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Spillover Impact of the US Unconventional Monetary Policy and Uncertainties on Stock-Bond Correlations

Summary: This paper investigates the spillover impact of US unconventional monetary policy and uncertainty factors on the time-varying co-movements between the US stock market and 14 advanced countries' bond markets, as based on monthly data from January 2002, to October 2015, and utilising the conditional nonlinear quantile regression approach. The empirical results reveal that US unconventional monetary policy has an asymmetric positive effect on stock-bond market co-movements, with a nonlinear effect in France and Denmark and a strong effect in the UK and Finland. Further, US bond market uncertainty has heterogeneous effects on stock-bond market co-movements, with a nonlinear effect in France and Denmark and a strong effect in Finland and Sweden. In addition, default risk spread positively influences stock-bond market co-movements across most countries for all quantiles. In contrast, stock-bond market co-movements negatively and symmetrically respond to the US stock market uncertainty in most countries. Finally, stock-bond co-movements exhibit mixed responses to US economic policy uncertainty across countries. Our results have valuable implications for international investors who allocate capital across developed countries' stock and bond markets. Our findings provide important information for financial communities with regard to diversification and hedging.

Keywords: Cross-country cross-asset correlations, Unconventional monetary policy, Uncertainties, Quantile regression.

JEL: C22, E52, G15.

The US monetary policy and uncertainty factors have powerful influences on the financial markets (Marcel Fratzscher, Marco Lo Duca, and Roland Straub 2019). As a response to the 2008 crisis, the Federal Reserve (FED) resorted to implementing an unconventional monetary policy (UMP) using forward guidance and quantitative easing (QE) programmes to improve liquidity conditions and boost future economic growth. The UMP also affected stock and bond prices within the US and had spillover effects on the international financial markets. On the other hand, uncertainty factors of the US, namely stock market, bond market, and economic policy uncertainties, have strong impacts on the global financial markets as well. They could cause a change in the investors' portfolio assets allocation decision and might trigger the flight-to-quality or the flight-from-quality phenomenon. Therefore, the mentioned factors are expected to have an influence on the correlations among the financial assets, both on the internal and the international level. This study investigates the spillover effects of the US UMP, and financial market and economic policy uncertainties on the time-varying co-movements between the US stock market and advanced countries' bond markets. To our best knowledge, this is the first paper that addresses this research question at the cross-country and cross-asset level. It also expands the literature by considering both macroeconomic and uncertainty factors. Our MGARCH BEKK model adequately captures the volatility transmissions between the US stock market and advanced countries' bond markets. The findings of this study provide important information for asset allocation-risk management strategies and policy making.

The rest of the paper is organised as follows. Section 1 discusses the literature review. Section 2 addresses research methodology. Section 3 provides empirical result and discussion. Finally, Section 4 represents conclusions.

1. Literature Review

The literature has predominantly investigated the effects of macroeconomic factors on the time-varying correlation between stock and bond markets within countries (Lingfeng Li 2004; Stefano d'Addona and Axel H. Kind 2006; Magnus Andersson, Elizaveta Krylova, and Sami Vähämaa 2008; Lieven Baele, Geert Bekaert, and Koen Inghelbrecht 2010). However, the controversy over this relationship still continues. However, the controversy over this relationship still continues. Andersson, Krylova, and Vähämaa (2008) found that macroeconomic factors have very little to contribute in explaining stock and bond return correlations. It was found that expected inflation and economic growth both marginally impact the correlation in the UK, the US and Germany. Along the same lines, Baele, Bekaert, and Inghelbrecht (2010) demonstrated that interest rates, inflation, uncertainty about inflation and GDP are not important factors in explaining stock-bond return correlations in the US as microfinance factors, especially stock and bond market liquidity. In contrast to these studies, there are also findings that indicate the importance of macroeconomic factors. Li (2004) indicated that uncertainty about expected inflation and real interest rates participates in increasing the stock-bond correlation in G-7 countries. However, d'Addona and Kind (2006) showed that inflation volatility tends to reduce the stock-bond correlation in G-7 countries, while real interest rate volatility increases the correlation. Alexander David and Pietro Veronesi (2013) provided evidence that inflation plays a key role in predicting stock-bond correlations. In addition, Hossein Asgharian, Charlotte Christiansen, and Ai Jun Hou (2015, 2016) argued that, as the US macroeconomic uncertainty index raises, investors shift to bond markets (supporting the flight-to-quality phenomenon), thereby inducing negative stock-bond correlations within the US. Nebojsa Dimic et al. (2016) presented a new perspective on how stock-bond market correlations are affected by macroeconomic factors at different time horizons. Their results indicate that, in the short term, domestic monetary policy is the dominant force driving stock-bond correlations across emerging economies, while inflation is the dominant long-term factor.

Another strand of literature provides evidence on the impacts of macroeconomic factors on stock-bond correlations. Antti Ilmanen (2003) pointed out that, during periods of higher inflation, stock-bond correlation within the US is more likely to be positive, because the discount rate effect is the dominant force that leads to bond and stock prices simultaneously falling. In contrast, the stock-bond correlation becomes negative over lower inflation and recession periods. Also, Jian Yang, Yinggang Zhou, and Zijun Wang (2009) emphasised that stock-bond correlations within the US and UK are more likely to increase during the period of higher short rates when compared to a period of higher inflations. Nektarios Aslanidis and Charlotte Christiansen (2012) applied smooth transition regression and found that the economic state is significantly less important than the short rate and yield spread in shifting stock-bond correlations in the US. This indicates that, over periods of higher short rate and yield spread, it is more likely for the stock-bond correlation to be positive. However, the inflation rate stance is not associated with stock-bond correlations. Harumi Ohmi and Tatsuyoshi Okimoto (2016) argued that adding the trend effect and excluding the inflation rate from the model proposed by Aslanidis and Christiansen (2012) would alter the influence of macro-finance factors on stock-bond correlation regimes not only in the US, but also in Germany and the UK. Asgharian, Christiansen, and Hou (2016) provide evidence that the long-run stock-bond correlation is significantly and positively driven by the general state of the economy. However, neither inflation nor bond market liquidity has an explanatory power on the US stock-bond correlations. Therefore, when the economic stance is a boom, long-run stock-bond correlations tend to be a positive, advocating the flight-to-safe-haven-assets hypothesis, while this correlation becomes negative during poor economic periods.

Another segment of literature has given attention to uncertainty factors' effects on stock-bond market co-movements at the country level. Many studies found that stock market uncertainty is a particularly essential element for driving the direction of stock-bond correlations (Robert Connolly, Chris Stivers, and Licheng Sun 2007; Aslanidis and Christiansen 2012; Thomas C. Chiang, Jiandong Li, and Sheng-Yung Yang 2015). Several other researchers found that stock-bond correlations are negatively related to domestic or US stock market uncertainty, as gauged by Exchange Volatility Index (VIX), arguing that a higher period of stock market uncertainty makes more risk-averse investors switch funds to safe haven assets, such as bonds (Connolly, Stivers, and Sun 2007). Moreover, Connolly, Stivers, and Sun (2005) argued that, as the level of VIX exceeds 25 percent, there is a 36.5 percent chance that the future stock-bond correlation in the US will be negative, while there is only a 6.1 percent chance that the correlation is likely to be negative if VIX is less than 20 percent. In contrast, Baele, Bekaert, and Inghelbrecht (2010) found that VIX insignificantly affects stock-bond correlations in the US after adding variance premium, which was calculated as the difference between the square of VIX and the conditional variance of stock prices. Also, Dimic et al. (2016) found mixed effects of US stock market uncertainty on stock-bond correlations within emerging markets. Other studies have considered bond market uncertainty effects on stock-bond correlations. Chiang, Li, and Yang (2015) investigated the effect of bond market uncertainty on stock-bond correlations in six core financial markets and found that the correlation between stock and bond markets is highly and positively associated with the conditional variance of bond returns in all markets. In contrast, rising term spread and default risk spread, as another channel of bond market uncertainty, reduce stock-bond correlations, indicating a flight-to-quality phenomenon. However, Dimic et al. (2016) pointed out that US bond market uncertainty has marginal negative effects on stock-bond correlations within the US and high positive effects on stock-bond correlations within emerging markets. Stock-bond market co-movements may be influenced by economic policy uncertainty. Xiao-Ming Li, Bing Zhangb, and Ruzhao Gao (2015) conducted the only study on this subject, finding that stock-bond market co-movements within the US negatively react to US economic policy uncertainty.

While most previous literature has exclusively focused on factors that affect the conditional mean of stock-bond correlations, other studies have taken into account the tails of the distribution of the stock-bond correlation. Aslanidis and Christiansen (2014) employed quantile regression to point out that stock-bond correlations in the US are significantly explained by microfinance factors only at highly negative stock-bond correlation quantiles, while they are irrelevant at highly positive correlation quantiles. They explained these findings by arguing that bonds are vulnerable to macro-finance factors in all periods, while stocks are only exposed to these factors in intense volatile periods. Aslanidis and Christiansen (2010) indicated that, at low quantiles of stock-bond correlations, only the volatility of industrial production and bond markets plays a significant positive role in explaining stock-bond co-movements. They further indicated that, at high quantiles, stock-bond correlations are negatively influenced by inflation uncertainty, bond market liquidity and stock market volatility. However, bond market volatility still has a significant positive effect even at high quantiles.

There is a growing literature that is dedicated to the influence of the UMP on stock and bond markets. The vast majority of empirical research has concluded that UMP substantially reduces domestic and foreign long-term government bond yields (e.g. Joseph Gagnon et al. 2011; Arvind Krishnamurthy and Annette Vissing-Jorgensen 2011; Jonathan H. Wright 2012; Michael Bauer and Christopher J. Neely 2014; Bauer and Glenn D. Rudebusch 2014; Neely 2015). Gagnon et al. (2011) found that the QE announcement by the Fed remarkably reduces yields on 10-year government bonds relative to 2-year government bonds. Krishnamurthy and Vissing-Jorgensen (2011) provided supportive findings. The effect of the US UMP on the international government bonds market has also been investigated. Bauer and Neely (2014) indicated that signalling and portfolio rebalancing channels from US UMP reduced yields on government bonds in the US and other advanced countries. Similarly, Neely (2015) indicated that the US UMP significantly reduced the 10-year government bond yields of the US, Australia, Canada, Germany, Japan, and the UK. He pointed out that this effect can be attributed to the preferred-habit theory.

Many studies have investigated the effect of UMP on stock markets (e.g. Michael Joyce et al. 2012; Eric T. Swanson 2015; Sabri Boubaker et al. 2017; Fratzscher, Lo Duca, and Straub 2019; Hussain Imran Shah et al. 2019) and the literature mainly concluded that UMP positively affects prices in both domestic and international stock markets. Joyce et al. (2012) argued that QE conducted by the BOE generated an incentive for investors to rebalance their portfolios toward domestic stocks in place of government bonds. Richhild Moessner (2015) pointed out that US UMP exerted positive spillover effects on stock market prices in developed and emerging-market countries. Moreover, Boubaker et al. (2017) pointed out that QE-induced mutual funds rebalanced their portfolios toward stocks, which led to price increases in this market.

Finally, Shah et al. (2019) pointed out that QE done by Fed caused a significant reduction in the US equity risk premium, leading to an increase in the US equity prices, which provides evidence for an active portfolio rebalancing into risky assets following QE.

To date, there is no empirical evidence regarding the effect of US UMP on time-varying co-movements between stock and bond markets at the cross-market and cross-country levels. Assessing the role of UMP in determining the co-movements between stock and bond markets at the cross-market and cross-country levels has critical information to both investors and portfolio managers who internationally allocate their investments between the USA and advanced countries' markets. Negative or small positive correlations across these regions and markets offer opportunities for diversification and hedging. Also, this information helps institutional investors to set up their arbitrages strategies. Following the spread of the financial crisis in 2008, advanced countries and the US showed divergent macro-financial behaviour, which triggered concerns about the coordination of monetary policies between countries. Therefore, understanding the role of US UMP in determining the dynamic correlation between stock and bond markets at the cross-market and cross-country levels is essential to implement optimal policies at the national level and their coordination between the US and other advanced countries.

Further, nothing is known about the spillover implications of US economic policy uncertainty, especially on cross-country stock-bond correlation levels. Following the 2008 global financial crisis, economic policy uncertainty increasingly drove the business cycle fluctuations of the global economy (Nicholas Bloom 2014). It has been reported that much of the global economic policy uncertainty has stemmed from the US economy (International Monetary Fund 2013; Nguyen Ba Trung 2019), and, due to the highly integrated structure of the world economy, it has spillovers to the rest of the world (Trung 2019). Economic policy uncertainty shock causes a "flight to quality" phenomenon and is expected to influence the dynamic correlation between the US stock and advanced countries' bond markets. The interesting point is that the spillover effect of the US economic policy uncertainty is heterogeneous in the sense that its effects vary from one country to another (Valentina Colombo 2013). Thus ignoring the impact of the US economic policy uncertainty may cause suboptimal financial decisions.

The majority of previous studies which analysed the dependencies between financial/economic variables and stock-bond market correlations used the OLS method (e.g. d'Addona and Kind 2006; Andersson, Krylova, and Vähämaa 2008), regime switching models (e.g. Aslanidis and Christiansen 2012; Chiang, Li, and Yang 2015; Asgharian, Christiansen, and Hou 2016), and the wavelet estimation technique (Dimic et al. 2016). Although these methods provide important information, they have some drawbacks. The OLS method summarises the average relationship between a set of explanatory variables and the dependent variable based on the conditional mean function of the dependent variable; hence, it can only deliver a partial view of the interdependency between the stock and bond markets. Also, in the presence of outliers and non-normality OLS might produce biased estimates. Regime switching models can only consider the effect of a variable at two specific points, that is, before and after the transition of these variables into different regimes. The wavelet technique is sensitive to the selection of time horizon, especially if data have a high frequency. Based on the limitations of the mentioned methods, we were motivated to use conditional non-linear quantile regression (Roger Koenker and Gilbert Bassett 1978), in line with previous studies (Hyunchul Lee and Seung Mo Cho 2017) to provide a more comprehensive answer to our research question.

2. Research Methodology

2.1 Data and Variable Descriptions

The analysis was conducted using monthly data on the US stock market returns and 15 advanced countries' bond market returns (Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Switzerland, Sweden, Spain and the UK). These countries have been selected because of their larger stock markets and their financial marks being highly integrated with the US market. Moreover, the Euro-area bond yields, short-term interest rates and Euro exchange rate against the US Dollar are significantly influenced by US short-term rates, US bond yields and US stock market returns. Also, US bond yields and dollar exchange rate against the Euro are only significantly affected by the Euro bond yield and short-term rates, while the US short-term interest rates are affected by the Euro short-term rates, bond yields and stock market returns markets (Michael Ehrmann, Marcel Fratzscher, and Roberto Rigobon 2011). This indicates substantial linking between these two markets. The monthly stock and bond returns are calculated as $Ln\ (P_t/\ P_{t-1})\ \times 100$, where P_t is the price index for stock and bond indices. The stock market price index for the US is Standard & Poor's 500 (S&P 500), and the bond market price indices are represented by 10-year benchmark government bond indices for each of the countries being considered. The data on stocks and bond indices were collected from Thomson Reuters DataStream.

The sample period ranged from January 2002M1 to November 2015M11. The starting point for the sample period was chosen due to data availability. However, the sample end is 2015M11 because the FED decided to begin raising the target range for the federal funds from ZLB in December 2015. We used a dummy variable to divide our whole sample into two equivalent periods. The first subsample, 2002M1-2008M12, represents the conventional monetary policy period, while the second one, 2009M1-2015M11, represents the UMP. Hence, this choice enables us to identify the effect of both the FED's conventional and unconventional monetary policies on the dynamic correlation between US stock and advanced countries' bond markets and make a comparison between these two approaches. We used the federal funds rate (FFR) as the interest rate for the 2002-2009 period. Following, Ozan Eksi and Bedri Kamil Onur Tas (2017) the shadow federal funds rate reflects the effect of unconventional monetary policy actions following the ZLB period. As a result, the shadow rate of the federal fund rate as representative for US UMP was computed up to November 2015.

Table 1 displays descriptive statistics of the US stock market and the bond returns of the chosen 15 countries. The average returns of the 15 advanced bond markets are relatively lower than the US stock market returns. However, standard deviations reveal that all advanced countries' 10-year bond returns exhibit significantly lower volatility than the US stock returns, in line with the safe haven characteristic of government bonds.

Table 1 Descriptive Statistics for US Stocks and Advanced Countries' Bond Market Returns

Countries	Mean	Median	Maximum	Minimum	Std. dev.	Skewness	Kurtosis
Australia	0.001	0.000	0.051	-0.054	0.019	0.050	2.958
Belgium	0.002	0.004	0.077	-0.059	0.018	-0.175	4.886
Canada	0.001	0.002	0.054	-0.034	0.015	0.032	3.296
Denmark	0.002	0.005	0.046	-0.044	0.017	0.039	2.947
Spain	0.002	0.004	0.090	-0.101	0.022	-0.076	6.981
Finland	0.002	0.004	0.043	-0.034	0.015	-0.030	2.742
France	0.002	0.006	0.044	-0.048	0.016	-0.294	2.938
Germany	0.002	0.005	0.047	-0.030	0.016	-0.017	2.675
Italy	0.001	0.000	0.051	-0.054	0.016	0.045	3.492
Japan	0.001	0.002	0.022	-0.044	0.009	-1.058	6.287
Netherlands	0.002	0.004	0.047	-0.036	0.016	-0.074	3.101
Norway	0.003	0.004	0.106	-0.093	0.026	-0.089	4.938
Sweden	0.001	0.003	0.046	-0.056	0.017	-0.448	3.266
Switzerland	0.001	0.001	0.044	-0.089	0.015	-1.116	10.005
UK	0.002	0.003	0.050	-0.048	0.017	-0.040	3.318
US*	0.003	0.010	0.102	-0.185	0.042	-0.890	5.070

Notes: * it represents the US stock market returns.

Source: Authors' calculation.

Table 2 Unconditional Correlations between the US Stock Market and Advanced Countries' Bond Markets

Countries	Correlation	p-value
Australia	-0.287	0.000
Belgium	-0.160	0.038
Canada	-0.271	0.000
Denmark	-0.275	0.000
Finland	-0.294	0.000
France	-0.266	0.000
Germany	-0.367	0.000
Italy	-0.293	0.015
Japan	-0.084	0.277
Netherlands	-0.299	0.000
Norway	0.426	0.000
Sweden	-0.300	0.000
Switzerland	-0.226	0.003
Spain	0.209	0.006
UK	-0.277	0.000

Source: Authors' calculation.

We also examined whether stock and bond return time series are stationary or not using augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. Obtained unit root test results suggest that the null hypothesis of unit root can be rejected at a 1 percent significance level for all the return series under investigation, implying that these variables are stationary[1]. The unconditional relations between the US stock market and advanced countries' bond markets reported in Table 2 shows that the vast majority of advanced bond market returns exhibit a negative and statistically significant correlation with the US stock market returns, with Japan as an exception. This indicates that that advanced countries' bond markets may be considered a safe haven asset for US stock market investors.

2.2 Test for ARCH and GARCH Effects

To generate the independent variable, we employed multivariate GARCH (MGARCH) models. However, before running these models, we had to test for the existence of autoregressive conditional heteroscedasticity (ARCH) and generalised ARCH (GARCH) effects. To do so, the standard Lagrange Multiplier (LM) test (Robert F. Engle 1982) was applied to identify the presence of the ARCH effect. As shown in Table 3, this displayed strong support for ARCH effects in all returns series except Spain. Therefore, Spain was excluded from our study. To test GARCH effects, we estimated the Ljung-Box Q-statistics for serial correlation using both returns and squared returns. The serial correlation existed in all series, indicating the existence of GARCH effects in these returns.

Table 3 ARCH and GARCH Effect Tests for Advanced Countries' Bond Markets and the US Stock Market

Countries	LM test		Q test on row data		Q test on squared data	
	F(2,81)	F(5,78)	Q (2)	Q (5)	Q (2)	Q (5)
Australia	3.152**	2.532**	0.422**	2.863 *	6.522**	6.848
Belgium	2.888*	2.080*	4.655*	5.955	15.678***	17.087**
Canada	5.784***	2.710 **	4.522	5.395**	6.299**	10.011*
Denmark	3.012**	1.484	3.519***	5.049	12.582**	14.157**
Finland	6.932***	2.821**	2.226**	3.717*	3.253	10.814**
Franc	2.914*	2.141*	3.275	4.910**	9.777*	11.191***
Germany	10.122***	8.033***	2.789 **	4.127*	19.235***	28.719***
Italy	0.772	6.025***	1.464 **	3.124***	5.425*	9.006
Japan	2.938*	3.214***	1.169 *	2.144**	9.223*	11.606**
Netherland	9.886***	6.895***	2.201**	4.190*	16.072***	18.681**
Norway	4.465**	2.262*	3.796**	5.654**	5.863*	7.164
Sweden	2.393**	1.400	2.853*	6.794**	14.245 ***	14.804**
Switzerland	3.820**	2.041*	1.382*	7.165**	18.036***	26.419***
Spain	2.388	1.674	3.803	4.887**	10.341**	13.091**
UK	4.446**	1.760	6.485**	6.573*	13.858***	15.950**
US*	2.814*	2.841**	5.725*	8.482	7.214**	9.636*

Notes: The F-statistics (k, n) related to the Lagrange Multiplier (LM) test, where k is the lag length and n is the sample size. The Q test represents Ljung -Box statistical for serial correlation up to the 2th and 5th lag. US* represents the US stock returns. $p^{***} < 1$, $p^{***} < 5$, $p^{*} < 10$.

Source: Authors' calculation.

[1] We do not report the unit root results, but they are available on request.

2.3 Multivariate Generalized Autoregressive Conditional Heteroskedasticity (MGARCH) Models

We employed the diagonal Engle and Kenneth F. Kroner (BEKK 1995) model because it does not impose constraints, which makes the correlation constant between two variables over time and because it contains a quadratic form to ensure that the conditional variance for each variable and the conditional covariance between each variable are both positive (Ruey S. Tsay 2010). Furthermore, the BEKK model is capable of capturing the volatility spillover effects between various assets across different markets, as well as the time-varying correlations between different markets.

The first step, to estimate MGARCH-BEKK (1, 1), required estimating the mean equation by ARMA (p, q) model using a return series to eliminate the effect of serial correlation in returns as follows:

$$R_{it} = \alpha_i + \psi R_{i,t-1} + \omega M_{i,t-1} + \Phi B_{i,t} + \varepsilon_{i,t}; \quad (1)$$

$$\varepsilon_{i,t} = \eta_t \sqrt{h_{i,t}}\, \eta_{i,t} \sim iid\,(0,1), \quad (2)$$

where R_{it} refers to returns on assets i, α_i is a constant term of assets i, ψ refers to the coefficient of lagged returns of stock i, ω is the coefficient of lagged return i residual, Φ is the coefficient for the structural break effects of asset i returns and ε_t is an error term following independently and identically normal distribution. Subscripts $i = S$ and B stand for stocks and bonds, respectively.

The second step is to estimate the conditional variance equation using a diagonal BEKK model as follows:

$$H_t = CC' + A\varepsilon_{t-1}A' + Bh_{t-1}B', \quad (3)$$

where H_t is the conditional variance matrix of R_i, the matrix C is an upper triangular matrix signifies the asymmetric effect coefficients, A and B are diagonal matrixes expressing the ARCH and the GARCH parameters, respectively. For simplicity, the diagonal BEKK is demonstrated as follows:

$$h_{Si,t} = c_S^2 + a_S^2\, \varepsilon_{1.t-1} + B_S^2 h_{S,t-1}; \quad (4)$$

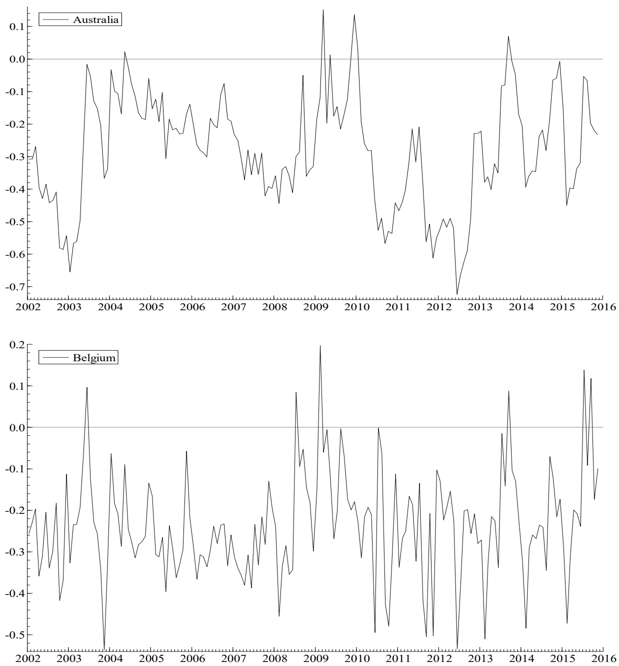
$$h_{Bj,t} = c_B^2 + a_B^2 \varepsilon_{2,t-1}^2 + B_B^2 h_{B,t-1}; \quad (5)$$

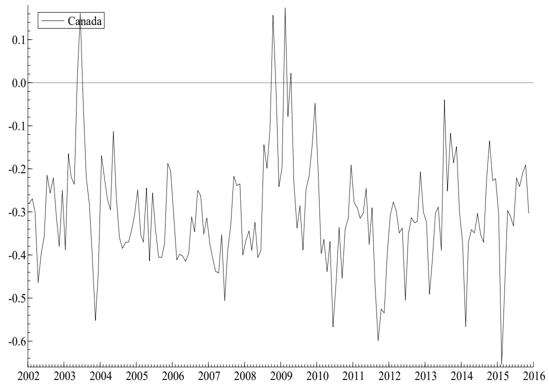
$$h_{SiBj,t} = c_{SB}c_B + a_S a_B\, \varepsilon_{1.t-1}\, \varepsilon_{2,t-2} + B_S B_B h_{SB,t-1}; \quad (6)$$

$$\rho_{SiBj,t} = \sqrt{h_{Si,t}}\sqrt{h_{Bj,t}}/h_{SiBj,t}, \quad (7)$$

where $h_{S,t}$ and $h_{B,t}$ are the conditional variance of US stock market returns and each advanced country bond market returns, respectively, $h_{SB,t}$ is the conditional covariance between US stock market returns and each advanced countries' bond market returns that captures volatility spillover between the two markets and $\rho_{SB,t}$ is the time-varying conditional correlation between US stock market returns and each advanced countries' bond market returns, which represents the dependent variable.

Figure 1 illustrates the monthly time-varying correlation between the US stock market and advanced countries' bond markets, where most countries' bond markets exhibit negative time-varying correlation with the US stock market. This is an indication that the inclusion of these bond markets into US investors' portfolio enables them to take advantage of diversification and, hence, reduce portfolio risks. It is notable to mention that the time-varying correlation between the US stock market and the Norwegian bond market was negative before 2009, while it turned out to be positive since then. We can attribute this dramatic change to altered investors' perception. Many investors noticed that the implementation of UMP in 2009 reduced the level of macroeconomic uncertainty. This perception made the time-varying correlation between the US stock market and the Norwegian bond market positive. This is consistent with Suk-Joong Kim, Fariborz Moshirian, and Eliza Wu (2006) who found that the time-varying correlation between stock and bond market in Italy turned out to be positive at the inception of the European Union and its post period. Also, in the case of Japan, the correlations fluctuated between negative and positive values in Japan during 2002-2004. The positive stock-bond market correlations can be as a result of the 2002-2003 recession in the US. This period corresponded to an episode of adverse economic growth shocks. Thus, such shocks depress the expected path of short-term interest rates, thereby lowering US government bond yields, leading investors to seek Japanese government bonds and, thus, increase their prices. This development has a strong effect on Japanese financial markets because Japan is the largest foreign holder of the US government bonds. Also, the US stock prices tend to increase when the expected path of short-term interest rate is low if expected dividend increases by more than the decline in the discount rate (as a result of lower expected short-term interest rates). Therefore, the US stock prices and the Japanese government bond price tend to move in the same direction, leading the correlation to be positive between them.




Canada
0.1
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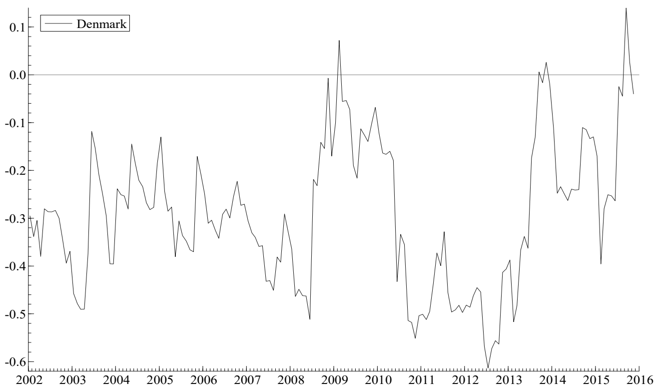
Denmark
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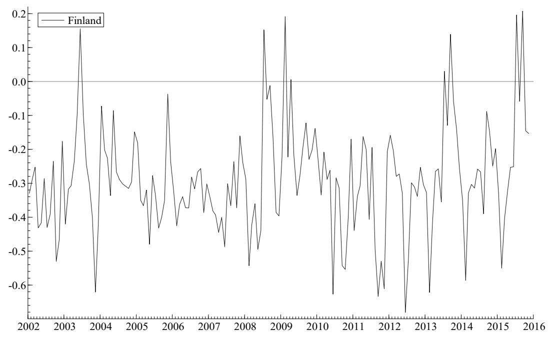
Finland
0.2
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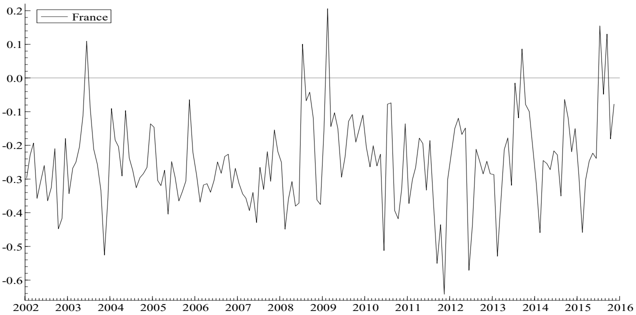
-0.6
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016


France
0.2
0.1
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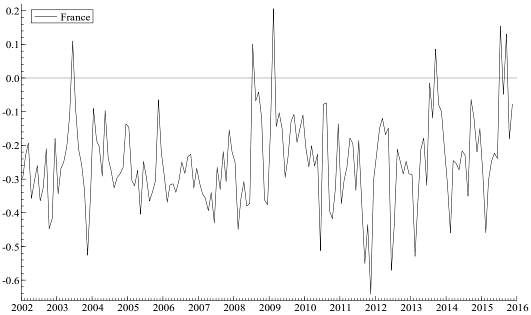
France
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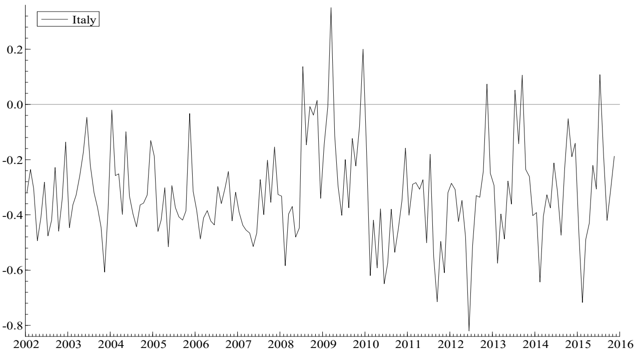
Italy
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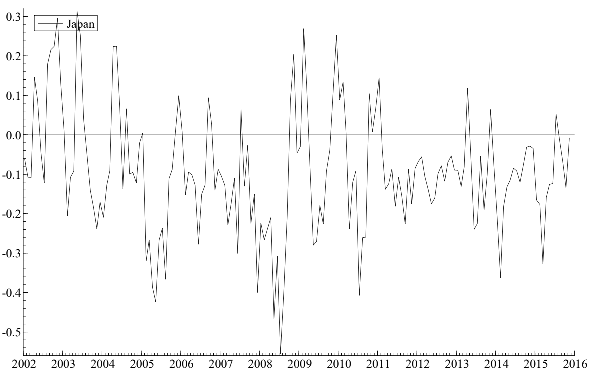
-0.6
-0.8
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016


Japan
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0.2
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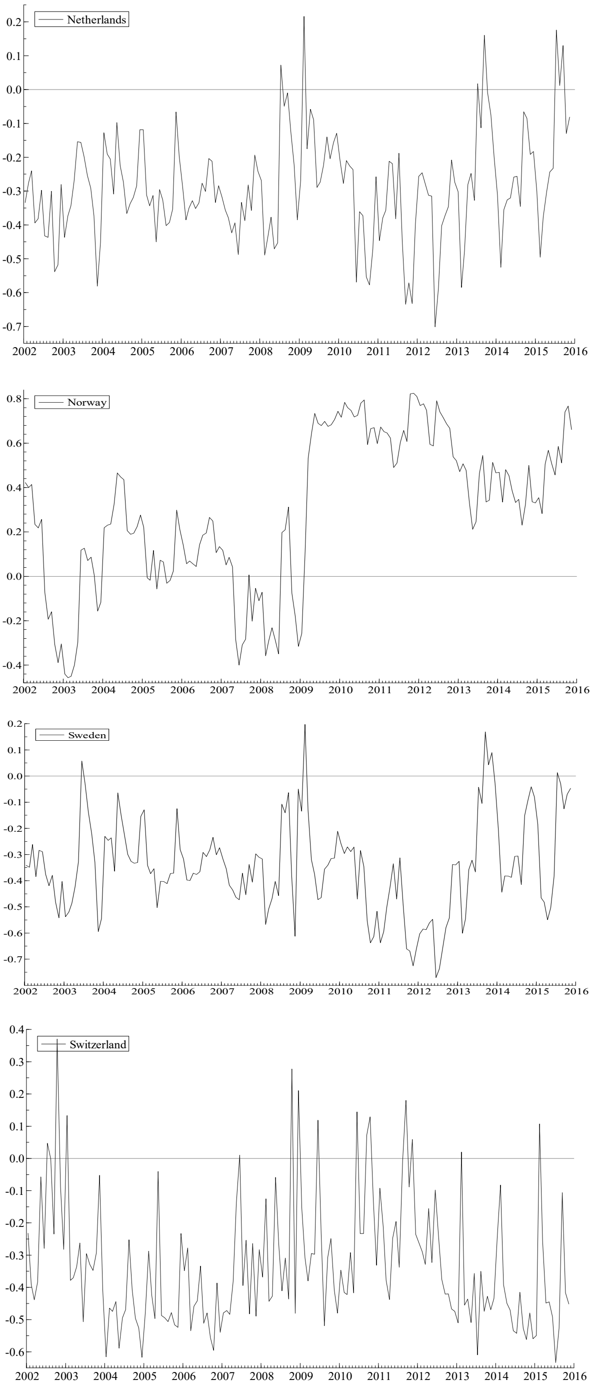
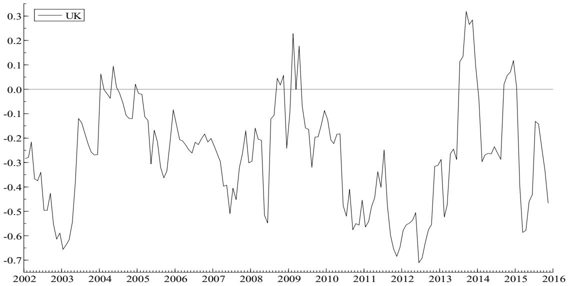
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016


Netherlands
Norway
Sweden
Switzerland



Source: Authors' calculation.

Figure 1 Time-Varying Correlation between US Stock and Advanced Countries' Bond Markets

Table 4 shows the results of the GARCH-BEKK (1, 1) estimation. We display the coefficients of the variance equation. Results indicate that all models are stationary, since the sum of squared coefficient of stocks and bonds past shocks and past volatility $(a_S^2 + B_S^2)$<1 and $(a_B^2 + B_B^2) < 1$, respectively. Also, all the sums are close to one, signifying that volatility in the US stock market and each bond market reverts slowly to the mean. The vast majority of advanced bond markets' volatility and the US stock market's volatility are statistically influenced by past volatility, past shocks and their own and spillover asymmetric shocks, making the term $h_{SB,t}$ (Equation 5) statistically significant. This indicates volatility spillover between the US stock market and advanced countries' bond markets, except for France, Italy and Switzerland.

Table 4 Estimated GARCH-BEKK Parameters for Advanced Countries' Bond Markets and US Stock Market

Countries	B_S	B_B	a_S	a_B	C_S	C_{SB}	C_B
Australia	0.819***	0.885***	0.486***	0.300***	0.012	-0.002	0.006**
Belgium	0.445***	0.829***	0.557***	0.477***	0.013***	-0.008	0.008
Canada	0.490***	0.800***	0.262***	0.510***	0.012***	-0.006**	0.012
Denmark	0.970***	0.789***	0.197***	0.507***	0.002	-0.009	0.090
Finland	0.338***	0.800***	0.407***	0.503***	0.013***	-0.006**	0.011***
France	0.355	0.822***	0.324***	0.477***	0.014***	-0.005**	0.010
Germany	0.427*	0.786***	0.324***	0.489***	0.013***	-0.007**	0.013***
Italy	0.239	0.766***	0.446***	0.549***	0.014***	-0.008**	0.012***
Japan	0.553***	0.817***	0.427**	0.519***	0.006***	-0.002**	0.011**
Netherlands	0.514**	0.814***	0.384***	0.473***	0.012***	-0.005**	0.012***
Norway	0.890***	0.853***	0.406***	0.462***	0.005***	-0.002	0.010***
Sweden	0.788***	0.794***	0.363***	0.494***	0.008***	-0.005**	0.013***
Switzerland	0.063	0.821***	0.435	0.465***	0.013***	-0.013***	0.000
UK	0.882***	0.842***	0.365***	0.456***	0.005***	-0.003	0.015

Notes: $B_S a_S$: are past shocks and past volatility coefficients of each countries' bonds respectively; B_B a_B: are US stocks' past shocks and past volatility coefficients respectively; $C_S C_B$: Representing each country bonds US stocks owns' asymmetric effect coefficients respectively. C_{SB}: The spillover asymmetric effect from US stock to each country's bond markets. $p^{***} < 1$, $p^{***} < 5$, $p^{*} < 10$.

Source: Authors' calculation.

Table 5 shows Li and McLeod's test to check the existence of serial correlation in the residual and squared residual of multivariate BEKK GARCH (1,1) models. Results indicate that we cannot reject the null of no serial correlation in residual and squared residual for all multivariate models except for Japan.

Table 5 Diagnostics on Multivariate Models' Standardized and Squared Residuals

Countries	$Lag\ (10)$	$Lag\ (20)$	$Lag\ (50)$	$Lag\ (10)^2$	$Lag\ (20)^2$	$Lag\ (50)^2$
Australia	37.110	86.3103	200.241	42.523	70.785	190.271
Belgium	46.110	79.255	204.558	46.760	94.363	211.839
Canada	47.580	96.565	206.112	32.349	63.646	149.365
Denmark	39.880	80.349	33.204	33.204	69.818	175.581
Finland	40.073	75.917	193.503	37.533	80.008	205.517
France	35.756	69.643	189.095	37.422	70.870	206.659
Germany	41.894	79.174	39.611	39.791	81.631	205.628
Italy	37.765	79.704	190.160	47.928	92.330	232.219
Japan	40.226	94.627	208.842	35.411	63.999	153.880**
Netherland	41.243	79.203	203.983	42.191	80.011	203.159
Norway	44.320	82.419	210.525	36.464	83.042	201.767
Sweden	40.056	87.053	200.668	49.262	87.131	180.950
Switzerland	40.004	67.097	180.493	43.383	60.791	133.916
UK	46.038	90.691	205.948	45.651	91.725	202.678

Notes: $p^{***} < 1$, $p^{***} < 5$, $p^{*} < 10$.

Source: Authors' calculation.

2.4 Explanatory Variables

Shadow federal funds rate $(SFFR)$, established by Jing Cynthia Wu and Fan Dora Xia (2014, 2016), is used as a proxy for the US UMP. This variable was obtained from Federal Reserve Bank of Atlanta. The advantage of using shadow rate instated of federal fund rate is that shadow rate can track federal fund rate during normal situations and/or abnormal situations where it can take negative values and, thus, account for unconventional monetary policy which resulted in expansion of the FED's balance sheet when official interest rates were at zero lower bound (Marco Jacopo Lombardi and Feng Zhu 2014). To achieve this goal, we included an interacting dummy variable $(SFFR * dummy)$ into our empirical model to account for the effect of US UMP. The dummy variable took the value of "zero" before January 2009 and "one" for 2009M1-2015M11. The first period, 2002M1-2008M12, represents the conventional monetary policy proxied by (FFR). Therefore, the total impact of FED monetary policy actions will be $(FFR + SFFR * dummy)$.

The economic policy uncertainty (EPU) index developed by Scott R. Baker, Bloom, and Steven J. Davis (2016) accounts for US economic policy uncertainty, following Li and Lu Peng (2017). The EPU was collected from the Federal Reserve Bank of St Louis. The EPU index has three components, namely media coverage of economic policy uncertainty news, federal tax code provisions to expire, and the disagreements of financial analysts on their predictions about policy-related variables. By combining all these components, the EPU index covers the comprehensive dimensions of uncertainty, reflects concerns, and captures confidence about the future state of the economy (Baker, Bloom, and Davis 2016). Hence the EPU index is a good proxy for real-world economic policy uncertainty (Wang, Chen, and Huang 2014). To capture the effect of stock and bond market uncertainty, we followed the empirical studies of Aslanidis and Christiansen (2012) and Chiang, Li, and Yang (2015) by employing the VIX and The Merrill lynch Option Volatility Estimate ($MOVE$) implied volatility indices, which are constructed by the Chicago Board Options Exchange and the Bank of America Merrill Lynch. These variables were obtained from Thomson Reuters DataStream. Moreover, following Chiang, Li, and Yang (2015) and Asgharian, Christiansen, and Hou (2016), we used the default risk spread of the US bond market ($DEFR$) as another measure for bond market risk, calculated as the difference in the yields between Moody's Baa- and Aaa-rated bonds.

We included control variables into our model to make our results robust. Differential inflation rates ($DIFINF$), which are a proxy for a pairwise monetary performance difference, were gauged by the difference between each of the advanced countries' and the US's consumer price indexes (Seema Narayan, Sivagowry Sriananthakumar, and Syed Z. Islam 2014; Lee and Cho 2017). We used differential long interest rates ($DIF10BY$) as another monetary performance difference. The $DIF10BY$ was computed as the difference between the 10-year government bond yield of each county and its US counterpart. We include the first lag of the dependent variable ($\rho_{Si,Bj,t-1}$) to mitigate the serial correlation, following Kim, Moshirian, and Wu (2006) and Andersson, Krylova, and Vähämaa (2008). We also include the exchange rate of the US dollar against each core country currency (EXR). Data on inflation rates and 10-year government bond yields were collected from Thomson Reuters DataStream, and exchange rates were collected from the Federal Reserve Bank of St. Louis. All explanatory variables were standardised, such that they had the same scale.

2.5 The Quantile Regression Specification

To investigate the spillover effect of the US UMP and uncertainties on correlations between the US stock market and advanced countries' bond markets, we applied the conditional nonlinear quantile regression developed by Koenker and Bassett (1978), in line with previous studies (Aslanidis and Christiansen 2014; Lee and Cho 2017). Quantile regression enabled us to investigate the dependence under different stock-bond market correlation levels, including scenarios of highly negative correlation (lower quantile) and highly positive correlation (upper quantile) (Aslanidis and Christiansen 2014). However, ordinary least squares (OLS) provides the same effect of explanatory variables, despite the existence of various levels of the dependent variables; hence, explanatory variables influenced the correlation in precisely the same way. As such, we can see that quantile regression provides a comprehensive view on different effects of a set of regressors across various quantiles of the conditional distribution of the regression variable (Huiming Zhu 2017). This property of quantile regression then gives robust and informative results, even for data on response variables with large extreme outliers that are non-normally distributed (Bassam Fattouh, Pasquale Scaramozzino, and Laurence Harris 2005; Aslanidis and Christiansen 2014). More specifically, outliers and non-normality may influence the mean of a distribution more than the median; hence, the application of OLS might produce biased estimates, while quantile regression reveals more robust outcomes even in the presence of outliers and non-normality (Fattouh, Scaramozzino, and Harris 2005). The quantile regression takes the following form:

$$Q_{yi}(\tau|x_i) = \alpha_i(\tau) + x_i' B(\tau) + (\varepsilon_i|x_i)\,, \tag{8}$$

where $Q_{yi}(\tau|x_i)$ is the τ^{th} conditional quantile of y_i given x_i ,$0 < \tau < 1$, α presents the intercept, β is the vector of unknown parameters to be estimated at different quantile, x_i are independent variables, and $(\varepsilon_i|x_i)$ signifies the value of the error term (ε_i) conditional on the regressors (x_i) which is assumed to be equal to zero. Estimating the coefficient B at various level of τ allows us to trace the whole distribution of y_i given x_i. Thus, the conditional quantile regression estimator for $\beta(\tau)$ is estimated as:

$$'B(\tau) = \arg\min \sum_{i=1}^{n} \rho_\tau(y_i \text{-} x_i' B(\tau) - \alpha(\tau)), \tag{9}$$

where $\rho_\tau(u) = u(\tau - I(u{<}0))$ is the check function, and $I(.)$ is an indicator function equal to $(u = y_i \text{-} x_i' B(\tau) - \alpha(\tau))$. The estimation method is robust since it divides the residuals into positives and negatives and gives weights of τ and $1\text{-}\tau$.

To examine the different impact of the US unconventional monetary policy and uncertainties on the US stock market and the sample bond market return correlations, we estimate the following model:

$$Q(\rho_{SiBj,t}|x_{i,t}) = \alpha_i B_0(\tau) + B_1(\tau) SFFR_{i,t} + B_2(\tau) MOVE_{i,t} + B_3(\tau)\mathrm{DEFR}_{i,t} + B_4(\tau) VIX_{i,t} + B_5(\tau) EUP_{i,t} + B_6(\tau) DIF10BY_{i,t} + B_7(\tau) EXR_{i,t} + B_8(\tau)\mathrm{DIFINF}_{i,j,t} + B_9(\tau) SFFR * D + B_{10}(\tau)\rho_{Si,Bj,t-1}, \tag{10}$$

where $Q(\rho_{Si,Bj}|x_{i,t})$ represents the τ^{th} quantile of the pairwise time-varying correlation among the US stock return and the sample bond market returns at month i, conditional on the vector of independent variables $x_{i,t}$. Since the time varying correlation coefficient is a limited value between (-1, +1), while the other variables do not have such limit, we use a Fisher-Z transformation as $\frac{1+\rho_{SiBj,t}}{1-\rho_{SiBj,t}}$ to make the dependent variable unrestricted to the range (-1, +1) before running the regression model, in line with other studies on monthly stock-bond returns (Andersson, Krylova, and Vähämaa 2008). α_i is the intercept and $SFFR_{i,t}$, $MOVE_{i,t}$, $\mathrm{DEFR}_{i,t}$, $VIX_{i,t}$, $EPU_{i,t}$, $DIF10BY_{i,t}$, $EXR_{i,t}$ and $\mathrm{DIFINF}_{i,j,t}$, $\rho_{Si,Bj,t-1}$ represent independent variables selected to account for co-movements between the US stock market and advanced countries' bond markets. We include a dummy interaction term $(SFFR * Dummy_{i,t})$ to account for the structural change in $SFFR$, and the break date is identified by conducting the Quandt Andres test[2]. The date that maximises the estimated likelihood ratio is highly significant on 2008M12, which indicates a break point date that takes the value of one after 2008M12, otherwise zero. We are interested in lower and higher quantiles, because, at these two quantiles, explanatory variables have different effects according to their signs; a negative sign of an explanatory variable at the lower quantiles (0.05, 0.25) implies that the greater the explanatory's variable effect is, the stronger the correlation (a negative correlation becomes closer to -1). At the upper quantiles (0.75, 0.95), a negative effect indicates that the correlation becomes weaker as the explanatory variable coefficients become larger. Similarly, at the lower quantiles, a positive effect of

[2] The result of the Quandt-Andres test is available on request.

explanatory variables implies a weaker correlation (closer to zero) as this effect increases, while the correlation gets stronger at the upper quantile.

3. Empirical Result and Discussion

We estimate the econometric model in Equation (10) at the 5th, 25th, 50th, 75th and 95th quantiles for the pairwise stock-bond correlations between the US stock market and 14 advanced countries' bond market returns. Table 6 presents the empirical results for quantile regression models. First, the effect of the US shadow rate ($SFFR * D$) indicates that US UMP has predominantly positive significant effects on stock-bond co-movements at most quantiles for the great majority of countries. In contrast, the impact of US conventional monetary policy (FFR) is negative. Also, the total effect of FED's policy actions ($FFR + SFFR * D$) is positive, indicating that the impact of US UMP is greater than the impact of US conventional monetary policy on the dynamic correlation between US stock and advanced countries' bond markets. The US UMP has stronger positive effects for both lower and upper quantiles in Finland, Sweden and the UK, which can be attributed to the implementation of arbitrageur strategies by traders in these countries to exploit the effect of UMP to make a profit (Korhan K. Gokmenoglu and Abobaker Al. Al. Hadood 2020). For the rest of the countries, it exhibits weaker positive effects for most quantiles. This empirical finding is in line with our expectations, which are built on the previous empirical studies by Dimitri Vayanos and Jean-Luc Vila (2009), Robin Greenwood and Vayanos (2010), Gagnon et al. (2011), Daniel L. Thornton (2013), John H. S. Rogers, Chiara Scotti, and Jonathan H. Wright (2014), Severin Bernhard and Till Ebner (2017) and Fratzscher, Lo Duca, and Straub (2019). However, as US UMP reduces US government bond yields and thus increases their prices. Risky investors are driven to seek stocks in the US, while risk-averse investors are driven to look for international bonds. Therefore, the US stock price and international bond prices tend to increase and, thus, move together, which implies that a US UMP contributes to an increase in co-movements between US stock markets and advanced countries' bond market. This finding is consistent with an earlier study by Valentyn Panchenko and Wu (2009), which found that stock-bond concordance within emerging markets is positively influenced by US short-term interest rates. It is worth noting that the magnitude of the estimated coefficients notably varies across quantiles in Denmark and France, with weaker effects for lower quantiles and stronger effects for higher quantiles. This provides evidence of nonlinearity, by which US UMP differently affects the co-movement between the US stock market and these countries' bond markets, depending on different quantiles of the stock-bond return correlations distribution.

Second, the two measures of bond market uncertainty, MOVE and DEFR, positively drive the stock-bond market co-movements, which means that the larger these risks are, the less negative the stock-bond market co-movements are. This finding is compatible with the findings of Chiang, Li, and Yang (2015) and Dimic et al. (2016). The positive effect of MOVE originates from the fact that a higher MOVE can cause a rise in the US bond market's risk premium, leading to a decrease in their prices. This encourages investors to shift funds into US stocks, resulting in an increase in US stocks prices if their risk premium has decreased. However, escalation in MOVE may spill over to international bond markets, raising their prices, which essentially makes make the US stock market prices and advanced countries' bond market prices move together, leading to positive co-movements between them. MOVE weakly affects stock-bond co-movements across most quantiles in most other countries, except Sweden, where the effect was comparatively stronger for all quantiles. Interestingly, like the US UMP non-linear effect, MOVE explicitly is more weakly exhibited for lower quantiles and more strongly exhibited for upper quantiles in Denmark and France, forming a nonlinear relationship between MOVE and these countries' bond-US stock market co-movements. Also, the DEFR positively impacts stock-bond co-movements across most countries, but does not show any non-linear effects. The positive effect can be attributed from one side; the intervention of the FED to stimulate the economy by lowering the interest rate makes the economic conditions quite promising, giving rise to an increase in US stock prices. From the other side, an increasing default risk spread implies deterioration in firms' financial health, which may encourage investors to seek safe international assets, leading to an increase in prices. Therefore, the default risk spread leads to a positive effect on cross-market and cross-asset market co-movements. Despite the fact that US UMP and bond market uncertainty positively drive the stock-bond correlation, international investors still can gain advantages from diversification, because they have weaker effect on stock-bond correlations at the lower quantiles by holding a portfolio consisting of US stocks and one of Italian, French, Australian, Canadian, Danish, German, Norwegian or Swedish bonds.

The VIX negatively affects stock-bond market co-movements for most countries. This evidence is consistent with previous literature by Connolly, Stivers, and Sun (2007), Aslanidis and Christiansen (2012), Chiang, Li, and Yang (2015) and Dimic et al. (2016). Thus, the VIX causes the flight-to-quality phenomenon, which implies a negative impact on the co-movement between the US stock market and advanced countries' bond markets. This, in turn, indicates a greater opportunity for diversification through allocating higher capital into bond markets such as Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy and the Netherlands.

The EPU has mixed impacts on stock-bond market co-movements across countries and quantiles. For Australia, Canada, Denmark, France, Germany and Italy, bond market co-movements with the US stock market are negatively influenced by the EPU. Our findings are consistent with the scenario where a rise in the US EPU is considered by investors to be a less promising economic environment and outlook, promoting risk-averse investors to sell US stocks and purchase safer assets from local or international bond markets, thus leading to the flight-to-quality phenomenon. Therefore, to obtain a high level of portfolio diversification, international investors should focus on the Australian, Danish, French, German and Italian bond markets and the US stock market. However, the correlation positively responds to the EPU at most quantiles in Belgium, Finland, Japan, Switzerland and Sweden. The heterogeneous spillover effects of US EPU on the dynamic correlation can be attributed to the asymmetric response of bond capital flows across countries (Trung 2019). Therefore, the US EPU has positive or negative effects on stock-bond market correlations across countries. On the one hand, if bond capital flows into some advanced countries negatively affected by the US EPU, bond prices of those developed countries tend to decrease. Also, US stock prices are likely to decline in response to the US EPU. In such situations, US stock prices and those advanced countries' bond prices move in the same direction. Thus, the US EPU would positively affect the correlation between the US stock market and developed countries' bond markets. On the other hand, if bond flows into other advanced countries positively respond to the US EPU, developed countries' bond prices are more likely to increase. In such a situation, developed countries' bond prices and the US stock prices tend to move in the opposite direction. Thus, the US EPU would negatively affect the dynamic correlation between the US stock market and advanced countries' bond markets.

The quantile regression's result show that $DIF10BY$ has negative effects on the co-movement between the US stock market and the selected countries' bond markets in most quantiles. This is due to the fact of higher interest rate differences (lower interest rate similarities), implying that the level of long interest rates in advanced countries is greater than its counterparts in the US, inducing investors to prefer to invest in these countries' bond markets rather than the US stock market, which, in turn, leads to negative stock-bond correlations. The results suggest a nonlinear effect in Belgium, France and Switzerland, where the $DIF10BY$ coefficients are weaker for lower quantiles and stronger for upper quantiles in Belgium and France; in Switzerland, $DIF10BY$ coefficients are stronger for lower quantiles and weaker for upper quantiles. The coefficient of $DIFINF$ exhibits significant negative effects for all quantiles in all countries except Belgium, France and the Netherlands, in line with Narayan, Sriananthakumar, and Islam (2014) and Lee and Cho (2017). Therefore, our results indicate that as price differences rise (lower price similarities) between the US and any country, the stock-bond market movements between the two negatively increase. Since the lower price similarities imply that the inflation level in the advanced countries is greater than in the US, this is bad news for bondholders, as this will negatively affect bond prices in the advanced countries. This, in turn, drives investors to move funds to the US stock market, thereby leading to a negative correlation between the US stock market and advanced countries' bond markets. Therefore, the non-monetary convergence allows international investors to benefit from diversification opportunities should they hold a portfolio that comprises of US stocks and one among the advanced countries' bonds. Finally, any given exchange rate (EXR) has a marginal positive effect on the co-movement between US stocks and advanced countries' bond markets for most of the countries at all quantiles, with exception of Belgium and the Netherlands, where it has a highly positive effect at all quantiles.

To conduct a robustness check of the empirical results, we ran Wald tests for the slope equality test across the quantiles, following Koenker and Bassett (1982). This tested whether the coefficients of the same variable differed across the quantiles in the quantile regression. The null hypothesis was that the variables' coefficient for each quantile was equal. In Table 7 we display the results of testing whether the coefficients of independent variables at lower quantiles (0.05) are equal to the same variables' coefficients at medium (0.50) and upper (0.95) quantiles. Moreover, we tested the jointly equal coefficients of the lower, medium and upper quintiles and the results indicated the rejection of the null hypothesis, implying that the coefficients were significantly different from each other across the quantiles. As such, we can confirm the argument that the relationships between the correlation between the US stock market and the selected countries' bond markets, the US UMP and uncertainties factors vary across the quantiles.

Table 6 Quantile Regression Results

Country	FFR	$MOVE$	$DEFR$	VIX	EPU	$DIFBY10$	EXR	$DIFINF$	$\rho_{Si,Bj,t-1}$	$SFFR*D$	$SFF*D$ $+FFR$
Australia											
0.05	-0.142***	0.140***	0.014	-0.017***	-0.064***	-0.185***	0.555***	-0.025***	0.313***	0.333***	0.191
0.25	-0.083***	0.076***	-0.009**	-0.028***	-0.014***	-0.076***	0.090***	-0.013***	0.552***	0.216***	0.133
0.5	-0.029***	0.026***	0.000	0.001	-0.015***	-0.034***	0.090***	-0.005***	0.735***	0.066***	0.037
0.75	-0.051***	0.061***	0.030***	0.000	-0.023***	-0.081***	0.174***	-0.021***	0.706***	0.095***	0.044
0.95	-0.050*	0.114***	0.025***	-0.034***	0.051***	-0.085***	-0.271***	-0.040***	0.626***	0.1823**	0.132
Belgium											
0.05	0.019	0.123***	0.003	-0.036*	0.059***	-0.131***	0.367***	0.003	0.396***	0.116*	0.097
0.25	-0.103***	0.068*	0.001	-0.042***	0.085***	-0.154***	0.445***	0.015**	0.129***	0.120	0.017
0.5	-0.062***	-0.001	0.053***	-0.001	0.021**	-0.053***	0.156***	0.005	0.331***	0.084***	0.022
0.75	-0.023***	0.019**	0.042***	0.010	0.020*	0.012	0.046	0.009**	0.334***	0.014	-0.009
0.95	-0.160***	0.076***	0.165***	-0.052***	0.026**	-0.035*	0.301***	-0.037	0.451***	0.312***	0.152
Canada											
0.05	0.013	-0.001	-0.047***	-0.033***	-0.004**	-0.083*	-0.349***	-0.015	0.734***	0.004	0.017
0.25	-0.040***	0.048***	0.000	-0.036***	0.013**	-0.014	-0.207***	-0.012**	0.326***	0.142***	0.102
0.5	-0.038***	0.025***	0.016**	-0.007*	-0.004	0.009	0.036	-0.001	0.420***	0.083***	0.045
0.75	-0.061***	0.018	0.005	0.000	-0.008*	-0.014	0.022	-0.297***	0.297***	0.130***	0.069
0.95	-0.103***	0.170***	0.094***	-0.045*	-0.046**	0.098	0.014	-0.033***	0.022	0.339***	0.236
Denmark											
0.05	-0.022***	0.004	0.003	-0.040	-0.032***	0.011***	0.237	-0.008**	0.848***	0.007	-0.015
0.25	-0.028***	0.014	-0.023**	0.004	-0.020***	-0.014***	0.296*	0.001	0.857***	0.052***	0.024
0.5	-0.024***	0.037***	0.027***	-0.002	-0.023***	-0.011***	0.005	-0.231	0.869***	0.051***	0.027
0.75	-0.120***	0.144***	0.018	0.001	-0.090***	-0.007	0.795*	0.015	0.778***	0.411***	0.291
0.95	-0.199***	0.240***	0.082**	-0.059	-0.109***	0.078	1.901**	-0.018	0.660***	0.572***	0.373
Finland											
0.05	0.209***	-0.419***	0.096	-0.116***	0.130***	0.163***	-0.105	-0.001	0.983***	-1.121***	-0.912
0.25	-0.036*	-0.035	0.037***	-0.049***	0.063***	-0.020	-0.087	-0.023**	0.522***	-0.154**	-0.19
0.5	0.050***	-0.064***	0.031***	0.030***	0.031***	0.017	-0.060***	-0.022***	0.506***	-0.309***	0.259
0.75	-0.083	0.087**	0.017	0.052***	0.002	-0.149***	-0.002	-0.038***	0.619***	0.102	0.019
France											
0.05	-0.073***	0.020	-0.007	0.030**	-0.062***	-0.096***	-0.003	0.163	0.739***	0.130***	0.057
0.25	-0.045***	0.006*	-0.008	-0.003**	-0.022***	-0.041***	0.116*	0.003	0.851***	0.067***	0.022
0.5	-0.070***	0.009	0.026***	-0.001	-0.012***	-0.058***	0.173*	0.011***	0.831***	0.102***	0.032
0.75	-0.091***	0.040	0.037***	-0.026**	-0.008	-0.130***	0.211*	-0.001	0.732***	0.241**	0.15
0.95	-0.166	0.119*	0.104	-0.027	-0.046	-0.146*	0.276	-0.021	0.606***	0.472***	0.306
Germany											
0.05	0.017	-0.068	0.033**	-0.001**	-0.002**	-0.146***	0.236*	-0.008	0.561***	0.013	-0.004
0.25	-0.049***	0.008	-0.004	-0.021	0.010	-0.054***	0.184**	0.000	0.409***	0.131***	0.082
0.5	-0.023***	0.037***	0.000	-0.012***	-0.001	-0.041***	-0.062	-0.015***	0.315***	0.056***	0.033
0.75	-0.059***	0.042***	0.018**	-0.011	-0.008**	-0.023**	0.056	-0.009***	0.284***	0.133***	0.074
0.95	-0.126***	0.079***	0.092***	0.079***	-0.104***	0.040	0.275***	-0.008	0.300***	0.215***	0.089
Italy											
0.05	0.102**	-0.002	0.106***	-0.210***	0.031	-0.040***	-0.629	-0.048***	0.350***	0.400***	0.298
0.25	0.110***	0.135***	0.066***	-0.074**	-0.003	-0.045*	0.069	-0.035**	0.334***	0.465***	0.355
0.5	0.133***	0.020	0.090***	0.010	-0.052***	0.001	0.012	-0.014	0.305***	0.169***	0.036
0.75	0.090**	0.046	0.029	0.073***	-0.069***	-0.002	0.210	-0.021	0.180	0.180***	0.09
0.95	0.107*	0.410***	0.052**	-0.014	0.006	-0.115***	0.880***	-0.056***	0.611***	0.912***	0.805
Japan											
0.05	0.209***	-0.419***	0.096	-0.116***	0.130***	0.163***	-0.105	-0.001	0.983***	-1.121***	-0.912
0.25	-0.036*	-0.035	0.037***	-0.049***	0.063***	-0.020	-0.087	-0.023**	0.522***	-0.154**	-0.19
0.5	0.050***	-0.064***	0.031***	0.030***	0.031***	0.017	-0.060***	-0.022***	0.506***	-0.309***	0.259
0.75	-0.083	0.087**	0.017	0.052***	0.002	-0.149***	-0.002	-0.038***	0.619***	0.102	0.019
0.95	-0.192***	0.053	-0.066**	0.080***	-0.138***	0.010	0.089***	0.051***	0.422***	0.793***	0.601

Netherlands											
0.05	-0.047***	0.047***	0.012*	-0.040***	0.001	-0.052***	-0.016	0.000	0.325***	0.183***	0.136
0.25	-0.061***	0.028**	-0.017**	-0.006	0.014*	-0.076***	0.164***	0.005	0.478***	0.206***	0.145
0.5	-0.047***	0.011**	0.015***	-0.015***	0.002	-0.035***	0.067***	-0.001	0.578***	0.104***	0.057
0.75	-0.032***	0.045***	-0.001	-0.016**	-0.002	0.019	0.129***	0.014***	0.466***	0.136***	0.104
0.95	-0.166***	0.142***	0.051***	0.017	-0.045***	-0.115***	0.505***	0.025***	0.155***	0.513***	0.347
Norway											
0.05	-0.071***	0.073***	0.079***	-0.161***	0.138***	-0.135***	-0.128	-0.042***	0.691***	0.094***	0.023
0.25	-0.077***	-0.042	0.010	-0.012	0.061***	-0.115***	0.060***	0.002	0.891***	0.093**	0.016
0.5	-0.024	-0.069***	0.009	0.016	0.016**	-0.029	0.009	0.001	0.911***	0.092**	0.068
0.75	-0.104***	0.057***	0.120***	-0.032	0.035*	-0.071***	0.025***	-0.011**	0.826***	0.142*	0.038
0.95	-0.241***	0.205**	0.2660***	-0.112	0.066**	-0.141*	0.047**	-0.055***	0.704***	0.513*	0.272
Sweden											
0.05	-0.152***	0.181***	-0.103*	0.046	0.039	-0.326***	-0.077***	-0.123***	0.435***	0.400***	0.284
0.25	-0.124***	0.113***	0.048***	-0.149**	0.055**	-0.141***	-0.003	-0.047***	0.693***	0.386***	0.262
0.5	-0.108***	0.153***	-0.032**	-0.046***	0.031***	-0.110***	-0.004	-0.018***	0.664***	0.401***	0.293
0.75	-0.090***	0.100***	0.025	-0.024	-0.013	-0.135***	0.002	-0.024***	0.686***	0.254***	0.155
0.95	-0.223***	0.237*	0.175**	-0.072	0.005	-0.186	-0.027	-0.106	0.628***	0.595**	0.372
Switzerland											
0.5	-0.036	0.135***	-0.030	-0.043**	0.053**	-0.164***	0.034	0.001	0.091***	0.293***	0.257
0.25	-0.063***	0.107***	0.011	0.039***	0.021***	-0.108***	0.012	0.004	0.043***	0.240***	0.177
0.5	-0.055***	0.059***	0.038***	-0.025***	0.023***	-0.048***	-0.003	-0.006***	0.017***	0.111***	0.056
0.75	-0.090	0.103***	0.021***	-0.002	0.033***	-0.068***	0.019**	0.0187	0.015	0.257***	0.167
0.95	-0.144***	-0.001	0.070**	0.070	-0.024	0.004	-0.146***	-0.016	0.058**	0.241**	0.097
UK											
0.05	-0.247***	0.161**	0.086**	-0.033**	-0.045	-0.523***	1.216*	-0.039**	0.813***	0.550***	0.303
0.25	-0.229***	0.060***	0.074***	-0.063***	-0.001	-0.288***	0.588*	-0.004	0.256***	0.436***	0.207
0.5	-0.155***	0.017	0.025	-0.007	0.011	-0.163***	0.251***	0.250	0.375***	0.251***	0.096
0.75	-0.106**	0.078	-0.009	0.020	0.007	-0.005	0.131	0.018	0.261***	0.265**	0.159
0.95	-0.162***	0.242***	0.205***	-0.125***	-0.050**	-0.247***	-0.239	-0.044***	0.083**	0.460***	0.244

Notes: $p^{***} < 1$, $p^{***} < 5$, $p^{*} < 10$.

Source: Authors' calculation.

To conduct a robustness check of the empirical results, we ran Wald tests for the slope equality test across the quantiles, following Koenker and Bassett (1982). This tested whether the coefficients of the same variable differed across the quantiles in the quantile regression. The null hypothesis was that the variables' coefficient for each quantile was equal. In Table 7 we display the results of testing whether the coefficients

Table 7 Wald Tests for Equality of Slopes

Countries	(0.05,0.5)	(0.05,0.95)	0.50,0.95)	(0.05, 0.5, 0.95)
Australia	3.872***	8.191***	4.223***	4.322***
Belgium	11.206***	2.424***	3.271***	6.905***
Canada	4.937***	6.46***	4.319***	6.283***
Denmark	4.262***	2.948***	3.111***	3.693***
Finland	5.824***	4.517***	6.946***	6.13***
France	2.665***	1.64*	3.978***	3.236***
Germany	4.163***	1.929*	2.006**	2.989***
Italy	1.871**	3.537***	6.734***	3.468***
Japan	2.714***	3.79***	5.56***	4.618***
Norway	8.264***	5.261***	33.161***	19.57***
Netherlands	1.829*	1.884**	2.396***	2.612***
Sweden	6.567***	1.468	0.899	3.682***
Switzerland	5.061***	4.034***	2.126**	3.928***
UK	1.498	3.633***	3.181***	2.687***

Notes: ***, ** and * indicate that coefficient is significant at the 1%, 5%, and 10% levels.

Source: Authors' calculation.

of independent variables at lower quantiles (0.05) are equal to the same variables' coefficients at medium (0.50) and upper (0.95) quantiles. Moreover, we tested the jointly equal coefficients of the lower, medium and upper quintiles and the results indicated the rejection of the null hypothesis, implying that the coefficients were significantly different from each other across the quantiles. As such, we can confirm the argument that the relationships between the correlation between the US stock market and the selected countries' bond markets, the US UMP and uncertainties factors vary across the quantiles.

4. Conclusion

This paper investigated the spillover effect of uncertainties regarding US UMP, the US financial market and US economic policy on the correlations between the US stock market and 14 advanced bond markets. To this end, we utilised the conditional quantile regression approach to capture the nonlinear effect of independent variables on stock-bond market co-movements. The findings deliver new evidence on the effect of FED monetary policy stance on stock-bond market correlations. Principally, the dynamic correlation between the US stock market and advanced countries' bond markets are positively and negatively affected by MP and UMP, respectively. Moreover, for some countries, the effect of MP and UMP is non-linear. Although the impact of MOVE is weak, positive, and non-linear, the impact of DEFR is mostly positive and linear. The effect of VIX is mostly negative, implying a better opportunity for diversification**.** Further, bond market uncertainty regarding MOVE and DEFR positively affects stock-bond market co-movements. In contrast, VIX has shown a negative relation with stock-bond market co-movements. The last uncertainty factor, EPU, has a mixed effect on pairwise stock-bond market co-movements across countries, with negative impacts in some countries and positive impacts in others. Finally, we found that differences in inflation rates and 10-year bond yields between the US and advanced counties decreases the pairwise stock-bond market correlations. Importantly, US UMP, MOVE and DIF10BY have nonlinear effects on stock-bond market co-movements and have limited effects in some countries, such as Belgium, Denmark, France and Switzerland. Our results have important implications for portfolio managers, monetary policy makers and academics. First of all, the co-movement of international stock and bond markets is of interest to portfolio managers. Referring to this study, portfolio managers and investors who diversify their investments internationally can reassess portfolio construction, given that the changes in the US stock market and advanced countries' bond market correlations are significantly associated with US UMP and stock, bond and economic policy uncertainties. This relevant information can enable investors to reallocate capital between US stocks and certain advanced countries' bond markets. Monetary policy makers may use the information that prices of stocks and bonds are increasingly used by monetary authority to measure, for example, market investors' growth and inflation expectations. Therefore, stock-bond return correlations may help policy makers determine whether investors are changing their views on inflation or monetary prospects. For academics, this study can provide a deeper understanding of transmission mechanisms regarding the spillover effects of US unconventional monetary policies and uncertainties on global stock-bond markets' interdependence. While our study provides evidence on the spillover impact of US UMP and uncertainties on co-movements between the US stock market and advanced countries' bond markets, future research should examine these effects in relation to emerging countries' bond markets. This will enable us to compare the importance of these effects at the levels of advanced and emerging countries.

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