (VIX), short rate (R), yield spread (SPR). */**/*** indicates that the variable is significant at the 10%/5%/1% level of significance, respectively. Linearity test reports the LM-type statistic of null of no STR-type nonlinearity. Additive non-linearity shows the LM-Type statistic of null on no remaining STR-type nonlinearity.

Table 2: Estimation results of the model with time trend component (Model 2)

	US		GE		UK	
	Coef	St. err	Coef	St. err	Coef	St. err
ρ_1	0.297**	0.140	0.630***	0.052	0.502***	0.117
ρ_2	-0.368***	0.099	-0.580***	0.027	-0.440***	0.075
ϕ	0.346*	0.192	0.140***	0.028	0.156	0.105
VIX	1.925***	0.616	1.142***	0.083	1.163***	0.354
R	-0.576	0.461	1.323***	0.039	0.159	0.140
SPR	-0.294	0.672	0.051	0.049	-0.450***	0.161
T	2.571***	0.943	2.804***	0.010	2.725***	0.311
c	0.071	0.165	-0.144***	0.054	-0.065	0.158
Log-likelihood	-248.23		-248.25		-247.29	
Linearity test	10.95***		24.26***		21.54***	
Additive nonlinearity test	1.28		2.55		0.09	

Note: The table shows the estimation results of the STR Model 1 with transition variables; VIX index (VIX), short rate (R), yield spread (SPR), time trend (T). */**/*** indicates that the variable is significant at the 10%/5%/1% level of significance, respectively. Linearity test reports the LM-type statistic of null of no STR-type nonlinearity. Additive non-linearity shows the LM-Type statistic of null on no remaining STR-type nonlinearity.

Table 3: Results of in-sample comparison

	US		GE		UK	
	AIC	SIC	AIC	SIC	AIC	SIC
Model 1	511.72	536.54	515.90	540.71	510.68	535.50
Model 2	512.46	540.82	512.51	540.87	510.58	538.95
Model 3	508.54	529.81	509.30	530.58	507.01	528.28

Note: The table reports the AIC and SIC for STR Models 1-3 to compare in-sample performance.

Table 4: Results of out-of-sample comparison

	US		GE		UK	
	RMSE	MAE	RMSE	MAE	RMSE	MAE
Model 1	0.201	0.155	0.322	0.257	0.259	0.212
Model 2	0.203	0.161	0.297	0.231	0.274	0.221
Model 3	0.174	0.136	0.296	0.231	0.241	0.199

Notes: The table reports the out-of-sample RMSE and MAE for STR Models 1-3. The forecast horizon is 1 month and the forecast period is 2000/12-2012/05.

Table 5: Estimation results of the parsimonious model (Model 3)

	US		GE		UK	
	Coef	St. err	Coef	St. err	Coef	St. err
ρ_1	0.289***	0.001	0.459***	0.002	0.483***	0.185
ρ_2	-0.363***	0.002	-0.570***	0.006	-0.419**	0.173
ϕ	0.359***	0.001	0.136***	0.005	0.173	0.192
VIX	1.983***	0.003	1.901***	0.009	1.373***	0.345
T	2.959***	0.003	3.315***	0.095	2.808***	0.675
c	0.068*	0.041	0.005	0.067	-0.106	0.192
LL	-248.27		-248.65		-247.51	
Linearity test	21.33***		36.88***		38.87***	
Additive nonlinearity test	1.25		0.02		0.61	

Note: The table shows STR Model 3 with transition variables; VIX index (VIX), Time Trend (T). */**/*** indicates that the variable is significant at the 10%/5%/1% level of significance, respectively. Linearity test reports the LM-type statistic of null of no STR-type nonlinearity. Additive non-linearity shows the LM-Type statistic of null on no remaining STR-type nonlinearity.

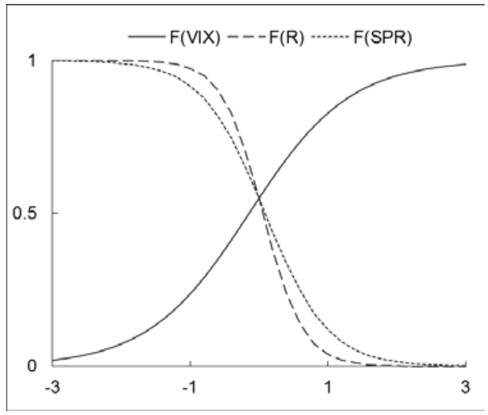
Table 6: Estimation results of Model 3 for other countries

	AU		CA		FR		JP	
	Coef	St. err	Coef	St. err	Coef	St. err	Coef	St. err
ρ_1	0.403***	0.114	0.265**	0.126	0.483***	0.115	-0.152*	0.090
ρ_2	-0.511***	0.046	-0.291***	0.132	-0.346***	0.076	-0.413***	0.103
ϕ	0.173***	0.061	0.272**	0.092	0.334***	0.098	0.207**	0.101
VIX	1.191***	0.102	2.385***	0.287	1.686***	0.290	13.905**	6.507
T	1.969***	0.185	2.983***	0.601	2.760***	0.307	300.000	NA
c	-0.057	0.052	-0.158	0.185	-0.335***	0.119	0.081	0.053
LL	-220.31		-219.70		-220.22		-217.98	
	SW		IT		PO		SP	
	Coef	St. err	Coef	St. err	Coef	St. err	Coef	St. err
ρ_1	0.234***	0.083	-0.193*	0.112	-0.162	0.135	-0.222**	0.095
ρ_2	-0.427***	0.070	0.206***	0.070	0.232*	0.126	0.229**	0.094
ϕ	0.204**	0.101	0.451***	0.091	0.302**	0.145	0.392***	0.095
VIX	2.262***	0.172	28.155***	6.601	0.000	NA	0.000	NA
T	3.540***	0.303	300.000	NA	300.000	NA	300.000	NA
c	-0.124	0.117	0.860***	0.037	0.911***	0.071	0.907***	0.138
LL	-219.25		-124.15		-121.54		-123.90	

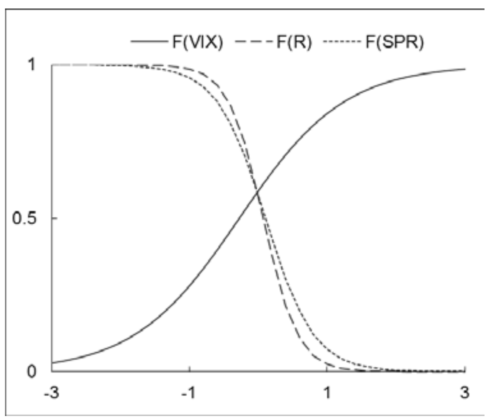
Note: The table shows STR Model 3 with transition variables; VIX index (VIX), Time Trend (T). */**/*** indicates that the variable is significant at the 10%/5%/1% level of significance, respectively.

Figure 1: Estimated transition function

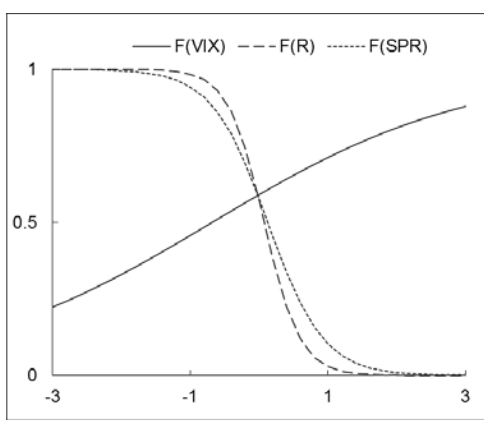
(a) US



(b) GE



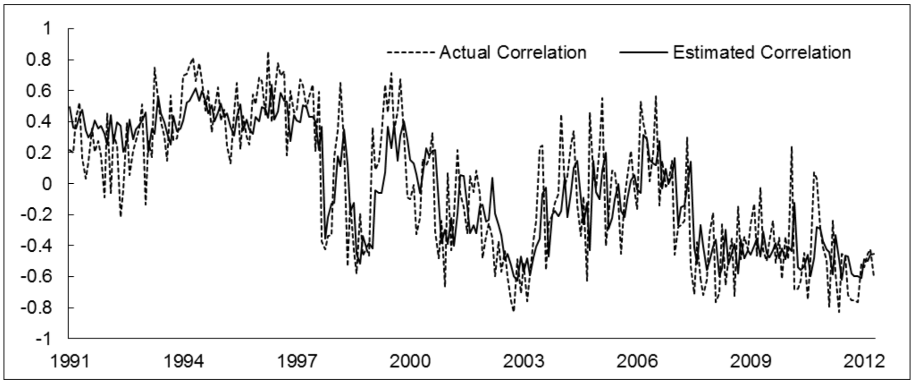
(c) UK



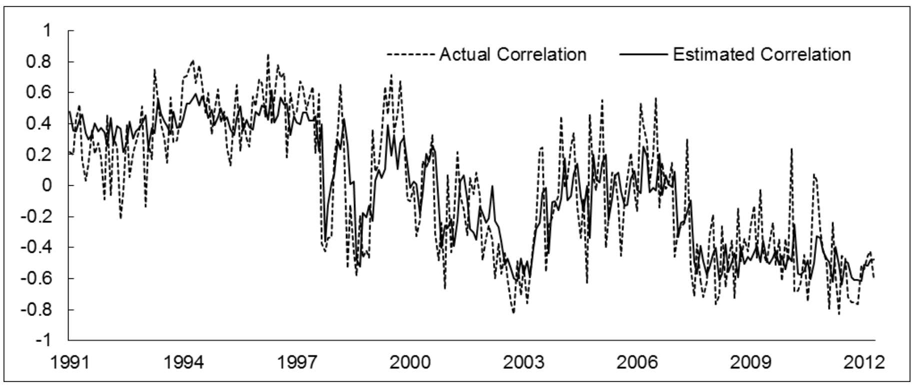
Notes: The graph shows the estimated transition function of model1 against each of the transition variables holding the other transition variables constant at their sample mean. The transition variables are VIX index (VIX), short rate (R), and yield spread (SPR).

Figure 2: Estimated stock-bond correlation for US

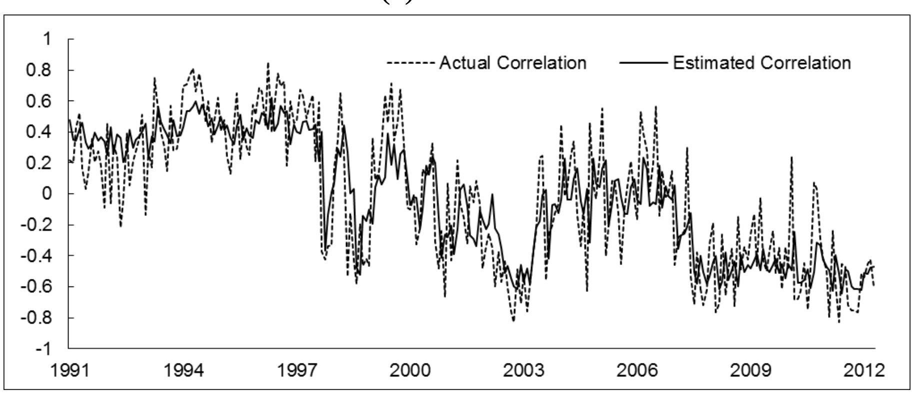
(a) Model 1



(b) Model 2



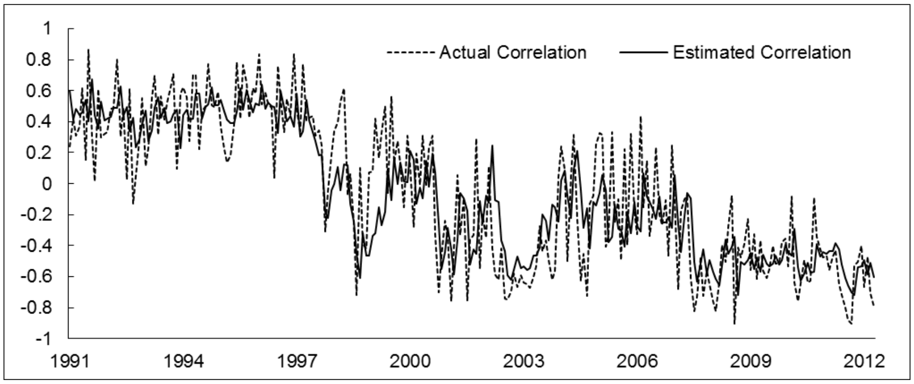
(c) Model 3



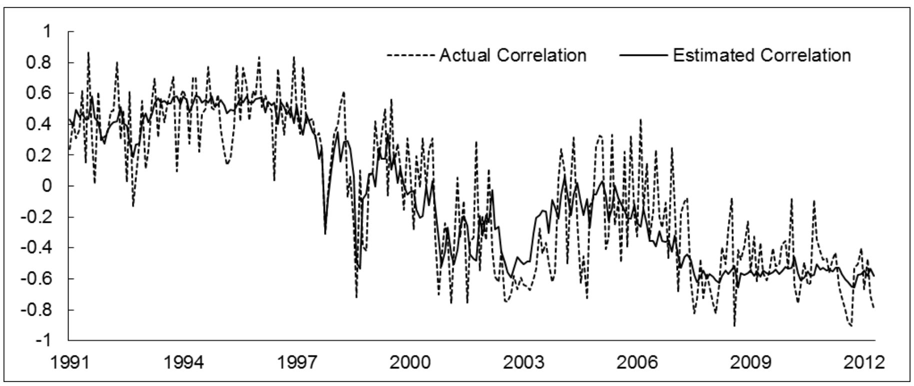
Notes: The graph shows the time series of the actual and estimated stock-bond correlation for Models 1-3 for US.

Figure 3: Estimated stock-bond correlation for GE

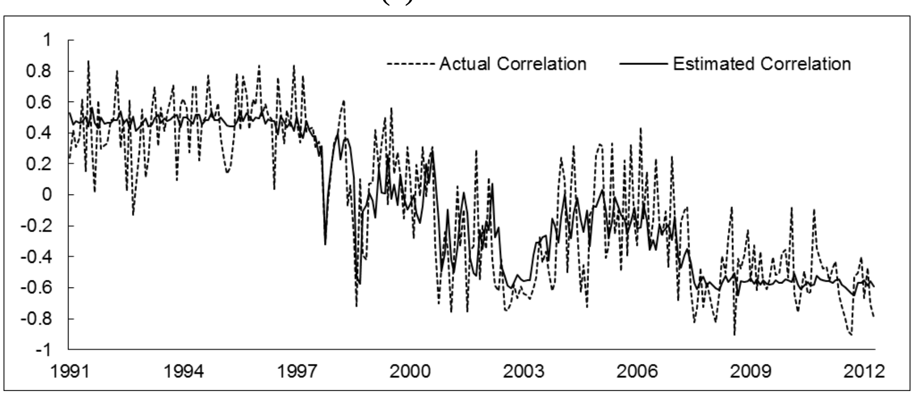
(a) Model 1



(b) Model 2



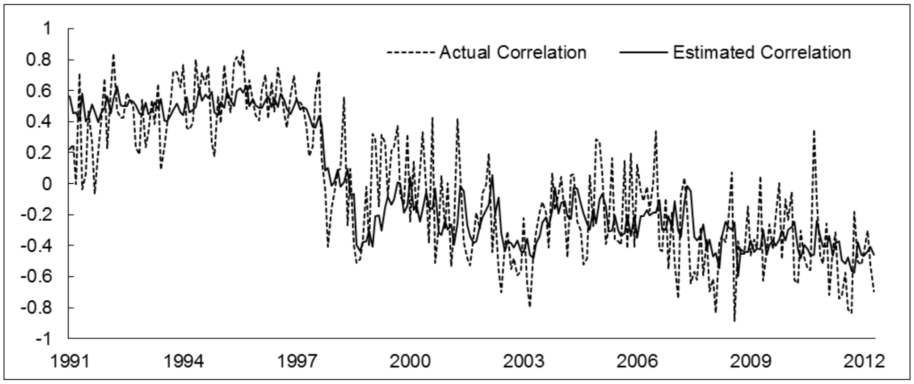
(c) Model 3



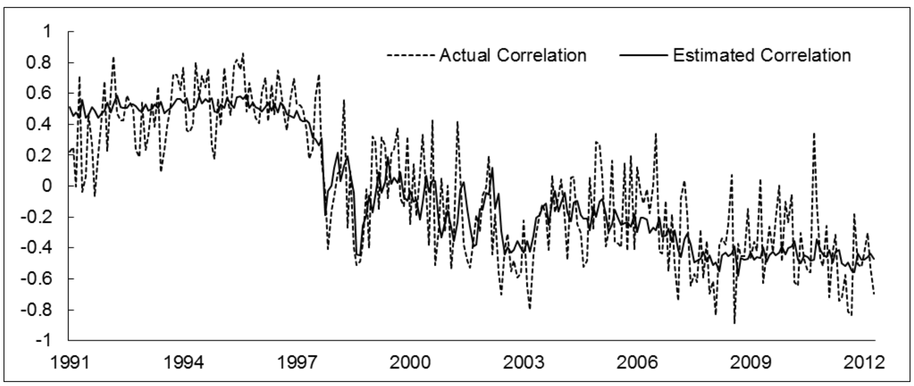
Notes: The graph shows the time series of the actual and estimated stock-bond correlation for Models 1-3 for GER.

Figure 4: Estimated stock-bond correlation for UK

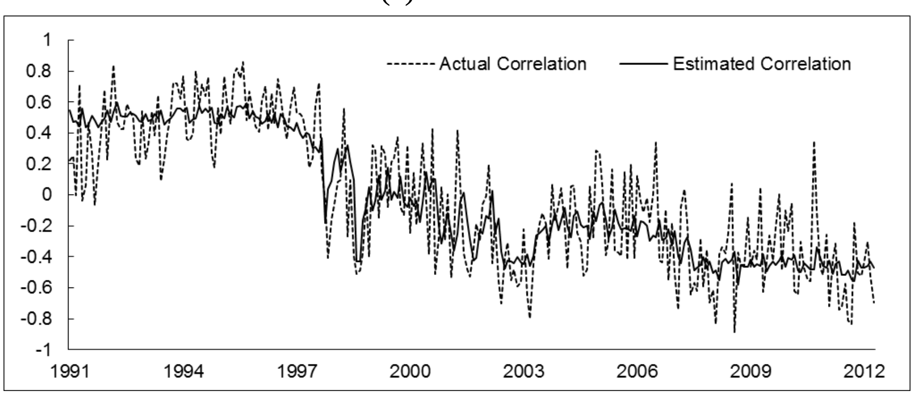
(a) Model 1



(b) Model 2



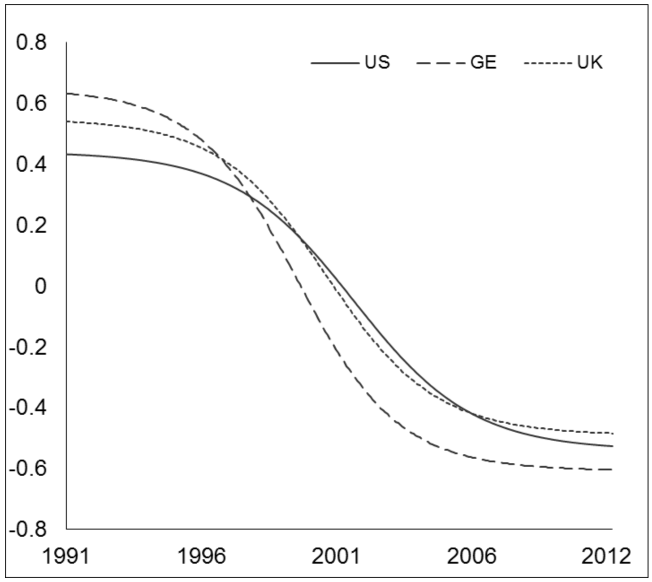
(c) Model 3



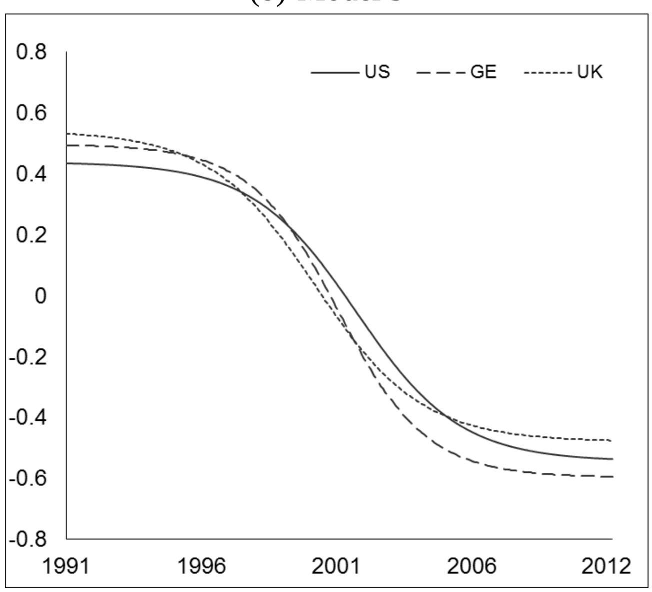
Notes: The graph shows the time series of the actual and estimated stock-bond correlation for Models 1-3 for UK.

Figure 5: Estimated time trend component in the stock-bond correlation

(a) Model 2



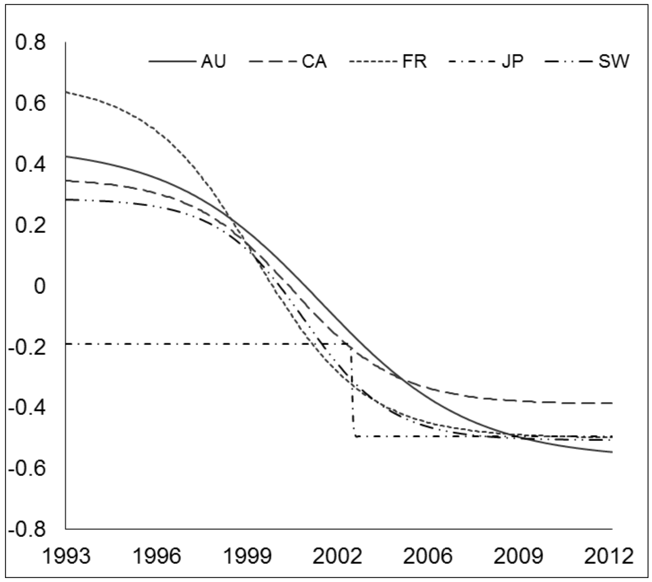
(b) Model 3



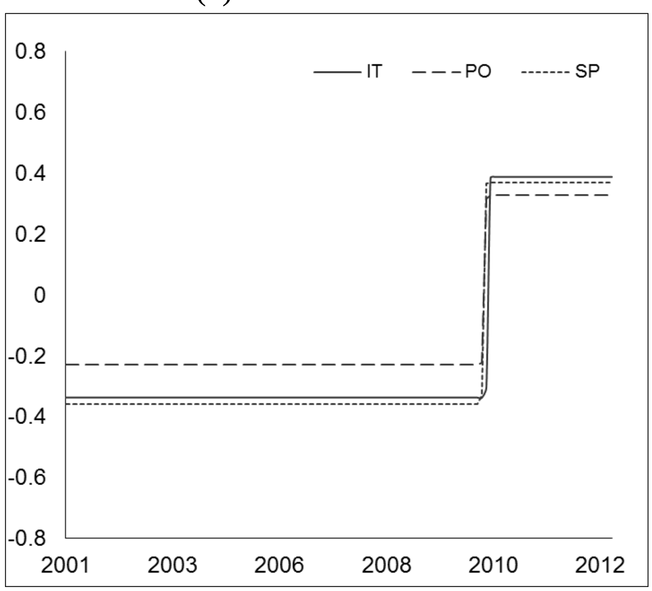
Note: The graph shows the time series of the estimated time trend component in the stock-bond correlation for Models 2 and 3.

Figure 6: Estimated time trend component in the stock-bond correlation for other countries

(a) Safer countries



(b) Riskier countries



Note: The graph shows the time series of the estimated time trend component in the stock-bond correlation for Models 3 for other countries.