Quarterly Review of Economics and Finance 95 (2024) 280–293

Contents lists available at ScienceDirect

Quarterly Review of Economics and Finance

journal homepage: www.elsevier.com/locate/qref

# Energy-related uncertainty and international stock market volatility[☆]

Afees A. Salisu[a,b,*], Ahamuefula E. Ogbonna[a], Rangan Gupta[c], Elie Bouri[d]

[a] Centre for Econometrics & Applied Research, Ibadan, Nigeria
[b] Department of Economics & Department of Economics, University of Pretoria, Private, South Africa
[c] Department of Economics, University of Pretoria, Private Bag X20, Hatfield 0028, South Africa
[d] School of Business, Lebanese American University, Lebanon

ARTICLE INFO

*JEL Classification:*
C32
C53
G15
G17
Q43

*Keywords:*
Monthly energy-related uncertainty index
Daily stock returns volatility
Developed and developing economies
GARCH-MIDAS
Predictions

ABSTRACT

This paper predicts the daily return volatility of 28 advanced and developing stock markets using monthly metrics of the corresponding country and global energy-related uncertainty indexes (EUIs) recently proposed in the literature. Using data in their "natural" frequencies to avoid aggregation bias, the results show that country-specific and global EUIs have predictive powers for stock returns volatility for the in-sample periods, with increased levels of EUIs exhibiting the tendency to heighten volatility. This predictability also withstands various out-of-sample forecast horizons, implying that EUI is a statistically relevant predictor in the out-of-sample analysis. The forecast precision of the GARCH-MIDAS model is improved by incorporating global EUIs relatively more than country-specific EUIs. The robustness of the findings with respect to the choice of EUI and sample definition is further confirmed. The outcomes have important policy implications for the concerned stakeholders who are concerned with stability in the global financial system and economy.

## 1. Introduction

The present value model of asset prices (Shiller, 1981a, 1981b) shows that asset market volatility depends on the variability of cash flows and the discount factor. Therefore, the possibility of a linkage between time-variation in asset market volatility and the evolving uncertainty associated with future discount factors and expected cash flows is rather pronounced (Bernanke, 1983). Again, while interest rates and expected cash flows are largely informed by economic conditions, it is rather plausible that any variation in uncertainty about future macroeconomic conditions would result in an equal change in the asset return volatility (Schwert, 1989). Relying on this theoretical background, the objective of this paper is to examine the predictive power of the country and global energy-related uncertainty indexes (EUIs), recently developed by Dang et al. (2023) reflecting both economic and energy-market-related uncertainties, for the return volatility of 28 developed and developing stock market indices.

This current investigation is based on two strands of empirical literature. The first relates to the predictive ability of economic uncertainty. The second concerns the well-established nexus between (sectoral and aggregate) stock and crude oil (Degiannakis et al., 2018; and Smyth & Narayan, 2018), specifically the role of oil market-related uncertainty in predicting stock returns volatility both in in-sample and out-of-sample settings. These issues involving general and crude oil market uncertainties independently have been studied in previous studies, including Liu and Zhang (2015), Feng et al. (2017), Liu et al. (2017), Dutta et al. (2020), Yu et al. (2021), Xiao et al. (2021), Gong et al. (2022), Qin and Bai (2022), Ghani and Ghani (2023), Li et al. (2023), Salisu et al. (2023) and Wang et al. (2023a). In light of this, our current paper can be considered an extension of these strands of research by bringing for the first time the information content of economic and energy market uncertainties together,[1] realizing that oil prices are not necessarily a good measure for energy prices (Kilian, 2008; Melichar, 2016; Cross & Nguyen, 2018), for forecasting the volatility of international stock indices. This link is understandable since the energy-related uncertainty has been shown by Dang et al. (2023) to hinder economic activity and output, not only at a country level but also at an industry level, thus it is likely to feed into the variability of discount factors and expected cash flows. Obviously, our exercise here will be of value to investors as accurate stock prediction give useful guidance to investors

☆ We would like to thank an anonymous referee and the Editor, Professor Eric Hughson, for many helpful comments. Any remaining errors are our own.
* Corresponding author at: Centre for Econometrics & Applied Research, Ibadan, Nigeria.
*E-mail address:* adebare1@yahoo.com (A.A. Salisu).

[1] Previous studies indicate that uncertainty can be driven by the overall uncertainty in macroeconomic fundamentals and energy shocks (see, Jurado et al., 2015).

https://doi.org/10.1016/j.qref.2024.04.005
Received 16 December 2023; Received in revised form 18 March 2024; Accepted 13 April 2024
Available online 18 April 2024

on portfolio selection and management of risk (Poon & Granger, 2003; Rapach et al., 2008). It also matters for policymakers concerned with the factors affecting stock market volatility and, thus, the stability in the global financial system and economy.

To achieve our objective empirically, we employ GARCH-MIDAS model originally developed by Engle et al. (2013).[2] Several reasons justify this choice. Firstly, the stock market data are available at very high frequency [in this case, daily], while the predictor variable [i.e. EUIs data] occurs in monthly frequency. In this case, the use of GARCH-MIDAS becomes the optimum choice. This ensures accurate completeness of information where otherwise could have happened if the data are averaged from daily data to monthly data (Clements & Galvão, 2008), with the simultaneous use of the GARCH framework for modelling and forecasting. Secondly, the GARCH model is the most common method of modelling and forecasting financial series, ever since the seminal contribution of Bollerslev (1986) (as an extension of the ARCH model of Engle, 1982).[3] It accounts for various stylized facts of stock returns, notably volatility clustering, heavy tails in the return distribution, and autocorrelation of absolute returns. Thirdly, the GARCH-MIDAS model is justified by the argument that volatility has two different variants: the one that relate to immediate-term fluctuations and the other, to a long-term aspect, with the latter likely to be affected by slow-moving predictors, i.e., the energy-related uncertainty index in our case.

At this stage, we must emphasize that the decision to predict the daily volatility of stock index returns emanates not only from the statistical need to give an accurate measure of volatility (Ghysels et al., 2019) but also the relevance of conducting high-frequency (e.g. daily) predictions, particularly out-of-sample. This is very relevant for traders and investors to make timely investment portfolio decision and for the features exhibited by daily forecast concerning value-at-risk (VaR) and expected shortfall estimates (Ghysels & Valkanov, 2012). Furthermore, being a measure of financial market uncertainty, the variability of stock returns is also a policy concern because it can impact economic activity negatively (Bloom, 2009; Ludvigson et al., 2021). Hence, high-frequency predictability of uncertainty related to the stock market would help policymakers to nowcast the future path of low-frequency (e.g. monthly) real activity variables, using MIDAS-based models (Bańbura et al., 2011), and in the process, serves the basis to prevent a recession.

Naturally, even though we consider in-sample predictions of stock returns volatility due to energy-related uncertainty, a real-time forecasting analysis specifically, besides being a well-established stronger test of predictability from an academic perspective (Campbell, 2008), should be of pertinent importance to investors and policy authorities in making their respective decisions optimally.

The main results show that both country-specific and global EUIs have the power to predict the volatility of stock index returns in the in-sample analysis, with increased levels of EUIs tending to heighten stock index volatility. Predictability is also significant for various out-of-sample forecast horizons. The forecast precision of the GARCH-MIDAS model improves when global EUIs are used compared to country-specific EUIs. Further analysis reveals in many cases that integrating global and/or country-specific energy uncertainty indexes (EUIs) enhances the accuracy of out-of-sample forecasts compared to models relying on alternative indicators of oil price uncertainty or economic policy uncertainty. This suggests that EUIs offer a broader coverage compared to the limited proxies for oil price uncertainty, as shown in the above-mentioned literature. In the same vein, our analysis also adds to the existing studies on the general economic uncertainty and forecasting of equity-returns volatility, outlined above. Naturally, our contribution, using the obtained results, is to highlight that combining information of the overall energy market in terms of uncertainty, beyond what is reflected for the crude oil market only and the economy in general, is necessary for a more accurate forecasting of international stock market volatility. Given the importance of accurate equity volatility forecasts for both investors and policymakers, as outlined above, our findings are of paramount importance and raise practical implications.

The rest of the paper is structured as follows: Section 2 provides an overview of the data, while Section 3 outlines the methodology. Section 4 presents the results, and Section 5 concludes the paper.

## 2. Data and preliminary analyses

The dataset used in this study consists of the monthly Energy Uncertainty Index (EUI) and daily MSCI stock market index (in US dollars to avoid the influence of exchange rate fluctuations) of the corresponding 28 developed and developing countries. Monthly data on EUI are sourced from Dang et al. (2023)[4] whereas daily MSCI stock data are downloaded from Refinitiv Datastream. The data cover the period of 1996:01–2022:10, although the data for Croatia, Russia and Vietnam start at 2002:05, 1996:12, and 2006:11, respectively, based on the availability of their stock prices. In other words, barring the cases of Croatia, Russia and Vietnam, the other twenty-five countries have 7000 observations each, and therefore, the EUI data is aligned with the MSCI stock index data from which the log-returns and their volatility are calculated.

Dang et al. (2023) construct monthly EUI indexes in three steps. Firstly, they construct an economic uncertainty index for each country, as in Ahir et al. (2022), by counting the number of terms such as "uncertain", "uncertainty", and "uncertainties" that occur in monthly report of the Economist Intelligence Unit (EIU) for various countries. They then find its ratio with respect to total word counts in the entire report and normalize each resulting country-level index to a mean of 100 over time. As for other step, they employ the same steps as in the previous approach to construct country-level energy-related index using similar source. Specifically, energy-related keywords in Table 1a of their paper are used, most of which align with Afkhami et al. (2017). In the final step, they derive country-level EUI values at monthly frequency as the simple mean of the economic uncertainty and energy-related indexes. Dang et al. (2023) also compute the Global EUI series as the equal-weighted and GDP-weighted means of the country-specific EUI series.

Table 1, below, illustrates the preliminary statistics for EUI and stock index returns. The standard deviation shows how dispersed the series with respect to means. While skewness gives information on the direction of the fluctuation either to positive or negative sides, the kurtosis indicates the tailedness of a distribution. The EUI ranges between 15.68 and 29.18 for Singapore and France, respectively, suggesting that, on average, energy-related uncertainty in France is the highest compared to other countries. Considering stock index returns, Greece has the lowest mean of returns (−0.01) whereas the highest mean is reported for Denmark (0.05).

The Russian market is the most unstable, with a standard deviation value of 3.14, while the US market is the most stable (with a 1.21 standard deviation value). Skewness is positive for all the countries' EUIs, whereas it is mixed for stock returns. Except for India, Japan, Singapore, South Korea and Sweden, the stock index returns of all countries are negatively skewed. The kurtosis statistic indicates that the distribution of EUI series and stock index reruns is leptokurtic, barring the EUI of Brazil. These outcomes suggest that the series are not normally distributed.

[2] A large amount of literature uses variants of the GARCH-MIDAS model to predict daily aggregate and industry-level international stock returns volatility, and the reader is referred to Salisu and Gupta (2021), Salisu et al. (2022, forthcoming a, b) and Segnon et al. (2023) for detailed reviews.

[3] See Bollerslev (2023) for an insightful discussion on the history of GARCH models.

[4] See data here: https://www.policyuncertainty.com/energy_uncertainty.html. Note interpolation is used for missing the EUI data

**Table 1 a**
Summary Statistics.

| | EUI | | | | | Stock index returns | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Country | Mean | Std. Dev. | Skew. | Kurt. | Obs. | Mean | Std. Dev. | Skew. | Kurt. | Obs. |
| Australia | 17.11 | 9.29 | 1.32 | 6.13 | 322 | 0.02 | 1.41 | -0.57 | 11.47 | 7000 |
| Belgium | 22.37 | 12.61 | 1.30 | 5.51 | 322 | 0.01 | 1.41 | -0.41 | 12.47 | 7000 |
| Brazil | 23.69 | 14.08 | 0.57 | 2.69 | 322 | 0.04 | 2.25 | -0.02 | 11.17 | 7000 |
| Canada | 21.27 | 13.23 | 1.08 | 4.25 | 322 | 0.03 | 1.34 | -0.60 | 15.02 | 7000 |
| Chile | 19.11 | 11.77 | 1.19 | 4.42 | 322 | 0.01 | 1.42 | -0.18 | 5.63 | 7000 |
| China | 18.88 | 11.44 | 0.77 | 3.29 | 322 | 0.01 | 1.84 | 0.26 | 9.59 | 7000 |
| Colombia | 24.68 | 15.17 | 1.32 | 4.87 | 322 | 0.03 | 1.69 | -0.21 | 18.72 | 7000 |
| Croatia | 23.31 | 14.60 | 1.50 | 6.40 | 322 | 0.01 | 1.29 | -0.09 | 13.18 | 5326 |
| Denmark | 18.51 | 11.38 | 1.30 | 5.46 | 322 | 0.05 | 1.35 | -0.18 | 8.97 | 7000 |
| France | 29.18 | 13.10 | 0.81 | 3.84 | 322 | 0.03 | 1.47 | -0.02 | 10.53 | 7000 |
| Germany | 25.56 | 13.14 | 0.57 | 3.06 | 322 | 0.02 | 1.53 | -0.04 | 9.16 | 7000 |
| Greece | 24.36 | 13.12 | 0.68 | 3.28 | 322 | -0.01 | 2.27 | -0.14 | 10.71 | 7000 |
| India | 19.34 | 14.65 | 1.35 | 4.52 | 322 | 0.04 | 1.61 | 0.01 | 12.43 | 7000 |
| Ireland | 26.14 | 14.55 | 1.03 | 4.65 | 322 | 0.01 | 1.65 | -0.43 | 12.02 | 7000 |
| Italy | 23.40 | 11.41 | 0.73 | 3.66 | 322 | 0.01 | 1.61 | -0.27 | 11.44 | 7000 |
| Japan | 21.29 | 11.38 | 1.22 | 5.41 | 322 | 0.01 | 1.36 | 0.16 | 8.03 | 7000 |
| Mexico | 28.79 | 14.65 | 0.89 | 3.93 | 322 | 0.04 | 1.70 | -0.04 | 12.88 | 7000 |
| Netherlands | 23.41 | 11.69 | 0.60 | 3.60 | 322 | 0.03 | 1.44 | -0.05 | 9.31 | 7000 |
| New Zealand | 20.15 | 11.49 | 1.10 | 4.51 | 322 | 0.01 | 1.36 | -0.26 | 9.35 | 7000 |
| Pakistan | 22.56 | 14.01 | 1.55 | 6.34 | 322 | 0.00 | 1.72 | -0.25 | 9.65 | 7000 |
| Russia | 22.18 | 11.94 | 1.07 | 4.92 | 322 | 0.02 | 3.14 | -5.23 | 174.27 | 6571 |
| Singapore | 15.68 | 9.85 | 1.21 | 4.62 | 322 | 0.01 | 1.34 | 0.16 | 10.34 | 7000 |
| South Korea | 24.50 | 13.33 | 1.02 | 4.09 | 322 | 0.04 | 2.17 | 0.78 | 21.94 | 7000 |
| Spain | 24.21 | 12.84 | 0.80 | 3.67 | 322 | 0.02 | 1.60 | -0.02 | 11.74 | 7000 |
| Sweden | 21.43 | 11.62 | 0.90 | 3.96 | 322 | 0.04 | 1.76 | 0.09 | 8.58 | 7000 |
| UK | 27.45 | 12.75 | 0.78 | 3.91 | 322 | 0.01 | 1.30 | -0.14 | 13.69 | 7000 |
| US | 23.18 | 13.61 | 1.08 | 4.56 | 322 | 0.03 | 1.21 | -0.22 | 12.98 | 7000 |
| Vietnam | 22.02 | 15.01 | 1.37 | 5.19 | 322 | 0.00 | 1.53 | -0.13 | 4.88 | 4152 |
| All | 22.63 | 13.24 | 1.07 | 4.56 | 9016 | 0.02 | 1.68 | -1.20 | 84.18 | 191049 |

**Note**: EUI denotes the energy uncertainty index, while Std. Dev., Skew., Kurt., and Obs. Means, standard deviation, skewness, kurtosis and observations, respectively. The stock returns series, on the other hand, is computed as $[\ln(S_{it}/S_{it-1})* 100]$, where $S_{it}$ is the i-th country's stock price at time t. The sample spans the period 1996:01 to 2022:10.

We test, in Table 1b, for the presence of heteroscedasticity and autocorrelation using an autoregressive conditional heteroscedasticity (ARCH) test and a Q-statistic with its squared form based on the Ljung-Box autocorrelation test. We find strong evidence of both conditional heteroscedasticity and autocorrelation in both variables across the sample countries. This supports our preference for the GARCH-MIDAS model to examine the predictive power of energy uncertainty for stock index returns volatility.

## 3. Methodology

We employ the mixed data sampling (MIDAS) technique to maintain and reflect the authenticity of our dataset combining monthly with daily series. Specifically, we adopt a GARCH-MIDAS approach, which has the ability to connect high-frequency data (in our case, daily stock returns) with lower-frequency data, such as monthly EUIs within a single model framework. This allows us to examine the impact of EUI on stock returns volatility directly, thus avoiding information loss that is typical of data slicing and aggregation through various techniques.

By including all variables in the model at their normal form, the present model ensures that we fully leverage the information contained in the original data, leading to more accurate estimation results. Previous research in the field empirically demonstrates the superiority of the MIDAS framework over other competing models that require variables to be synchronized to a uniform frequency (as discussed in detail in Salisu and Gupta, 2021, Salisu et al., 2022a; b, 2023; forthcoming a, b), Wang et al., (2022, 2023b), and Segnon et al. (2024)).

The GARCH-MIDAS model specification for the stock returns on $i^{\{th\}}$ day in the $t^{\{th\}}$ month is given as:

$$r_{i,t} = \nu + \sqrt{\mu_t \times \tau_{i,t}} \times \varepsilon_{i,t}, \forall i = 1, 2, \ldots, N_t \quad (1)$$

$$\varepsilon_{i,t} | \varsigma_{i-1,t} N(0, 1) \quad (2)$$

Eq. (1) specifies daily stock returns $(r_{i,t})$ as a function of an unconditional mean $(\nu)$ of stock returns, a conditional variance $(\sqrt{\mu_t \times \tau_{i,t}})$ and the error term, $\varepsilon_{i,t}$. The subscript $(i, t)$ distinguishes between daily and monthly frequencies, in order, with $N_t$ indicating the number of days in month $t$. The conditional variance, $\sqrt{\mu_t \times \tau_{i,t}}$, comprises two components, a short-term variable denoted by $(\tau_{i,t})$ and a long-term equivalence denoted by $(\mu_t)$. The error term, $\varepsilon_{i,t}$, in Eq. (2), follows a Gaussian distribution and $\varsigma_{i-1,t}$ is the information set available up to the $(i-1)^{th}$ day of month $t$.

The short-run component $\tau_{i,t}$ of the conditional variance is defined as:

$$\tau_{i,t} = \left(1 - \lambda - \gamma\right) + \lambda \frac{(r_{i-1,t} - \nu)^2}{\mu_t} + \gamma \tau_{i-1,t} \quad (3)$$

where $\lambda$ and $\gamma$ denote the ARCH and GARCH terms, respectively, that are constrained to be non-negative, with values that sum up to less than unity. Additionally, the monthly energy uncertainty index is transformed into a daily frequency, a process that is done without any loss of generality (for detailed technical explanations, refer to Engle et al., 2013). As part of this transformation, the days in a month $t$ are adjusted without explicit tracking. Eqs. (4) and (5) subsequently define the daily long-term component $(\mu_i)$ for realized volatility and the exogenous factor, respectively:

$$\mu_i = m + \varphi \sum_{k=1}^{K} \theta_k(\omega_1, \omega_2) RV_{i-k} \quad (4)$$

$$\mu_i = m + \varphi \sum_{k=1}^{K} \theta_k(\omega_1, \omega_2) X_{i-k} \quad (5)$$

where $m$ represents the long-run intercept and $\varphi$ denotes the coefficient associated with the predictor, which can be either the realized

**Table 1b**
Conditional Heteroscedasticity and Autocorrelation Tests.

| | EUI | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Country | ARCH (2) | ARCH (4) | ARCH (6) | Q(2) | Q(4) | Q(6) | $Q^2(2)$ | $Q^2(4)$ | $Q^2(6)$ |
| Australia | 19.2$^{a}$ | 9.6$^{a}$ | 6.36$^{a}$ | 6.35$^{b}$ | 10.7$^{b}$ | 16.8$^{b}$ | 31.1$^{a}$ | 31.1$^{a}$ | 31.2$^{a}$ |
| Belgium | 3.83$^{b}$ | 2.58$^{b}$ | 2.55$^{b}$ | 6.47$^{b}$ | 28.5$^{a}$ | 32.39$^{a}$ | 7.9$^{b}$ | 11.3$^{b}$ | 15.5$^{b}$ |
| Brazil | 4.46$^{b}$ | 6.81$^{a}$ | 4.85$^{a}$ | 10.9$^{a}$ | 31.8$^{a}$ | 40.4$^{a}$ | 0.09$^{a}$ | -0.02$^{a}$ | 0.01$^{a}$ |
| Canada | 7.12$^{a}$ | 4.25$^{a}$ | 2.84$^{b}$ | 6.37$^{b}$ | 24.5$^{a}$ | 28.60$^{a}$ | 16.4$^{a}$ | 21.95$^{a}$ | 22.2$^{a}$ |
| Chile | 2.32 | 1.22 | 2.41$^{b}$ | 7.99$^{b}$ | 12.4$^{b}$ | 21.96$^{a}$ | 4.72$^{c}$ | 4.98 | 16.5$^{b}$ |
| China | 25.50$^{a}$ | 13.19$^{a}$ | 8.74$^{a}$ | 16.1$^{a}$ | 25.8$^{a}$ | 35.62$^{a}$ | 38.7$^{a}$ | 38.84$^{a}$ | 39.1$^{a}$ |
| Colombia | 14.92$^{a}$ | 10.35$^{a}$ | 8.91$^{a}$ | 8.51$^{b}$ | 15.6$^{a}$ | 16.00$^{b}$ | 27.6$^{a}$ | 44.31$^{a}$ | 64.6$^{a}$ |
| Croatia | 30.86$^{a}$ | 15.33$^{a}$ | 10.47$^{a}$ | 16.0$^{a}$ | 19.4$^{a}$ | 28.49$^{a}$ | 66.0$^{a}$ | 73.60$^{a}$ | 82.6$^{a}$ |
| Denmark | 4.12$^{b}$ | 4.27$^{a}$ | 2.93$^{a}$ | 8.45$^{b}$ | 22.6$^{a}$ | 28.0$^{a}$ | 9.05$^{b}$ | 19.78$^{a}$ | 20.7$^{a}$ |
| France | 3.22$^{b}$ | 1.59 | 1.11 | 13.3$^{a}$ | 16.9$^{a}$ | 17.95$^{a}$ | 7.18$^{b}$ | 7.47 | 7.86 |
| Germany | 2.43$^{c}$ | 1.26 | 1.60 | 8.56$^{b}$ | 9.25$^{c}$ | 12.1$^{c}$ | 5.04$^{c}$ | 5.39 | 10.22 |
| Greece | 12.15$^{a}$ | 7.66$^{a}$ | 5.52$^{a}$ | 29.5$^{a}$ | 35.3$^{a}$ | 38.47$^{a}$ | 28.1$^{a}$ | 30.33$^{a}$ | 35.4$^{a}$ |
| India | 5.52$^{a}$ | 3.57$^{a}$ | 2.42$^{b}$ | 15.3$^{a}$ | 18.6$^{a}$ | 18.98$^{a}$ | 5.01$^{c}$ | 5.06 | 5.70 |
| Ireland | 18.92$^{a}$ | 10.22$^{a}$ | 7.08$^{a}$ | 39.8$^{a}$ | 47.8$^{a}$ | 51.7$^{a}$ | 38.9$^{a}$ | 46.7$^{a}$ | 47.4$^{a}$ |
| Italy | 4.24$^{b}$ | 4.72$^{a}$ | 3.58$^{a}$ | 9.87$^{a}$ | 19.9$^{a}$ | 20.61$^{a}$ | 9.14$^{b}$ | 22.89$^{a}$ | 28.1$^{a}$ |
| Japan | 2.00 | 7.16$^{a}$ | 4.94$^{a}$ | 1.12 | 21.9$^{a}$ | 27.6$^{a}$ | 4.43 | 31.63$^{a}$ | 38.5$^{a}$ |
| Mexico | 57.24$^{a}$ | 30.65$^{a}$ | 21.90$^{a}$ | 19.9$^{a}$ | 47.4$^{a}$ | 56.19$^{a}$ | 121$^{a}$ | 159.6$^{a}$ | 177$^{a}$ |
| Netherlands | 5.17$^{a}$ | 4.58$^{a}$ | 3.09$^{a}$ | 14.4$^{a}$ | 15.9$^{a}$ | 29.03$^{a}$ | 10.8$^{a}$ | 21.08$^{a}$ | 22.1$^{a}$ |
| New Zealand | 9.60$^{a}$ | 5.21$^{a}$ | 3.93$^{a}$ | 7.27$^{b}$ | 10.7$^{b}$ | 15.96$^{b}$ | 21.4$^{a}$ | 22.48$^{a}$ | 28$^{a}$ |
| Pakistan | 30.54$^{a}$ | 15.10$^{a}$ | 9.92$^{a}$ | 12.4$^{a}$ | 14.3$^{a}$ | 19.52$^{a}$ | 47.5$^{a}$ | 48.21$^{a}$ | 48.4$^{a}$ |
| Russia | 2.47$^{c}$ | 4.62$^{a}$ | 4.55$^{a}$ | 3.367 | 14.5$^{a}$ | 39.01$^{a}$ | 5.4$^{c}$ | 20.65$^{a}$ | 35.0$^{a}$ |
| Singapore | 0.43 | 0.40 | 1.15 | 2.07 | 9.06$^{c}$ | 18.88$^{a}$ | 1.16 | 2.02 | 6.99 |
| South Korea | 9.13$^{a}$ | 6.36$^{a}$ | 6.86$^{a}$ | 6.03$^{b}$ | 14.5$^{a}$ | 18.4$^{a}$ | 19.3$^{a}$ | 32.4$^{a}$ | 62.4$^{a}$ |
| Spain | 13.62$^{a}$ | 6.67$^{a}$ | 4.83$^{a}$ | 27.2$^{a}$ | 32.5$^{a}$ | 33.8$^{a}$ | 31.8$^{a}$ | 35.7$^{a}$ | 36.6$^{a}$ |
| Sweden | 27.46$^{a}$ | 22.83$^{a}$ | 15.0$^{a}$ | 24.4$^{a}$ | 31.9$^{a}$ | 38.6$^{a}$ | 56.3$^{a}$ | 114.7$^{a}$ | 126$^{a}$ |
| UK | 6.80$^{a}$ | 3.67$^{a}$ | 2.84$^{b}$ | 19.7$^{a}$ | 27.4$^{a}$ | 27.9$^{a}$ | 15.6$^{a}$ | 19.5$^{a}$ | 24.7$^{a}$ |
| US | 3.29$^{b}$ | 1.68 | 2.29$^{b}$ | 2.65 | 7.14 | 10.89$^{c}$ | 7.07$^{b}$ | 7.48 | 16$^{b}$ |
| Vietnam | 8.89$^{a}$ | 4.58$^{a}$ | 3.05$^{a}$ | 11.0$^{a}$ | 15.3$^{a}$ | 23.57$^{a}$ | 19.8$^{a}$ | 20.28$^{a}$ | 20.7$^{a}$ |

| | Stock Returns | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Country | ARCH (2) | ARCH (4) | ARCH (6) | Q(2) | Q(4) | Q(6) | $Q^2(2)$ | $Q^2(4)$ | $Q^2(6)$ |
| Australia | 1010$^{a}$ | 727.8$^{a}$ | 489.1$^{a}$ | 2.56 | 7.31 | 10.86$^{c}$ | 1826$^{a}$ | 371$^{a}$ | 4870$^{a}$ |
| Belgium | 244.6$^{a}$ | 151.3$^{a}$ | 163.6$^{a}$ | 0.25 | 5.45 | 11.13$^{c}$ | 527.7$^{a}$ | 836.3$^{a}$ | 1479$^{a}$ |
| Brazil | 797.5$^{a}$ | 433.8$^{a}$ | 331.2$^{a}$ | 1.48 | 2.95 | 16.62$^{b}$ | 1619$^{a}$ | 2497$^{a}$ | 3382$^{a}$ |
| Canada | 601.2$^{a}$ | 446.6$^{a}$ | 357.3$^{a}$ | 6.89$^{b}$ | 19.5$^{a}$ | 57.63$^{a}$ | 1358$^{a}$ | 27645$^{a}$ | 4196$^{a}$ |
| Chile | 535.6$^{a}$ | 306.5$^{a}$ | 254.5$^{a}$ | 1.54 | 21.5$^{a}$ | 29.9$^{a}$ | 1090$^{a}$ | 1605$^{a}$ | 2213$^{a}$ |
| China | 462.5$^{a}$ | 277.4$^{a}$ | 197.5$^{a}$ | 1.36 | 4.11 | 26.97$^{a}$ | 1037$^{a}$ | 1633.8$^{a}$ | 2056$^{a}$ |
| Colombia | 631.2$^{a}$ | 361.4$^{a}$ | 336.3$^{a}$ | 11.8$^{a}$ | 16.7$^{a}$ | 23.34$^{a}$ | 1289$^{a}$ | 1913.6$^{a}$ | 2927$^{a}$ |
| Croatia | 310.2$^{a}$ | 171.5$^{a}$ | 120.4$^{a}$ | 6.34$^{b}$ | 18.1$^{a}$ | 22.91$^{a}$ | 706.7$^{a}$ | 985.86$^{a}$ | 1166 |
| Denmark | 336.3$^{a}$ | 259.3$^{a}$ | 266.4$^{a}$ | 5.5$^{c}$ | 17.3$^{a}$ | 34.56$^{a}$ | 726.5$^{a}$ | 1470.8$^{a}$ | 2560$^{a}$ |
| France | 216.0$^{a}$ | 227.5$^{a}$ | 179.2$^{a}$ | 2.39 | 17.6$^{a}$ | 38.69$^{a}$ | 462.2$^{a}$ | 1202.7$^{a}$ | 1762$^{a}$ |
| Germany | 187.1$^{a}$ | 209.7$^{a}$ | 158.2$^{a}$ | 0.85 | 5.01 | 16.61$^{b}$ | 393.7$^{a}$ | 1067.1$^{a}$ | 1488$^{a}$ |
| Greece | 178.5$^{a}$ | 119.1$^{a}$ | 93.5$^{a}$ | 0.46 | 9.0$^{c}$ | 13.44$^{b}$ | 396$^{a}$ | 660.6$^{a}$ | 902.8$^{a}$ |
| India | 182.4$^{a}$ | 119.9$^{a}$ | 106.2$^{a}$ | 0.12 | 4.51 | 30.56$^{a}$ | 409.4$^{a}$ | 663.3$^{a}$ | 1031$^{a}$ |
| Ireland | 281.2$^{a}$ | 221.5$^{a}$ | 252.2$^{a}$ | 3.05 | 12.9$^{b}$ | 36.86$^{a}$ | 622.7$^{a}$ | 1207.3$^{a}$ | 2378$^{a}$ |
| Italy | 129.8$^{a}$ | 145.7$^{a}$ | 105.8$^{a}$ | 0.004 | 8.96$^{c}$ | 22.70$^{a}$ | 287$^{a}$ | 762.2$^{a}$ | 992.0$^{a}$ |
| Japan | 314.6$^{a}$ | 210.6$^{a}$ | 146.9$^{a}$ | 10.7$^{a}$ | 12.7$^{b}$ | 21.06$^{a}$ | 660.6$^{a}$ | 1164.4$^{a}$ | 1448$^{a}$ |
| Mexico | 375.9$^{a}$ | 230.6$^{a}$ | 171.4$^{a}$ | 5.58$^{c}$ | 9.80$^{b}$ | 19.23$^{a}$ | 842.2$^{a}$ | 1263.6$^{a}$ | 1591$^{a}$ |
| Netherlands | 261.6$^{a}$ | 261.0$^{a}$ | 239.9$^{a}$ | 2.37 | 26.8$^{a}$ | 46.74$^{a}$ | 570.2$^{a}$ | 1430.9$^{a}$ | 2342$^{a}$ |
| New Zealand | 375.3$^{a}$ | 216.4$^{a}$ | 150.7$^{a}$ | 2.19 | 2.83 | 12.13$^{c}$ | 840.8$^{a}$ | 1240.9$^{a}$ | 1436$^{a}$ |
| Pakistan | 323.9$^{a}$ | 194.6$^{a}$ | 136.0$^{a}$ | 4.83$^{c}$ | 14.1$^{a}$ | 18.4$^{a}$ | 721$^{a}$ | 1122.7$^{a}$ | 1371$^{a}$ |
| Russia | 410.7$^{a}$ | 205.8$^{a}$ | 148.3$^{a}$ | 1.86 | 3.35 | 6.35 | 926.5$^{a}$ | 1030.3$^{a}$ | 1171$^{a}$ |
| Singapore | 562.4$^{a}$ | 342.9$^{a}$ | 235.2$^{a}$ | 4.49 | 5.3 | 12.05$^{c}$ | 1237$^{a}$ | 2103.2$^{a}$ | 2631$^{a}$ |
| South Korea | 285.7$^{a}$ | 253.8$^{a}$ | 247.2$^{a}$ | 0.52 | 38.9$^{a}$ | 60.89$^{a}$ | 612.0$^{a}$ | 1390.6$^{a}$ | 2413$^{a}$ |
| Spain | 142.2$^{a}$ | 161.9$^{a}$ | 120.2$^{a}$ | 1.13 | 11.8$^{b}$ | 18.43$^{a}$ | 311.8$^{a}$ | 854.08$^{a}$ | 1142$^{a}$ |
| Sweden | 209.3$^{a}$ | 189.5$^{a}$ | 163.2$^{a}$ | 10.8$^{a}$ | 13.7$^{a}$ | 30.56$^{a}$ | 462.5$^{a}$ | 1055.9$^{a}$ | 1646$^{a}$ |
| UK | 269.1$^{a}$ | 256.6$^{a}$ | 215.9$^{a}$ | 6.32$^{b}$ | 31.2$^{a}$ | 59.73$^{a}$ | 593.8$^{a}$ | 1439.1$^{a}$ | 2198$^{a}$ |
| US | 893.8$^{a}$ | 476.5$^{a}$ | 396.7$^{a}$ | 0.23 | 3.01 | 16.85$^{b}$ | 1743$^{a}$ | 2652.8$^{a}$ | 3953$^{a}$ |
| Vietnam | 363.9$^{a}$ | 213.8$^{a}$ | 149.3$^{a}$ | 0.05 | 14.7$^{a}$ | 18.56$^{a}$ | 814.8$^{a}$ | 1328.5$^{a}$ | 1704$^{a}$ |

Note: we report F-statistics for the ARCH test and Ljung–Box Q-statistics for the autocorrelation test. Significance level is at 1%, 5%, and 10% levels, denoted respectively as a, b, and c.

volatility of stock returns or an exogenous factor (energy uncertainty index). We explore four variants of the long-term component in the GARCH-MIDAS model, with the distinguishing factor among the contending models being our choice of predictor(s). These variants take care the following predictors: (i) realized volatility (RV), which defines the conventional GARCH-MIDAS model and serves as a benchmark in this study; (ii) RV and country-specific EUI; (iii) RV and global EUI (equally weighted); and (iv) RV and global EUI (GDP weighted).

In Eqs. (4) and (5), the beta polynomial weights $\theta_k(w_1, w_2) \geq 0, \quad k = 1, \ldots, K$ are subject to the constraint that the weights must add up to one. We use a single-parameter beta polynomial to offer greater flexibility in the beta weighting scheme (Colacito et al., 2011). This weighting scheme allows us to transform a two-parameter beta weighting function $\left[\theta_k(w_1, w_2) = \frac{[k/(K+1)]^{w_1-1} \times [1-k/(K+1)]^{w_2-1}}{\sum_{j=1}^{K} [j/(K+1)]^{w_1-1} \times [1-j/(K+1)]^{w_2-1}}\right]$ into a one-parameter beta weighting function $\left[\theta_k(w) = \frac{[1-k/(K+1)]^{w-1}}{\sum_{j=1}^{K} [1-j/(K+1)]^{w-1}}\right]$ by setting $w_1$ to one and defining $w = w_2$, which ensures that the weighting function exhibits a monotonically decreasing pattern, as suggested by Engle et al. (2013). Here, the weights $(\theta_k)$ are constrained to be positive and add up to one $(\sum_{k=1}^{K} \theta_k = 1)$. Additionally, the parameter $(w)$ is constrained to be greater than one $(w > 1)$, ensuring that larger weights are assigned to more recent lag observations compared to distant observation lags. Consequently, we assess the statistical significance of the slope parameter, $\varphi$, to determine the in-sample predictability of the incorporated predictors; given that a significant estimate suggests predictability of the related predictor for stock returns volatility.

We are interested in evaluating the forecast performances of four competing GARCH-MIDAS model variants using an out-of-sample approach. To do this, we employ the modified version of the Diebold and Mariano (1995) test which accounts for contemporaneously correlated forecast errors, autocorrelated forecast errors and heavy-tailed error distributions. The modified DM test statistic is derived as:

$$DM^* = \left(\sqrt{\frac{T + 1 - 2h + T^{-1}h(h-1)}{T}}\right) DM \tag{6}$$

where $T$ is the length of the out-of-sample periods of the forecast errors; $h$ is the forecast horizon; $DM = \overline{d}/\sqrt{V(d)/T} \sim N(0,1)$ defines the conventional DM test, where $\overline{d} = 1/T\sum_{t=1}^{T} d_t$ is the mean loss differential $d_t \equiv g(\varepsilon_{it}) - g(\varepsilon_{jt})$ obtained as the difference between loss functions $g(\varepsilon_{it})$ and $g(\varepsilon_{jt})$ of the forecast errors $(\varepsilon_{it})$ and $(\varepsilon_{jt})$, respectively, from the contending models; and $V(d_t)$ is the unconditional variance of the loss differential $d_t$. We therefore test the null hypothesis that asserts equality in the forecast precisions of the contending paired models $(H_0 : d = 0)$, against an alternative hypothesis $(H_0 : d \neq 0)$. When we reject the null hypothesis, it means that the forecast precisions of the two models being compared are statistically different. The DM* statistic tells us which model is preferred. If the DM* statistic is negative, then our predictive GARCH-MIDAS-EUI model is preferred over the conventional GARCH-MIDAS-RV model. On the other hand, if the DM* statistic is positive, the opposite is true.

As a form of robustness on the stance of model outperformance, we also consider an alternative forecast evaluation tool, namely the out-of-sample $R^2$ statistic by Campbell and Thompson CT) (2008). The statistic is defined by $CT = 1 - \left[\sum_{t=1}^{T} \left(r_t - \widehat{r}_t^{(prd)}\right)^2 / \sum_{t=1}^{T} \left(r_t - \widehat{r}_t^{(bm)}\right)^2\right]$, where $\widehat{r}_t^{(prd)}$ and $\widehat{r}_t^{(bm)}$ indicate the forecasts from a contending exogeneous variable-based GARCH-MIDAS model and a specified benchmark model, respectively. A positive CT reflects a higher forecast precision of the exogeneous variable-based GARCH-MIDAS model than the benchmark model; and vice versa if the CT value is negative. We conduct our out-of-sample forecast evaluation using 75% of the full sample data. The forecasts are made for three different horizons: 20-, 60-, and 120-days ahead.

## 4. Empirical results and discussion

### 4.1. Main results

Our study presents the main results regarding the in-sample predictability of Energy Uncertainty Index (EUI) for stock returns' volatility and the out-of-sample forecast evaluation of paired GARCH-MIDAS models. We have considered three benchmarks in this study. Firstly, we have used the conventional GARCH-MIDAS-RV model as a benchmark to compare it with the GARCH-MIDAS models that incorporate EUI, either country-specific or global (equally or GDP-weighted). Secondly, we have taken the country-specific-EUI model as a benchmark for comparing it with the GARCH-MIDAS-[global-EUI] model. Thirdly, the GARCH-MIDAS-[global-EUI (GDP-weighted)] is considered the benchmark for the comparison between the GARCH-MIDAS-[global-EUI (equally-weighted)] model and the GARCH-MIDAS-[global-EUI (GDP-weighted)] model.

For the predictability, we only present the GARCH-MIDAS slope coefficient $(\varphi)$, for each country considered, as an indicator of in-sample predictability. In addition, we ascertain that the predictability extends beyond the in-sample period. We thus assess the out-of-sample forecast performance of the GARCH-MIDAS variants' prediction of stock returns volatility using the modified Diebold and Mariano (Harvey et al., 1997) test, as presented in Table 3. We do this at three forecast levels: 20-, 60- and 120-day ahead, in a way to test whether incorporating the energy uncertainty index as exogenous variable provides information content to improve the forecast accuracy of stock returns volatility model in this case.

Table 2 shows the in-sample predictability outcomes for the stock returns volatility over the considered sample periods for twenty-eight countries. It contains the MIDAS slope coefficient $(\varphi)$ associated with the realized volatility and the incorporated exogenous factors, which indicates the position of predictability of stock returns volatility due to RV (column 2), country-specific EUI (column 3), global EUI equally-weighted (column 4) and global EUI GDP-weighted (column 5). We find that the stock returns volatility responds positively to its own uncertainty, which is indicative of the tendency for own market uncertainty to heighten volatility in the stock market.

While the significant level of the MIDAS slope coefficient $(\varphi)$reflects whether or not the EUI has predictive potential for stock returns volatility, the associated sign for the slope coefficient indicates the direction of the impact of the former on the latter. There is a large proportion of evidence of significantly positive estimates of $\varphi$ across the EUI variants (country-specific EUI (in 100% of the significant cases), global EUI equally weighted (in approximately 86.4% of the significant cases), and global EUI GDP-weighted (in approximately 90.5% of the significant cases)) incorporated into the GARCH-MIDAS model. This finding generally aligns with our theoretical expectations discussed in the introduction, indicating that uncertainty about the future macroeconomic fundamentals, including energy-related uncertainties, can drive the volatility of stock index returns. In this regard, it is well-known that uncertainty can be driven by the overall uncertainty in macroeconomic conditions and energy shocks (Jurado et al., 2015). However, we also observe cases of significantly negative slope coefficients (in the cases of China under the global EUI equally weighted, and in both variants of the global EUIs for Greece and the UK), which could be a result of less trading in the risky asset (stock) following heightened uncertainty. But in general, the energy uncertainty index has in-sample-based predictive potential for the volatility of stock index returns in most cases.

Having established the predictability of EUI for stock returns volatility, we subject the contending GARCH-MIDAS models to forecast evaluation using the modified Diebold and Mariano test. We test whether the GARCH-MIDAS variants incorporating each of the EUIs outperform the RV version (see result in Table 3). Significantly negative

**Table 2**
In-Sample Predictability Results.

| | Realized Volatility | Country-Specific EUI | Global EUI (Equally Weighted) | Global EUI (GDP Weighted) |
|---|---|---|---|---|
| Australia | 0.0288 * ** | 0.1274 * ** | 0.1556 * ** | 0.1375 * ** |
| | [0.0028] | [0.0424] | [0.0447] | [0.0479] |
| Belgium | 0.0290 * ** | 0.1534 * ** | 0.2000 * ** | 0.2046 * ** |
| | [0.0026] | [0.0413] | [0.0401] | [0.0397] |
| Brazil | 0.0220 * ** | 0.0422 * ** | 0.0551 * ** | 0.0555 * ** |
| | [0.0026] | [0.0153] | [0.0146] | [0.0146] |
| Canada | 0.0404 * ** | -0.0432 | -0.0666 | -0.0625 |
| | [0.0021] | [0.0662] | [0.0662] | [0.0530] |
| Chile | 0.0229 * ** | 0.2206 * ** | 0.2184 * ** | -0.0446 |
| | [0.0033] | [0.0462] | [0.0455] | [0.0555] |
| China | 0.0315 * ** | -0.0392 | -0.0255 * * | -0.0351 |
| | [0.0026] | [0.0343] | [0.0127] | [0.0444] |
| Colombia | 0.0266 * ** | 0.2382 * ** | 0.2525 * ** | 0.2448 * ** |
| | [0.0026] | [0.0245] | [0.0241] | [0.0254] |
| Croatia | 0.0262 * ** | 0.4205 * ** | 0.4191 * ** | 0.3856 * ** |
| | [0.0016] | [0.0325] | [0.0332] | [0.0320] |
| Denmark | 0.0265 * ** | 0.1775 * ** | 0.2074 * ** | 0.2064 * ** |
| | [0.0029] | [0.0409] | [0.0397] | [0.0393] |
| France | 0.0303 * ** | 0.1841 * ** | 0.2585 * ** | 0.2735 * ** |
| | [0.0032] | [0.0442] | [0.0371] | [0.0369] |
| Germany | 0.0241 * ** | -0.0262 | 0.1449 * ** | 0.1589 * ** |
| | [0.0038] | [0.0415] | [0.0494] | [0.0468] |
| Greece | 0.0407 * ** | 0.1386 * ** | -0.0932 * ** | -0.0839 * ** |
| | [0.0022] | [0.0084] | [0.0337] | [0.0323] |
| India | 0.0270 * ** | 0.1542 * ** | 0.1736 * ** | 0.1576 * ** |
| | [0.0029] | [0.0324] | [0.0325] | [0.0312] |
| Ireland | 0.0287 * ** | 0.1785 * ** | 0.1912 * ** | 0.1952 * ** |
| | [0.0029] | [0.0184] | [0.0176] | [0.0193] |
| Italy | 0.0327 * ** | 0.2764 * ** | -0.0400 | 0.3009 * ** |
| | [0.0031] | [0.0356] | [0.0370] | [0.0329] |
| Japan | 0.0285 * ** | 0.1640 * * | 0.2774 * ** | 0.3187 * ** |
| | [0.0031] | [0.0720] | [0.0815] | [0.0696] |
| Mexico | 0.0297 * ** | 0.0322 | 0.1173 * ** | 0.1279 * ** |
| | [0.0023] | [0.0428] | [0.0353] | [0.0301] |
| Netherlands | 0.0319 * ** | 0.1569 * ** | -0.028 * * | 0.2347 * ** |
| | [0.0031] | [0.0530] | [0.0133] | [0.0449] |
| New Zealand | 0.0319 * ** | 0.1070 | 0.1269 | -0.0123 |
| | [0.0026] | [0.0731] | [0.0841] | [0.0138] |
| Pakistan | 0.0275 * ** | 0.2565 * ** | 0.3043 * ** | 0.2674 * ** |
| | [0.0030] | [0.0357] | [0.0361] | [0.0332] |
| Russia | 0.0299 * ** | 0.0786 * ** | 0.0797 * ** | 0.0822 * ** |
| | [0.0031] | [0.0090] | [0.0089] | [0.0087] |
| Singapore | 0.0323 * ** | 0.1018 | -0.0379 | -0.0675 |
| | [0.0030] | [0.0767] | [0.0328] | [0.0423] |
| Korea | 0.0235 * ** | -0.0500 | -0.0663 | -0.0393 |
| | [0.0026] | [0.0628] | [0.0502] | [0.0322] |
| Spain | 0.0296 * ** | 0.1971 * ** | 0.2184 * ** | 0.233 * ** |
| | [0.0029] | [0.0302] | [0.0296] | [0.0282] |
| Sweden | 0.0342 * ** | -0.0235 | -0.028 | -0.0243 |
| | [0.0026] | [0.0551] | [0.0293] | [0.0166] |
| UK | 0.0301 * ** | 0.1983 * ** | -0.0322 * * | -0.0333 * ** |
| | [0.0026] | [0.0444] | [0.0138] | [0.0128] |
| USA | 0.0263 * ** | 0.1452 * ** | 0.1731 * ** | 0.2121 * ** |
| | [0.0025] | [0.0444] | [0.0446] | [0.0436] |
| Vietnam | 0.0178 * ** | 0.3479 * ** | 0.379 * ** | 0.2841 * ** |
| | [0.0043] | [0.0839] | [0.0875] | [0.0608] |
| ***No. of sig. cases*** | ***28*** | ***20*** | ***22*** | ***21*** |
| ***No. of sig. +ve*** | ***28*** | ***20*** | ***19*** | ***19*** |
| ***% of sig. +ve*** | ***100%*** | ***100%*** | ***86.4%*** | ***90.5%*** |

**Note:** the figure in square brackets are the standard error of the estimate and the significance level is at 1%, 5% and 10% denoted respectively by * ** , * * and * , respectively.

DM* statistics imply that the EUI version with country-specific and global variants model is preferred over the RV version; significantly positive DM* indicates a preference for the benchmark GARCH-MIDAS-RV model; while non-significance indicates that the compared models are markedly different from one another. There is a large proportion of outperformance in favour of the GARCH-MIDAS-EUI, regardless of the variant of EUI being considered. There are cases of higher number of significant negative DM* statistics across the models with EUIs than significant positive DM* statistics. These results transcend the EUI proxies and indicate the statistical relevance of the incorporated EUI. In other words, EUI is confirmed to be a good predictor of stock returns volatility across the 28 countries considered. The stance of outperformance of the EUI-based GARCH-MIDAS model variants over the GARCH-MIDAS-RV model is further confirmed with the CT statistics (see Appendix Table A3), especially with respect to the global EUI-based GARCH-MIDAS models.

Similarly, the global EUI variants are compared with the country-specific EUI, as shown in Table 4, using the GARCH-MIDAS model incorporating an exogenous predictor, country-specific EUI, as the benchmark model in the global–country–specific pair. There is overwhelming evidence of outperformance of the global over the country-specific variant of EUI. The global EUI variants seem statistically more informative, improving the GARCH-MIDAS model's forecast precision more than the country-specific variant (see results in columns 2–7 of Table 4). The stances do not differ markedly when the CT statistic is used to adjudge the forecast precision of the contending models (see the results in columns 2–7 of Appendix Table A4). Also, the equally-weighted and GDP-weighted global EUI-based model pairs are examined in columns 8–10, with the latter GARCH-MIDAS model serving as the benchmark. The results show that the equal-weighted EUI outperforms the GDP-weighted global EUI; with clear evidence of agreement between the results from the DM* and the CT statistics. Summarily, the predictability holds beyond the in-sample to out-of-sample at various forecast horizons. Our findings are robust to the choice of the EUI variant and the forecast horizon (see further results for shorter forecast horizons ($h=1$; $h=5$; and $h=10$) in Appendix Tables A1 and A2, which do not differ markedly from the stances when larger forecast horizons were considered).

Taken together, our analysis highlights the importance of energy uncertainty for stock returns volatility, reflecting the responsiveness of the volatility of stock index returns in both developed and developing economies to uncertainty in the (global) energy market covering both economic and energy-market-related features. This finding nicely complements Megaritis et al. (2021) who argue that macroeconomic uncertainty has the ability to predict stock volatility. Uncertainty factors can trigger irrational trading and accentuate market fluctuations (Gong et al., 2022). Extreme shocks can trigger violent fluctuations in stock returns (Wang et al., 2020), pushing market participants to focus more on global stock market dynamics, especially large stock returns, possibly triggering herding activity, which can lead to a synchronized impact of uncertainty on international stock markets.

### 4.2. *Additional analysis*

In this sub-section, we further highlight our contribution and the importance of our analysis in terms of the need to consider a broader measure of energy uncertainty over just the one emanating from crude oil, as well as general the economic uncertainty. To this end, we compare the performance of the EUI in forecasting stock market volatility to that of disaggregated oil and economic uncertainty metrics. In other words, we consider additional exogeneous variables for the prediction of the volatility of the stock prices in the selected 28 countries. The considered variables include two different proxies of oil uncertainty: newspapers based Oil Price Uncertainty – OPU[5] (Abiad & Qureshi, 2023), and stochastic volatility of the unpredictable component of

[5] See: https://policyuncertainty.com/oil_uncertainty.html.

**Table 3**
Modified Diebold and Mariano Results (Realized Volatility-based Model is the Benchmark).

| Country | Country-Specific EUI Versus Realized Volatility | | | Global EUI [Equally weighted] Versus Realized Volatility | | | Global EUI [GDP-Weighted] Versus Realized Volatility | | |
|---|---|---|---|---|---|---|---|---|---|
| | $h=20$ | $h=60$ | $h=120$ | $h=20$ | $h=60$ | $h=120$ | $h=20$ | $h=60$ | $h=120$ |
| Australia | -3.8189 * ** | -3.8681 * ** | -3.7761 * ** | -4.3398 * ** | -4.514 * ** | -4.4615 * ** | -4.0657 * ** | -4.2459 * ** | -4.2204 * ** |
| Belgium | -3.0021 * ** | -2.9311 * ** | -2.9527 * ** | -3.4844 * ** | -3.4015 * ** | -3.4683 * ** | -4.6952 * ** | -4.589 * ** | -4.5928 * ** |
| Brazil | 0.2706 | 0.2189 | 0.1589 | -1.7203 * | -1.812 * | -1.9499 * | -2.0455 * * | -2.1681 * * | -2.3024 * * |
| Canada | -4.4806 * ** | -4.5123 * ** | -4.5258 * ** | -5.46 * ** | -5.4928 * ** | -5.484 * ** | -5.36 * ** | -5.3878 * ** | -5.3863 * ** |
| Chile | -0.4688 | -0.397 | -0.3692 | -3.9012 * ** | -3.9859 * ** | -4.0105 * ** | -4.0673 * ** | -4.1969 * ** | -4.2569 * ** |
| China | 3.7739 * ** | 3.5059 * ** | 3.785 * ** | 1.534 | 1.2946 | 1.7055 * | 3.8575 * ** | 3.6241 * ** | 3.9228 * ** |
| Colombia | -2.2697 * * | -2.1382 * * | -2.0224 * * | -2.0014 * * | -1.8715 * | -1.7619 * | -2.8024 * ** | -2.6778 * ** | -2.5718 * * |
| Croatia | 15.7697 * ** | 15.5646 * ** | 15.1417 * ** | 14.8766 * ** | 14.7822 * ** | 14.5864 * ** | 17.0725 * ** | 16.9961 * ** | 16.7803 * ** |
| Denmark | 3.8735 * ** | 3.8484 * ** | 4.1298 * ** | 2.1399 * * | 2.062 * * | 1.9764 * * | -6.0395 * ** | -5.9801 * ** | -5.7171 * ** |
| France | -3.6376 * ** | -3.6442 * ** | -3.6253 * ** | -4.9213 * ** | -5.0403 * ** | -5.0109 * ** | -5.2535 * ** | -5.2394 * ** | -5.2148 * ** |
| Germany | 0.6461 | 0.4928 | 0.2197 | -2.353 * * | -2.5373 * * | -2.595 * ** | -0.8219 | -0.9379 | -1.1711 |
| Greece | 15.0789 * ** | 13.829 * ** | 11.9155 * ** | -10.8958 * ** | -10.226 * ** | -8.8165 * ** | -11.3296 * ** | -10.561 * ** | -9.2469 * ** |
| India | 3.4059 * ** | 3.5522 * ** | 3.4156 * ** | 2.5121 * * | 2.5496 * * | 2.2311 * * | 3.3304 * ** | 3.3179 * ** | 3.015 * ** |
| Ireland | -0.5109 | -0.3496 | -0.1838 | -3.8104 * ** | -3.6333 * ** | -3.7777 * ** | -9.5783 * ** | -9.4115 * ** | -9.1821 * ** |
| Italy | -4.8108 * ** | -4.7442 * ** | -4.7111 * ** | -5.8095 * ** | -5.7704 * ** | -5.8943 * ** | -8.6643 * ** | -8.5871 * ** | -8.5023 * ** |
| Japan | 16.0455 * ** | 15.6532 * ** | 15.6383 * ** | 18.2356 * ** | 18.0361 * ** | 18.8894 * ** | 22.1675 * ** | 22.0812 * ** | 22.0707 * ** |
| Mexico | 0.8857 | 0.8746 | 0.6822 | 1.1659 | 1.0408 | 0.8823 | 2.2561 * * | 2.1488 * * | 1.8863 * |
| Netherlands | 6.1367 * ** | 6.0997 * ** | 6.0107 * ** | 6.75 * ** | 6.6543 * ** | 6.2944 * ** | 4.2937 * ** | 4.2012 * ** | 4.0152 * ** |
| New Zealand | 1.6256 | 1.5226 | 1.6937 * | 1.7319 * | 1.5764 | 1.6917 * | 2.4996 * * | 2.2938 * * | 2.4295 * * |
| Pakistan | 15.1148 * ** | 14.9748 * ** | 14.5887 * ** | -2.3945 * * | -2.211 * * | -2.3028 * * | -2.4631 * * | -2.3617 * * | -2.3144 * * |
| Russia | -1.7218 * | -1.7172 * | -1.7241 * | -1.7314 * | -1.7199 * | -1.7281 * | -1.7664 * | -1.7558 * | -1.7594 * |
| Singapore | -0.6376 | -0.9739 | -1.0423 | -3.2388 * ** | -3.478 * ** | -3.4336 * ** | -2.8706 * ** | -3.0547 * ** | -3.0001 * ** |
| Korea | 24.1643 * ** | 23.6036 * ** | 22.6459 * ** | 16.5102 * ** | 15.8783 * ** | 15.0113 * ** | 19.0165 * ** | 18.3984 * ** | 17.4294 * ** |
| Spain | -3.9086 * ** | -3.8815 * ** | -3.8937 * ** | -5.3948 * ** | -5.4783 * ** | -5.4117 * ** | -4.8085 * ** | -4.8856 * ** | -4.8877 * ** |
| Sweden | 3.4655 * ** | 3.1094 * ** | 2.8475 * ** | -0.3846 | -0.7706 | -0.8077 | 0.508 | 0.1402 | 0.0185 |
| UK | -3.8449 * ** | -3.814 * ** | -3.8253 * ** | -5.4954 * ** | -5.6223 * ** | -5.6313 * ** | -4.8717 * ** | -5.0027 * ** | -5.0683 * ** |
| USA | -3.4334 * ** | -3.4401 * ** | -3.4673 * ** | -4.7305 * ** | -4.759 * ** | -4.7683 * ** | -4.5107 * ** | -4.5333 * ** | -4.5572 * ** |
| Vietnam | -3.9747 * ** | -3.1608 * ** | -2.5324 * * | -9.6889 * ** | -8.8261 * ** | -8.2422 * ** | -9.5734 * ** | -8.6969 * ** | -8.1857 * ** |

**Note:** The modified Diebold and Mariano (DM*) test statistics compare each GARCH-MIDAS-EUI-based model with the GARCH-MIDAS-RV (benchmark) model. * ** , * * and * denote 1%, 5% and 10% significance levels, respectively.

oil price-reliant Oil Market Uncertainty Index – OMUI[6] (Nguyen et al., 2022; Cross et al., 2022), as well as country-specific economic policy uncertainties (sourced from EIU reports[7] for 25 of the selected countries; and Croatia, Denmark and New Zealand from the country-specific website under the main webpage of Economic Policy Uncertainty (EPU)[8]). We comparatively assess the performance of the GARCH-MIDAS models that incorporate these variables in contrast with the variants that incorporates the EUIs. The intuition is to formally establish the superiority of the EUIs over oil price uncertainty proxies (see the results in Tables 5 and 6) and the EPU (see the results in Table 7), given the broader natural coverage that characterize the EUIs. We report only the modified Diebold and Mariano based out-of-sample forecast evaluation results.

First, we find a sizeable number of outperformances with respect to the exogeneous variable based GARCH-MIDAS models over the GARCH-MIDAS-RV model, for both oil uncertainty proxies and the weighted-EUI variants (see the results in Table 5). Global EUIs (equally-weighted and GDP-weighted variants) improve the forecast precision of the GARCH-MIDAS model over the variants that incorporate oil uncertainty, especially oil price uncertainty (see the results in Table 6). It appears that the oil market uncertainty index encompasses more information dynamics that makes its forecast precision to rival that of global EUIs. However, it is evident that the global EUI- based GARCH-MIDAS model is preferred for the modelling of the stock returns volatility in most of the considered countries. The outperformance is robust to the forecast horizons, but not to the oil uncertainty proxy.

On the contrast between model variants incorporating country-specific EUIs and country-specific EPUs as predictors, we find the former to have more stances of outperformances than the latter (see the results in Table 7). This is again indicative that the country-specific EUIs are more informative than the country-specific EPUs, and notably the stances of outperformances are not sensitive the choice of forecast horizons. Accordingly, the appropriateness of our choice of the country-specific and global EUIs as predictors for stock volatility in the different selected countries is statistically ascertained as an optimal decision.

## 5. Conclusion

We forecast the volatility of daily stock index returns for 28 developed and developing countries based on monthly country-specific and global energy-related uncertainty indexes (EUIs) using the GARCH-MIDAS framework between January 1996 to December 2022. The outcome indicates that uncertainty indexes related to energy, both the country-specific and global variants, possess the potential to forecast the volatility of stock returns for the in-sample periods. Higher levels of energy uncertainty indexes tend to correspond with increased volatility in stock returns. This in-sample predictability withstands various out-of-sample forecast horizons. Additionally, when comparing the predictive power and effectiveness of uncertainty indexes, the performance of the GARCH-MIDAS model that integrates global energy uncertainty indexes is superior relative to that integrating the country-specific metrics or the restricted oil (economic) uncertainty measures. Importantly, our findings are robust to the choice of EUI proxies and sample definition.

On this basis, we can conclude that investors should monitor the comparative roles of country-specific versus global energy-related uncertainty indexes while making their stock portfolio decisions, with

[6] The reader is referred to the Data segment of the website of Dr. Bao H. Nguyen at: https://sites.google.com/site/nguyenhoaibao/datasets/oil-market-uncertainty?authuser= 0.

[7] See: https://worlduncertaintyindex.com/data/.

[8] See: https://policyuncertainty.com/croatia_monthly.html; https://policyuncertainty.com/denmark_monthly.html, and; https://www.policyuncertainty.com/new_zealand_monthly.html, respectively.

**Table 4**
Out-of-Sample Forecast Evaluation using Modified Diebold and Mariano Results (Comparison among the EUI-based Models).

| Country | Global EUI (Equally weighted) Versus Country-Specific EUI | | | Global EUI (GDP-Weighted) Versus Country-Specific EUI | | | Global EUI [Equally Weighted] Versus Global EUI [GDP-Weighted] | | |
|---|---|---|---|---|---|---|---|---|---|
| | $h = 20$ | $h = 60$ | $h = 120$ | $h = 20$ | $h = 60$ | $h = 120$ | $h = 20$ | $h = 60$ | $h = 120$ |
| Australia | -4.5221 * ** | -5.1087 * ** | -5.2306 * ** | -3.4656 * ** | -3.9314 * ** | -4.0869 * ** | 0.8797 | 1.0663 | 1.2742 |
| Belgium | -2.3329 * * | -2.2757 * * | -2.5674 * * | -8.5748 * ** | -8.4032 * ** | -8.2852 * ** | 17.2323 * ** | 16.917 * ** | 16.1669 * ** |
| Brazil | -4.4743 * ** | -4.5624 * ** | -4.736 * ** | -4.8392 * ** | -4.9915 * ** | -5.1499 * ** | 5.277 * ** | 5.7876 * ** | 5.8178 * ** |
| Canada | -5.8411 * ** | -5.8642 * ** | -5.8065 * ** | -5.4064 * ** | -5.4149 * ** | -5.3795 * ** | -3.9362 * ** | -4.1607 * ** | -3.8482 * ** |
| Chile | -5.5292 * ** | -5.7304 * ** | -5.7966 * ** | -5.1933 * ** | -5.416 * ** | -5.5162 * ** | 3.5988 * ** | 3.806 * ** | 3.9409 * ** |
| China | -4.0226 * ** | -4.0559 * ** | -3.6104 * ** | 0.8768 | 0.9092 | 1.0426 | -7.2524 * ** | -7.3156 * ** | -6.891 * ** |
| Colombia | 4.7614 * ** | 4.7468 * ** | 4.6586 * ** | -7.8737 * ** | -8.0959 * ** | -8.3587 * ** | 10.1841 * ** | 10.359 * ** | 10.5137 * ** |
| Croatia | 3.9074 * ** | 4.4073 * ** | 5.449 * ** | 1.042 | 1.651 * | 2.688 * ** | 2.5261 * * | 2.418 * * | 2.3825 * * |
| Denmark | -4.0573 * ** | -4.1628 * ** | -4.9495 * ** | -16.5491 * ** | -16.4667 * ** | -16.4008 * ** | 25.984 * ** | 25.6002 * ** | 24.8096 * ** |
| France | -5.3993 * ** | -5.6588 * ** | -5.6267 * ** | -8.4188 * ** | -8.3459 * ** | -8.3152 * ** | -2.3933 * * | -2.7248 * ** | -2.6988 * ** |
| Germany | -4.4899 * ** | -4.6554 * ** | -4.5073 * ** | -6.0093 * ** | -5.9421 * ** | -5.9178 * ** | -3.3193 * ** | -3.5207 * ** | -3.3645 * ** |
| Greece | -17.1942 * ** | -16.068 * ** | -14.4622 * ** | -17.2037 * ** | -16.0738 * ** | -14.4395 * ** | 3.1072 * ** | 2.1656 * * | 3.6005 * ** |
| India | -0.6201 | -0.8182 | -1.3586 | 1.5141 | 1.2214 | 0.7555 | -8.5997 * ** | -8.1443 * ** | -8.292 * ** |
| Ireland | -3.6478 * ** | -3.6357 * ** | -3.9833 * ** | -10.1799 * ** | -10.188 * ** | -10.1046 * ** | 18.1895 * ** | 18.2462 * ** | 17.6107 * ** |
| Italy | -4.9346 * ** | -4.9918 * ** | -5.4444 * ** | -10.6618 * ** | -10.6187 * ** | -10.4865 * ** | 15.5971 * ** | 15.4133 * ** | 14.6546 * ** |
| Japan | 10.9271 * ** | 10.3098 * ** | 10.9338 * ** | 19.2723 * ** | 18.7701 * ** | 18.1818 * ** | 0.4829 | -0.2013 | 0.7005 |
| Mexico | 0.7962 | 0.5081 | 0.5733 | 4.5033 * ** | 4.1933 * ** | 3.9433 * ** | -6.1558 * ** | -6.2785 * ** | -5.7396 * ** |
| Netherlands | 2.1357 * * | 2.0477 * * | 1.5393 | -2.0888 * * | -2.1698 * * | -2.3563 * * | 12.4487 * ** | 12.4268 * ** | 11.7305 * ** |
| New Zealand | 0.7905 | 0.2611 | -0.3601 | 3.9918 * ** | 3.516 * ** | 3.3413 * ** | -4.2266 * ** | -3.9349 * ** | -4.0525 * ** |
| Pakistan | -24.2808 * ** | -23.8957 * ** | -23.4812 * ** | -25.0655 * ** | -24.7659 * ** | -24.1813 * ** | 0.7513 | 1.0478 | 0.5273 |
| Russia | -1.7496 * | -1.4555 | -1.5244 | -2.5433 * * | -2.4013 * * | -2.3348 * * | 2.9079 * ** | 2.9362 * ** | 2.755 * ** |
| Singapore | -5.7554 * ** | -5.7911 * ** | -5.6138 * ** | -4.7792 * ** | -4.7256 * ** | -4.5442 * ** | -1.6417 | -1.9379 * | -2.0227 * * |
| Korea | -4.0854 * ** | -4.2527 * ** | -4.2053 * ** | -2.8982 * ** | -3.0567 * ** | -3.1336 * ** | -8.7034 * ** | -8.8754 * ** | -8.3528 * ** |
| Spain | -6.1026 * ** | -6.3498 * ** | -6.1803 * ** | -4.8958 * ** | -5.1635 * ** | -5.1456 * ** | -8.5586 * ** | -8.669 * ** | -8.1158 * ** |
| Sweden | -4.0484 * ** | -4.3422 * ** | -4.1551 * ** | -2.7784 * ** | -3.035 * ** | -2.9682 * ** | -5.2109 * ** | -5.3942 * ** | -4.9885 * ** |
| UK | -5.3888 * ** | -5.6914 * ** | -5.6946 * ** | -4.3644 * ** | -4.7037 * ** | -4.8274 * ** | -6.4138 * ** | -6.403 * ** | -6.0277 * ** |
| USA | -5.3361 * ** | -5.3933 * ** | -5.3671 * ** | -4.81 * ** | -4.8523 * ** | -4.8616 * ** | -2.8665 * ** | -2.9659 * ** | -2.697 * ** |
| Vietnam | -21.4084 * ** | -20.9602 * ** | -20.932 * ** | -21.0444 * ** | -20.5681 * ** | -20.9713 * ** | -1.7971 * | -1.9629 * * | -0.7949 |

**Note:** The figures in Columns 2–4 and Columns 5–7 are the DM* statistics that compare the GARCH-MIDAS model that is respectively based on global EUI (equally-weighted) and global EUI (GDP-Weighted) with the GARCH-MIDAS that is based on country-specific EUI (benchmark) model. Columns 8–10 are the DM* statistics that compare the GARCH-MIDAS model that is based on global EUI (equally-weighted) with the GARCH-MIDAS model that is based on global EUI (GDP-Weighted), where the latter is the benchmark. * ** , * * and * denote significance at levels indicates previously. For Columns 2–7, significantly negative DM* statistics imply that the GARCH-MIDAS model based on the global EUI variants is preferred over the GARCH-MIDAS model based on country-specific EUI; significantly positive DM* indicates a preference for the benchmark GARCH-MIDAS model with country-specific EUI; while non-significance indicates that the compared models are markedly different from one another. For Columns 8–10, significantly negative DM* statistics imply that the GARCH-MIDAS based on the global EUI (equally-weighted) variants is preferred over the GARCH-MIDAS model with global EUI (GDP-weighted), while significantly positive DM* indicates the converse.

relatively more emphasis on the latter, perhaps not surprisingly in line with an integrated global world system. With stock market volatility also capturing financial uncertainties, policymakers should be aware of the relative roles of macroeconomic and energy market uncertainties, both locally and worldwide, in formulating policy measures to prevent possible recessionary impacts and ensure economic stability.

As part of future research, looking at other asset markets, especially the exchange rate market, would be interesting, given the importance of the historical energy-exchange rate relationship (Salisu et al., 2021).

## Declaration of Competing Interest

The authors declare no conflict of interest.

## Appendix

**Table A1**
Modified Diebold and Mariano Results for Shorter Forecast Horizons (Realized Volatility-based Model is the Benchmark).

| Country | Country-Specific EUI Versus Realized Volatility | | | Global EUI [Equally weighted] Versus Realized Volatility | | | Global EUI [GDP-Weighted] Versus Realized Volatility | | |
|---|---|---|---|---|---|---|---|---|---|
| | $h = 1$ | $h = 5$ | $h = 10$ | $h = 1$ | $h = 5$ | $h = 10$ | $h = 1$ | $h = 5$ | $h = 10$ |
| Australia | -3.8044 * ** | -3.8066 * ** | -3.81 * ** | -4.235 * ** | -4.2603 * ** | -4.2811 * ** | -3.9943 * ** | -4.0067 * ** | -4.0202 * ** |
| Belgium | -3.017 * ** | -3.0365 * ** | -3.0421 * ** | -3.4707 * ** | -3.503 * ** | -3.5163 * ** | -4.6873 * ** | -4.7177 * ** | -4.7299 * ** |
| Brazil | 0.2961 | 0.2876 | 0.2709 | -1.6411 | -1.6642 * | -1.7 * | -1.9542 * | -1.9778 * * | -2.0183 * * |
| Canada | -4.4836 * ** | -4.4791 * ** | -4.4782 * ** | -5.4551 * ** | -5.4533 * ** | -5.4552 * ** | -5.3577 * ** | -5.3557 * ** | -5.3567 * ** |
| Chile | -0.5153 | -0.5056 | -0.4988 | -3.7401 * ** | -3.7799 * ** | -3.8338 * ** | -3.9295 * ** | -3.955 * ** | -3.9978 * ** |
| China | 4.4412 * ** | 4.2577 * ** | 4.1767 * ** | 2.0016 * * | 1.9026 * | 1.8526 * | 4.2832 * ** | 4.1889 * ** | 4.1516 * ** |
| Colombia | -2.3492 * * | -2.3463 * * | -2.3535 * * | -2.0751 * * | -2.0744 * * | -2.0823 * * | -2.8668 * ** | -2.8718 * ** | -2.8838 * ** |
| Croatia | 15.9638 * ** | 15.9219 * ** | 15.8471 * ** | 14.9984 * ** | 14.9751 * ** | 14.9235 * ** | 17.1898 * ** | 17.1658 * ** | 17.1136 * ** |
| Denmark | 3.9559 * ** | 3.9231 * ** | 3.9093 * ** | 2.3402 * * | 2.2626 * * | 2.223 * * | -5.8994 * ** | -5.9637 * ** | -5.9962 * ** |
| France | -3.6343 * ** | -3.6368 * ** | -3.637 * ** | -4.8221 * ** | -4.8467 * ** | -4.8648 * ** | -5.2076 * ** | -5.2249 * ** | -5.2357 * ** |
| Germany | 0.7471 | 0.7181 | 0.7027 | -2.1764 * * | -2.2169 * * | -2.2453 * * | -0.6814 | -0.7224 | -0.7477 |

(continued on next page)

**Table 5**
Additional Results on Modified Diebold and Mariano Results (Realized Volatility-based Model is the Benchmark).

| Country | Oil Price Uncertainty Versus Realized Volatility | | | Oil Market Uncertainty Index Versus Realized Volatility | | | Global EUI (Equally weighted) Versus Realized Volatility | | | Global EUI (GDP weighted) Versus Realized Volatility | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $h = 20$ | $h = 60$ | $h = 120$ | $h = 20$ | $h = 60$ | $h = 120$ | $h = 20$ | $h = 60$ | $h = 120$ | $h = 20$ | $h = 60$ | $h = 120$ |
| Australia | -4.52 * ** | -4.66 * ** | -4.7 * ** | -5.45 * ** | -5.4 * ** | -5.3 * ** | -4.34 * ** | -4.51 * ** | -4.46 * ** | -4.07 * ** | -4.25 * ** | -4.22 * ** |
| Belgium | -2.34 * * | -2.34 * * | -2.36 * * | -6.66 * ** | -6.58 * ** | -6.58 * ** | -3.48 * ** | -3.4 * ** | -3.47 * ** | -4.7 * ** | -4.59 * ** | -4.59 * ** |
| Brazil | -5.55 * ** | -5.79 * ** | -5.98 * ** | -4.57 * ** | -4.6 * ** | -4.6 * ** | -1.72 * | -1.81 * | -1.95 * | -2.05 * * | -2.17 * * | -2.3 * * |
| Canada | -5.04 * ** | -5.07 * ** | -5.11 * ** | -5.09 * ** | -5.12 * ** | -5.12 * ** | -5.46 * ** | -5.49 * ** | -5.48 * ** | -5.36 * ** | -5.39 * ** | -5.39 * ** |
| Chile | -3.56 * ** | -3.68 * ** | -3.66 * ** | -8.28 * ** | -8.28 * ** | -8.31 * ** | -3.9 * ** | -3.99 * ** | -4.01 * ** | -4.07 * ** | -4.2 * ** | -4.26 * ** |
| China | 8.92 * ** | 8.8 * ** | 9.07 * ** | 4.28 * ** | 4.12 * ** | 4.47 * ** | 1.53 | 1.29 | 1.71 * | 3.86 * ** | 3.62 * ** | 3.92 * ** |
| Colombia | -4.69 * ** | -4.64 * ** | -4.69 * ** | -5.83 * ** | -5.72 * ** | -5.62 * ** | -2 * | -1.87 * | -1.76 * | -2.8 * * | -2.68 * * | -2.57 * * |
| Croatia | 11.67 * ** | 11.66 * ** | 11.15 * ** | 16.66 * ** | 16.26 * ** | 15.54 * ** | 14.88 * ** | 14.78 * ** | 14.59 * ** | 17.07 * ** | 17 * ** | 16.78 * ** |
| Denmark | 11.47 * ** | 11.27 * ** | 11.14 * ** | -3.95 * ** | -3.92 * ** | -3.78 * ** | 2.14 * * | 2.06 * * | 1.98 * | -6.04 * ** | -5.98 * ** | -5.72 * ** |
| France | -3.35 * ** | -3.47 * ** | -3.47 * ** | -6.6 * ** | -6.58 * ** | -6.53 * ** | -4.92 * ** | -5.04 * ** | -5.01 * ** | -5.25 * ** | -5.24 * ** | -5.21 * ** |
| Germany | 1.06 | 0.83 | 0.55 | -5.22 * ** | -5.24 * ** | -5.28 * ** | -2.35 * * | -2.54 * * | -2.6 * * | -0.82 | -0.94 | -1.17 |
| Greece | -8.62 * ** | -8.04 * ** | -6.49 * ** | 13.15 * ** | 11.71 * ** | 9.41 * ** | -10.9 * ** | -10.23 * ** | -8.82 * ** | -11.33 * ** | -10.56 * ** | -9.25 * ** |
| India | 6.62 * ** | 6.55 * ** | 6.04 * ** | -1.27 | -1.28 | -1.36 | 2.51 * * | 2.55 * * | 2.23 * * | 3.33 * ** | 3.32 * ** | 3.02 * ** |
| Ireland | 3.26 * ** | 3.04 * ** | 3.29 * ** | -7.2 * ** | -7.15 * ** | -7.1 * ** | -3.81 * ** | -3.63 * ** | -3.78 * ** | -9.58 * ** | -9.41 * ** | -9.18 * ** |
| Italy | -1.52 | -1.75 * | -1.62 | -9.83 * ** | -9.77 * ** | -9.68 * ** | -5.81 * ** | -5.77 * ** | -5.89 * ** | -8.66 * ** | -8.59 * ** | -8.5 * ** |
| Japan | 19.89 * ** | 19.66 * ** | 20.86 * ** | 18.96 * ** | 18.73 * ** | 18.38 * ** | 18.24 * ** | 18.04 * ** | 18.89 * ** | 22.17 * ** | 22.08 * ** | 22.07 * ** |
| Mexico | 4.44 * ** | 4.31 * ** | 4.11 * ** | -5.32 * ** | -5.26 * ** | -5.39 * ** | 1.17 | 1.04 | 0.88 | 2.26 * * | 2.15 * * | 1.89 * |
| Netherlands | 12.43 * ** | 12.04 * ** | 11.81 * ** | -7.19 * ** | -7.18 * ** | -7.18 * ** | 6.75 * ** | 6.65 * ** | 6.29 * ** | 4.29 * ** | 4.2 * ** | 4.02 * ** |
| New Zealand | 2.4 * * | 2.19 * * | 2.32 * * | -6.05 * ** | -5.9 * ** | -5.68 * ** | 1.73 * | 1.58 | 1.69 * | 2.5 * * | 2.29 * * | 2.43 * * |
| Pakistan | 27.07 * ** | 26.48 * ** | 25.48 * ** | 14.88 * ** | 14.5 * ** | 13.8 * ** | -2.39 * * | -2.21 * * | -2.3 * * | -2.46 * * | -2.36 * * | -2.31 * * |
| Russia | -1.54 | -1.53 | -1.55 | -1.58 | -1.57 | -1.58 | -1.73 * | -1.72 * | -1.73 * | -1.77 * | -1.76 * | -1.76 * |
| Singapore | -1.59 | -2.02 * * | -1.99 * | -2.75 * * | -3.04 * ** | -3.06 * ** | -3.24 * ** | -3.48 * ** | -3.43 * ** | -2.87 * ** | -3.05 * ** | -3 * ** |
| Korea | 24.42 * ** | 23.81 * ** | 22.95 * ** | 24.25 * ** | 23.65 * ** | 22.63 * ** | 16.51 * ** | 15.88 * ** | 15.01 * ** | 19.02 * ** | 18.4 * ** | 17.43 * ** |
| Spain | -3.48 * ** | -3.58 * ** | -3.59 * ** | -6.27 * ** | -6.25 * ** | -6.24 * ** | -5.39 * ** | -5.48 * ** | -5.41 * ** | -4.81 * ** | -4.89 * ** | -4.89 * ** |
| Sweden | 2.84 * ** | 2.51 * * | 2 * | -2.27 * * | -2.41 * * | -2.56 * * | -0.38 | -0.77 | -0.81 | 0.51 | 0.14 | 0.02 |
| UK | -3.98 * ** | -4.11 * ** | -4.15 * ** | -7.36 * ** | -7.29 * ** | -7.25 * ** | -5.5 * ** | -5.62 * ** | -5.63 * ** | -4.87 * ** | -5 * ** | -5.07 * ** |
| USA | -4.48 * ** | -4.5 * ** | -4.55 * ** | -5.01 * ** | -5.02 * ** | -5.03 * ** | -4.73 * ** | -4.76 * ** | -4.77 * ** | -4.51 * ** | -4.53 * ** | -4.56 * ** |
| Vietnam | 0.11 | 0.93 | 1.24 | -4.54 * ** | -3.51 * ** | -2.96 * ** | -9.69 * ** | -8.83 * ** | -8.24 * ** | -9.57 * ** | -8.7 * ** | -8.19 * ** |

**Note:** The modified Diebold and Mariano (DM*) test statistics compare each exogeneous predictor based GARCH-MIDAS models with the GARCH-MIDAS-RV (benchmark) model. * ** , * * and * denote 1%, 5% and 10% significance levels, respectively.

**Table 6**
Additional Results on Modified Diebold and Mariano Results (Oil Price uncertainty-based Model is the Benchmark).

| Country | Global EUI (Equally weighted) Versus Oil Price Uncertainty | | | Global EUI (Equally weighted) Versus Oil Market Uncertainty Index | | | Global EUI (GDP weighted) Verus Oil Price Uncertainty | | | Global EUI (GDP weighted) Verus Oil Market Uncertainty Index | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $h = 20$ | $h = 60$ | $h = 120$ | $h = 20$ | $h = 60$ | $h = 120$ | $h = 20$ | $h = 60$ | $h = 120$ | $h = 20$ | $h = 60$ | $h = 120$ |
| Australia | -1.32 | -1.69 * | -1.03 | 5.78 * ** | 5.04 * ** | 4.82 * ** | -1.15 | -1.44 | -1.19 | 4.80 * ** | 4.06 * ** | 3.77 * ** |
| Belgium | -4.06 * ** | -3.67 * ** | -3.87 * ** | 10.93 * ** | 10.9 * ** | 10.75 * ** | -8.91 * ** | -8.47 * ** | -8.38 * ** | 8.65 * ** | 8.69 * ** | 8.69 * ** |
| Brazil | 8.51 * ** | 8.85 * ** | 8.99 * ** | 7.28 * ** | 7.18 * ** | 6.96 * ** | 7.66 * ** | 7.91 * ** | 8.05 * ** | 7.11 * ** | 6.95 * ** | 6.71 * ** |
| Canada | -7.21 * ** | -7.28 * ** | -6.95 * ** | -6.39 * ** | -6.46 * ** | -6.37 * ** | -6.21 * ** | -6.25 * ** | -5.98 * ** | -5.48 * ** | -5.52 * ** | -5.48 * ** |
| Chile | -3.49 * ** | -3.43 * ** | -3.63 * ** | 13.04 * ** | 12.84 * ** | 12.89 * ** | -3.7 * ** | -3.81 * ** | -3.96 * ** | 6.41 * ** | 6.14 * ** | 6.07 * ** |
| China | -5.63 * ** | -5.78 * ** | -5.27 * ** | -2.25 * * | -2.37 * * | -2.17 * * | -4.18 * ** | -4.35 * ** | -3.91 * ** | 0.15 | 0.01 | 0.03 |
| Colombia | 14.32 * ** | 14.83 * ** | 16.05 * ** | 18.46 * ** | 18.51 * ** | 18.58 * ** | 12.01 * ** | 12.48 * ** | 13.69 * ** | 15.48 * ** | 15.46 * ** | 15.47 * ** |
| Croatia | -5.52 * ** | -5.6 * ** | -4.85 * ** | 1.93 * | 2.09 * * | 2.34 * * | -5.13 * ** | -5.18 * ** | -4.53 * ** | 1.69 * | 1.88 * | 2.16 * * |
| Denmark | -18.81 * ** | -18.58 * ** | -19.13 * ** | 6.34 * ** | 6.22 * ** | 5.96 * ** | -23.78 * ** | -23.49 * ** | -23.71 * ** | -2.96 * ** | -2.92 * ** | -2.68 * * |
| France | -7.67 * ** | -7.73 * ** | -7.66 * ** | 4.82 * ** | 4.42 * ** | 4.4 * ** | -6.08 * ** | -5.57 * ** | -5.52 * ** | 7.62 * ** | 7.58 * ** | 7.52 * ** |
| Germany | -6.40 * ** | -6.47 * ** | -6.22 * ** | 7.22 * ** | 6.79 * ** | 6.79 * ** | -9.55 * ** | -9 * ** | -8.75 * ** | 9.58 * ** | 9.46 * ** | 9.23 * ** |
| Greece | -7.75 * ** | -7.66 * ** | -7.65 * ** | -15.77 * ** | -14.61 * ** | -12.95 * ** | -7.27 * ** | -6.97 * ** | -7.30 * ** | -15.9 * ** | -14.76 * ** | -13.08 * ** |
| India | -19.93 * ** | -19.49 * ** | -18.9 * ** | 4.04 * ** | 4.08 * ** | 3.96 * ** | -23.11 * ** | -22.78 * ** | -22.35 * ** | 4.87 * ** | 4.87 * ** | 4.76 * ** |
| Ireland | -6.42 * ** | -6.06 * ** | -6.49 * ** | 6.77 * ** | 6.88 * ** | 6.7 * ** | -11.00 * ** | -10.64 * ** | -10.79 * ** | 1.50 | 1.60 | 1.78 * |
| Italy | -3.95 * ** | -3.62 * ** | -3.93 * ** | 12.70 * ** | 12.63 * ** | 12.30 * ** | -6.60 * ** | -6.28 * ** | -6.36 * ** | 9.03 * ** | 9.02 * ** | 8.96 * ** |
| Japan | 1.90 * | 1.15 | 2.90 * ** | 7.09 * ** | 6.34 * ** | 6.61 * ** | 2.66 * * | 2.15 * * | 4.62 * ** | 8.29 * ** | 7.63 * ** | 7.35 * ** |
| Mexico | -6.55 * ** | -6.54 * ** | -6.47 * ** | 7.99 * ** | 7.76 * ** | 7.71 * ** | -6.08 * ** | -6.01 * ** | -6.21 * ** | 8.43 * ** | 8.25 * ** | 8.08 * ** |
| Netherlands | -13.48 * ** | -12.86 * ** | -13.32 * ** | 12.72 * ** | 12.63 * ** | 12.37 * ** | -15.94 * ** | -15.38 * ** | -15.4 * ** | 11.38 * ** | 11.29 * ** | 11.15 * ** |
| New Zealand | -11.84 * ** | -11.03 * ** | -11.44 * ** | 8.48 * ** | 8.14 * ** | 8.05 * ** | 0.57 | 0.61 | 0.67 | 8.97 * ** | 8.59 * ** | 8.52 * ** |
| Pakistan | -33.16 * ** | -32.47 * ** | -31.44 * ** | -10.95 * ** | -10.57 * ** | -10.22 * ** | -33.66 * ** | -32.98 * ** | -31.92 * ** | -10.51 * ** | -10.21 * ** | -9.76 * ** |
| Russia | 1.09 | 1.07 | 1.11 | 1.29 | 1.29 | 1.29 | 0.97 | 0.94 | 1.000 | 1.21 | 1.21 | 1.21 |
| Singapore | -5.71 * ** | -5.47 * ** | -5.43 * ** | -3.32 * ** | -3.37 * ** | -3.2 * ** | -4.31 * ** | -4 * ** | -3.91 * ** | -2.19 * * | -2.12 * * | -1.96 * |
| Korea | -8.96 * ** | -9.02 * ** | -8.37 * ** | -0.94 | -1.23 | -1.25 | -7.94 * ** | -7.94 * ** | -7.37 * ** | 1.47 | 1.18 | 0.98 |
| Spain | -8.47 * ** | -8.49 * ** | -8.26 * ** | 0.19 | -0.16 | 0.05 | -7.65 * ** | -7.63 * ** | -7.59 * ** | 3.68 * ** | 3.35 * ** | 3.32 * ** |
| Sweden | -5.88 * ** | -6.21 * ** | -5.49 * ** | 3.11 * ** | 2.58 * * | 2.77 * * | -4.16 * ** | -4.44 * ** | -3.81 * ** | 4.65 * ** | 4.21 * ** | 4.23 * ** |
| UK | -6.15 * ** | -6.18 * ** | -6.15 * ** | 3.86 * ** | 3.34 * ** | 3.24 * ** | -4.94 * ** | -4.99 * ** | -5.11 * ** | 5.54 * ** | 5.06 * ** | 4.81 * ** |
| USA | -4.98 * ** | -5.03 * ** | -4.86 * ** | -0.86 | -1.09 | -1.06 | -3.6 * ** | -3.62 * ** | -3.54 * ** | 0.54 | 0.39 | 0.29 |
| Vietnam | -16.74 * ** | -16.67 * ** | -16.11 * ** | -23.15 * ** | -23.2 * ** | -22.6 * ** | -17.1 * ** | -17.01 * ** | -16.59 * ** | -21.8 * ** | -21.76 * ** | -21.54 * ** |

**Note:** The figures in Columns 2–4 and Columns 5–7 are the DM* statistics that compare the GARCH-MIDAS model that is based on global EUI (equally-weighted) with the GARCH-MIDAS that is respectively based on the two proxies of oil price uncertainty (benchmark) model. Columns 8–10 and 11-13 are the DM* statistics that compare the GARCH-MIDAS model that is based on global EUI (GDP-weighted) with the GARCH-MIDAS model that is based on oil price uncertainty proxies, where the latter is the benchmark. * ** , * * and * denote 1%, 5% and 10% significance levels, respectively. For Columns 2–7, significantly negative DM* statistics imply that the GARCH-MIDAS model based on the global EUI (equally-weighted) is preferred over the GARCH-MIDAS model based on oil price uncertainty proxies; significantly positive DM* indicates a preference for the benchmark GARCH-MIDAS model with oil price uncertainty proxies; while non-significance indicates that the compared models are markedly different from one another. For Columns 8–13, significantly negative DM* statistics imply that the GARCH-MIDAS based on the global EUI (GDP-weighted) variants is preferred over the GARCH-MIDAS model with oil price uncertainty proxies, while significantly positive DM* indicates the converse.

**Table 7**
Out-of-Sample Forecast Evaluation using Modified Diebold and Mariano Results (Comparison among country-specific EPU- and EUI- based Models).

| Country | Country-Specific EPU Versus Realized Volatility | | | Country-Specific EUI Versus Realized Volatility | | | Country-Specific EUI Versus Country-Specific EPU | | |
|---|---|---|---|---|---|---|---|---|---|
| | $h=20$ | $h=60$ | $h=120$ | $h=20$ | $h=60$ | $h=120$ | $h=20$ | $h=60$ | $h=120$ |
| Australia | 4.577 * ** | 4.579 * ** | 4.576 * ** | -4.5 * ** | -4.542 * ** | -4.554 * ** | -5.081 * ** | -5.1 * ** | -5.105 * ** |
| Belgium | 8.431 * ** | 8.419 * ** | 8.372 * ** | -2.072 * * | -2.115 * * | -2.174 * * | -11.434 * ** | -11.473 * ** | -11.494 * ** |
| Brazil | -2.355 * * | -2.326 * * | -2.32 * * | -5.473 * ** | -5.476 * ** | -5.483 * ** | -1.149 | -1.205 | -1.219 |
| Canada | 6.918 * ** | 6.925 * ** | 6.936 * ** | -5.491 * ** | -5.496 * ** | -5.502 * ** | -7.321 * ** | -7.329 * ** | -7.342 * ** |
| Chile | 5.109 * ** | 5.111 * ** | 5.11 * ** | -6.385 * ** | -6.453 * ** | -6.384 * ** | -5.256 * ** | -5.262 * ** | -5.258 * ** |
| China | -5.841 * ** | -6.137 * ** | -6.847 * ** | -1.252 | -1.231 | -1.095 | 1.767 * | 1.92 * | 2.402 * * |
| Colombia | 4.235 * ** | 4.236 * ** | 4.239 * ** | 4.608 * ** | 4.599 * ** | 4.589 * ** | -4.235 * ** | -4.236 * ** | -4.239 * ** |
| Croatia | 5.365 * ** | 5.236 * ** | 5.142 * ** | 21.487 * ** | 20.641 * ** | 20.211 * ** | 10.399 * ** | 9.512 * ** | 9.152 * ** |
| Denmark | 7.861 * ** | 7.183 * ** | 5.991 * ** | -4.51 * ** | -4.66 * ** | -5.224 * ** | -9.046 * ** | -8.76 * ** | -8.495 * ** |
| France | 0.544 | 0.452 | 0.242 | -2.265 * * | -2.303 * * | -2.523 * * | -3.467 * ** | -3.425 * ** | -3.5 * ** |
| Germany | 0.778 | 0.689 | 0.47 | -3.07 * ** | -3.284 * ** | -4.066 * ** | -4.442 * ** | -4.6 * ** | -5.293 * ** |
| Greece | -0.968 | -0.943 | -0.663 | -7.373 * ** | -7.087 * ** | -6.589 * ** | -13.8 * ** | -13.224 * ** | -12.898 * ** |
| India | 9.567 * ** | 9.648 * ** | 9.801 * ** | 9.038 * ** | 9.036 * ** | 9.042 * ** | -3.379 * ** | -3.507 * ** | -3.732 * ** |
| Ireland | 9.075 * ** | 8.985 * ** | 8.724 * ** | 2.41 * * | 2.219 * * | 1.616 | -1.935 * | -2.065 * * | -2.49 * * |
| Italy | -1.371 | -1.486 | -1.691 * | -4.329 * ** | -4.482 * ** | -4.698 * ** | -5.573 * ** | -5.675 * ** | -5.758 * ** |
| Japan | -1.412 | -1.48 | -1.448 | 3.331 * ** | 3.098 * ** | 2.526 * * | 10.329 * ** | 9.92 * ** | 8.666 * ** |
| Mexico | 4.713 * ** | 4.626 * ** | 4.535 * ** | -4.281 * ** | -4.391 * ** | -4.518 * ** | -5.874 * ** | -5.851 * ** | -5.831 * ** |
| Netherlands | 1.753 * | 1.496 | 1.019 | 1.198 | 0.91 | 0.576 | -0.01 | -0.211 | -0.22 |
| New Zealand | 7.173 * ** | 7.17 * ** | 7.114 * ** | -1.969 * * | -1.957 * | -1.789 * | -7.394 * ** | -7.386 * ** | -7.256 * ** |
| Pakistan | 5.158 * ** | 5.19 * ** | 5.185 * ** | -8.747 * ** | -8.931 * ** | -8.408 * ** | -6.131 * ** | -6.178 * ** | -6.085 * ** |
| Russia | -4.429 * ** | -3.891 * ** | -3.153 * ** | -1.652 * | -1.188 | -0.567 | 12.941 * ** | 12.811 * ** | 12.574 * ** |
| Singapore | 5.031 * ** | 5.031 * ** | 5.024 * ** | -2.719 * ** | -2.708 * ** | -2.741 * ** | -7.169 * ** | -7.166 * ** | -7.187 * ** |
| Korea | -0.985 | -1.02 | -1.132 | 0.453 | 0.49 | 0.315 | 1.183 | 1.252 | 1.086 |
| Spain | -0.524 | -0.557 | -0.661 | 1.755 * | 1.946 * | 2.007 * * | 1.851 * | 2.043 * * | 2.142 * * |
| Sweden | 2.678 * ** | 2.555 * * | 2.26 * * | 0.462 | 0.46 | 0.436 | -1.18 | -1.106 | -0.947 |
| UK | 1.911 * | 1.922 * | 1.963 * | 0.211 | 0.3 | 0.608 | -1.952 * | -1.947 * | -1.934 * |
| USA | 5.012 * ** | 5.014 * ** | 5.018 * ** | -6.543 * ** | -6.609 * ** | -6.771 * ** | -5.04 * ** | -5.043 * ** | -5.048 * ** |
| Vietnam | 19.348 * ** | 19.436 * ** | 18.826 * ** | 8.643 * ** | 8.698 * ** | 8.012 * ** | 1.515 | 1.599 | 1.053 |

**Note:** The figures in Columns 2–4 and Columns 5–7 are the DM* statistics that compare the GARCH-MIDAS model that is respectively based on country-specific EPU and country-specific EUI with the GARCH-MIDAS that is based on Realized Volatility (benchmark) model. Columns 8–10 are the DM* statistics that compare the GARCH-MIDAS model that is based on country-specific EUI with the GARCH-MIDAS model that is based on country-specific EPU, where the latter is the benchmark. * ** , * * and * denote 1%, 5% and 10% significance levels, respectively. For Columns 2–7, significantly negative DM* statistics imply that the GARCH-MIDAS model based on the country-specific EPU and country-specific EUI are preferred over the GARCH-MIDAS-RV model; significantly positive DM* indicates a preference for the benchmark GARCH-MIDAS-RV model; while non-significance indicates that the compared models are markedly different from one another. For Columns 8–10, significantly negative DM* statistics imply that the GARCH-MIDAS based on country-specific EUI is preferred over the GARCH-MIDAS model with country-specific EPU, while significantly positive DM* indicates the converse.

**Table A1** (*continued*)

| Country | Country-Specific EUI Versus Realized Volatility | | | Global EUI [Equally weighted] Versus Realized Volatility | | | Global EUI [GDP-Weighted] Versus Realized Volatility | | |
|---|---|---|---|---|---|---|---|---|---|
| | $h=1$ | $h=5$ | $h=10$ | $h=1$ | $h=5$ | $h=10$ | $h=1$ | $h=5$ | $h=10$ |
| Greece | 15.6463 * ** | 15.5238 * ** | 15.3885 * ** | -10.482 * ** | -10.5248 * ** | -10.6741 * ** | -11.2221 * ** | -11.2122 * ** | -11.2831 * ** |
| India | 3.5851 * ** | 3.5157 * ** | 3.4679 * ** | 2.8632 * ** | 2.7279 * ** | 2.6286 * ** | 3.7418 * ** | 3.5914 * ** | 3.4765 * ** |
| Ireland | -0.7028 | -0.6396 | -0.6131 | -3.8326 * ** | -3.8493 * ** | -3.8514 * ** | -9.5516 * ** | -9.5771 * ** | -9.5898 * ** |
| Italy | -4.9526 * ** | -4.9192 * ** | -4.8916 * ** | -5.8264 * ** | -5.8299 * ** | -5.8289 * ** | -8.7272 * ** | -8.7165 * ** | -8.7082 * ** |
| Japan | 16.3718 * ** | 16.2782 * ** | 16.3658 * ** | 18.4001 * ** | 18.2896 * ** | 18.4852 * ** | 22.2609 * ** | 22.1516 * ** | 22.379 * ** |
| Mexico | 1.1082 | 1.0569 | 0.9805 | 1.5129 | 1.4415 | 1.3353 | 2.5747 * * | 2.508 * * | 2.4093 * * |
| Netherlands | 6.1433 * ** | 6.1359 * ** | 6.1388 * ** | 6.9753 * ** | 6.8969 * ** | 6.8429 * ** | 4.5585 * ** | 4.4698 * ** | 4.4056 * ** |
| New Zealand | 2.0464 * * | 1.8921 * | 1.8111 * | 2.2091 * * | 2.0389 * * | 1.9446 * | 2.9647 * ** | 2.8067 * ** | 2.7176 * ** |
| Pakistan | 15.3186 * ** | 15.2576 * ** | 15.2149 * ** | -2.2204 * * | -2.3074 * * | -2.36 * * | -2.2029 * * | -2.3167 * * | -2.3922 * * |
| Russia | -1.7216 * | -1.7216 * | -1.7217 * | -1.7368 * | -1.7361 * | -1.7351 * | -1.7704 * | -1.7698 * | -1.7692 * |
| Singapore | -0.5424 | -0.556 | -0.5635 | -3.1174 * ** | -3.1334 * ** | -3.1483 * ** | -2.8614 * ** | -2.8425 * ** | -2.83 * ** |
| Korea | 24.4009 * ** | 24.321 * ** | 24.2999 * ** | 16.7481 * ** | 16.676 * ** | 16.6529 * ** | 19.2473 * ** | 19.1744 * ** | 19.154 * ** |
| Spain | -3.9522 * ** | -3.9388 * ** | -3.9314 * ** | -5.3735 * ** | -5.3787 * ** | -5.3872 * ** | -4.7991 * ** | -4.8021 * ** | -4.8077 * ** |
| Sweden | 3.6248 * ** | 3.5905 * ** | 3.5779 * ** | -0.1768 | -0.2132 | -0.2309 | 0.6743 | 0.6457 | 0.6336 |
| UK | -3.7541 * ** | -3.7719 * ** | -3.7931 * ** | -5.2753 * ** | -5.3123 * ** | -5.3579 * ** | -4.7072 * ** | -4.7246 * ** | -4.758 * ** |
| USA | -3.4617 * ** | -3.4501 * ** | -3.4419 * ** | -4.7071 * ** | -4.708 * ** | -4.7118 * ** | -4.5017 * ** | -4.4989 * ** | -4.4991 * ** |
| Vietnam | -4.044 * ** | -4.1221 * ** | -4.1379 * ** | -9.5559 * ** | -9.7282 * ** | -9.7692 * ** | -9.4188 * ** | -9.5922 * ** | -9.635 * ** |

**Note:** The modified Diebold and Mariano (DM*) test statistics compare each GARCH-MIDAS-EUI-based model with the GARCH-MIDAS-RV (benchmark) model. * ** , * * and * denote 1%, 5% and 10% significance levels, respectively.

**Table A2**
Out-of-Sample Forecast Evaluation for Shorter Forecast Horizons using Modified Diebold and Mariano Results (Comparison among the EUI-based Models).

| Country | Global EUI (Equally weighted) Versus Country-Specific EUI | Global EUI (GDP-Weighted) Versus Country-Specific EUI | Global EUI [Equally Weighted] Versus Global EUI [GDP-Weighted] |
|---|---|---|---|

(*continued on next page*)

**Table A2** (*continued*)

| Country | Global EUI (Equally weighted) Versus Country-Specific EUI | | | Global EUI (GDP-Weighted) Versus Country-Specific EUI | | | Global EUI [Equally Weighted] Versus Global EUI [GDP-Weighted] | | |
|---|---|---|---|---|---|---|---|---|---|
| | $h=1$ | $h=5$ | $h=10$ | $h=1$ | $h=5$ | $h=10$ | $h=1$ | $h=5$ | $h=10$ |
| | $h=1$ | $h=5$ | $h=10$ | $h=1$ | $h=5$ | $h=10$ | $h=1$ | $h=5$ | $h=10$ |
| Australia | -4.11 * ** | -4.2121 * ** | -4.2923 * ** | -3.2691 * ** | -3.3034 * ** | -3.3389 * ** | 1.0867 | 0.9937 | 0.947 |
| Belgium | -2.1355 * * | -2.2141 * * | -2.2639 * * | -8.4353 * ** | -8.4916 * ** | -8.5286 * ** | 17.3127 * ** | 17.2787 * ** | 17.2614 * ** |
| Brazil | -4.3524 * ** | -4.3853 * ** | -4.4284 * ** | -4.6973 * ** | -4.7298 * ** | -4.7813 * ** | 5.0656 * ** | 5.0836 * ** | 5.1671 * ** |
| Canada | -5.8196 * ** | -5.8247 * ** | -5.8323 * ** | -5.3935 * ** | -5.3977 * ** | -5.4027 * ** | -3.808 * ** | -3.8183 * ** | -3.8576 * ** |
| Chile | -5.2263 * ** | -5.2997 * ** | -5.3914 * ** | -4.9726 * ** | -5.014 * ** | -5.077 * ** | 3.5448 * ** | 3.532 * ** | 3.5397 * ** |
| China | -4.3914 * ** | -4.2279 * ** | -4.1447 * ** | 0.1325 | 0.4002 | 0.5747 | -6.9564 * ** | -7.0082 * ** | -7.0696 * ** |
| Colombia | 4.8621 * ** | 4.8234 * ** | 4.8087 * ** | -7.5152 * ** | -7.6798 * ** | -7.7738 * ** | 9.9835 * ** | 10.0794 * ** | 10.1427 * ** |
| Croatia | 3.59 * ** | 3.6724 * ** | 3.7619 * ** | 0.6211 | 0.7145 | 0.8417 | 2.6267 * ** | 2.6137 * ** | 2.5781 * * |
| Denmark | -3.8351 * ** | -3.9234 * ** | -3.9721 * ** | -16.4629 * ** | -16.5101 * ** | -16.5435 * ** | 26.1833 * ** | 26.1257 * ** | 26.1023 * ** |
| France | -5.177 * ** | -5.2291 * ** | -5.2697 * ** | -8.2221 * ** | -8.2915 * ** | -8.3401 * ** | -2.2311 * * | -2.26 * * | -2.2849 * * |
| Germany | -4.2859 * ** | -4.3269 * ** | -4.3603 * ** | -5.7691 * ** | -5.8424 * ** | -5.8963 * ** | -3.1613 * ** | -3.187 * ** | -3.2095 * ** |
| Greece | -17.5477 * ** | -17.4599 * ** | -17.3964 * ** | -17.6408 * ** | -17.5378 * ** | -17.4485 * ** | 4.6315 * ** | 4.3462 * ** | 3.9861 * ** |
| India | -0.0655 | -0.2827 | -0.446 | 2.1672 * * | 1.9335 * | 1.7474 * | -9.2093 * ** | -9.0415 * ** | -8.8826 * ** |
| Ireland | -3.4508 * ** | -3.5443 * ** | -3.5772 * ** | -9.8999 * ** | -10.0148 * ** | -10.0641 * ** | 17.9915 * ** | 18.0221 * ** | 18.0639 * ** |
| Italy | -4.6072 * ** | -4.7088 * ** | -4.7774 * ** | -10.5367 * ** | -10.5775 * ** | -10.6107 * ** | 15.804 * ** | 15.7445 * ** | 15.7097 * ** |
| Japan | 11.4193 * ** | 11.3154 * ** | 11.316 * ** | 19.6334 * ** | 19.5215 * ** | 19.5769 * ** | 1.0829 | 1.0129 | 0.9399 |
| Mexico | 1.1391 | 1.0816 | 0.9962 | 4.8325 * ** | 4.7772 * ** | 4.6962 * ** | -5.9381 * ** | -5.9756 * ** | -6.0335 * ** |
| Netherlands | 2.5225 * * | 2.3941 * * | 2.296 * * | -1.6151 | -1.7694 * | -1.8896 * | 12.2117 * ** | 12.2693 * ** | 12.3324 * ** |
| New Zealand | 1.3563 | 1.1948 | 1.0591 | 4.2429 * ** | 4.2076 * ** | 4.1592 * ** | -4.233 * ** | -4.2781 * ** | -4.2919 * ** |
| Pakistan | -24.3649 * ** | -24.3817 * ** | -24.384 * ** | -25.0004 * ** | -25.073 * ** | -25.1189 * ** | 0.3856 | 0.5044 | 0.6016 |
| Russia | -1.9799 * * | -1.9509 * | -1.9036 * | -2.6379 * ** | -2.627 * ** | -2.6089 * ** | 2.854 * ** | 2.8627 * ** | 2.8763 * ** |
| Singapore | -5.6332 * ** | -5.6479 * ** | -5.6689 * ** | -4.8751 * ** | -4.8234 * ** | -4.791 * ** | -0.914 | -1.1469 | -1.3326 |
| Korea | -4.0494 * ** | -4.0541 * ** | -4.058 * ** | -2.876 * ** | -2.8779 * ** | -2.8791 * ** | -8.6045 * ** | -8.622 * ** | -8.6397 * ** |
| Spain | -5.9755 * ** | -6.0109 * ** | -6.0441 * ** | -4.7782 * ** | -4.8145 * ** | -4.8453 * ** | -8.4339 * ** | -8.4568 * ** | -8.4888 * ** |
| Sweden | -3.8535 * ** | -3.8807 * ** | -3.8982 * ** | -2.6595 * ** | -2.6722 * ** | -2.6796 * ** | -4.9114 * ** | -4.9676 * ** | -5.0058 * ** |
| UK | -5.0835 * ** | -5.1307 * ** | -5.1903 * ** | -4.1573 * ** | -4.1658 * ** | -4.2033 * ** | -5.8905 * ** | -6.0794 * ** | -6.194 * ** |
| USA | -5.2261 * ** | -5.2498 * ** | -5.2741 * ** | -4.7384 * ** | -4.7521 * ** | -4.767 * ** | -2.6004 * ** | -2.6709 * ** | -2.7373 * ** |
| Vietnam | -20.6082 * ** | -21.0647 * ** | -21.1913 * ** | -20.0668 * ** | -20.5238 * ** | -20.6621 * ** | -2.1526 * * | -2.1439 * * | -2.1291 * * |

**Note:** The figures in Columns 2–4 and Columns 5–7 are the DM* statistics that compare the GARCH-MIDAS model that is respectively based on global EUI (equally-weighted) and global EUI (GDP-Weighted) with the GARCH-MIDAS that is based on country-specific EUI (benchmark) model. Columns 8–10 are the DM* statistics that compare the GARCH-MIDAS model that is based on global EUI (equally-weighted) with the GARCH-MIDAS model that is based on global EUI (GDP-Weighted), where the latter is the benchmark. * ** , * * and * denote 1%, 5% and 10% significance levels, respectively. For Columns 2–7, significantly negative DM* statistics imply that the GARCH-MIDAS model based on the global EUI variants is preferred over the GARCH-MIDAS-RV model based on country-specific EUI; significantly positive DM* indicates a preference for the benchmark GARCH-MIDAS model with country-specific EUI; while non-significance indicates that the compared models are markedly different from one another. For Columns 8–10, significantly negative DM* statistics imply that the GARCH-MIDAS based on the global EUI (equally-weighted) variants is preferred over the GARCH-MIDAS model with global EUI (GDP-weighted), while significantly positive DM* indicates the converse.

**Table A3**
Campbell and Thompson (2008) Results (Realized Volatility-based Model is the Benchmark).

| Country | Country-Specific EUI Versus Realized Volatility | | | Global EUI [Equally weighted] Versus Realized Volatility | | | Global EUI [GDP-Weighted] Versus Realized Volatility | | |
|---|---|---|---|---|---|---|---|---|---|
| | $h=1$ | $h=5$ | $h=10$ | $h=1$ | $h=5$ | $h=10$ | $h=1$ | $h=5$ | $h=10$ |
| Australia | 2.00E-02 | 2.08E-02 | 2.13E-02 | 2.65E-02 | 2.83E-02 | 2.94E-02 | 2.71E-02 | 2.91E-02 | 3.04E-02 |
| Belgium | 1.40E-02 | 1.38E-02 | 1.43E-02 | 1.56E-02 | 1.54E-02 | 1.61E-02 | 2.08E-02 | 2.06E-02 | 2.12E-02 |
| Brazil | -1.55E-03 | -1.28E-03 | -9.81E-04 | 9.69E-03 | 1.04E-02 | 1.18E-02 | 1.19E-02 | 1.29E-02 | 1.44E-02 |
| Canada | 1.14E-01 | 1.17E-01 | 1.24E-01 | 1.79E-01 | 1.84E-01 | 1.94E-01 | 1.76E-01 | 1.81E-01 | 1.91E-01 |
| Chile | 5.57E-04 | 4.76E-04 | 4.53E-04 | 7.70E-03 | 7.94E-03 | 8.18E-03 | 1.07E-02 | 1.12E-02 | 1.16E-02 |
| China | -8.53E-03 | -8.04E-03 | -8.95E-03 | -4.11E-03 | -3.52E-03 | -4.77E-03 | -9.28E-03 | -8.83E-03 | -9.90E-03 |
| Colombia | 1.84E-02 | 1.77E-02 | 1.76E-02 | 1.64E-02 | 1.56E-02 | 1.55E-02 | 2.20E-02 | 2.14E-02 | 2.16E-02 |
| Croatia | -6.77E-02 | -6.79E-02 | -6.76E-02 | -7.12E-02 | -7.19E-02 | -7.27E-02 | -6.86E-02 | -6.94E-02 | -7.01E-02 |
| Denmark | -4.06E-03 | -4.12E-03 | -4.56E-03 | -2.03E-03 | -1.99E-03 | -1.97E-03 | 5.75E-03 | 5.81E-03 | 5.71E-03 |
| France | 1.22E-02 | 1.24E-02 | 1.28E-02 | 2.42E-02 | 2.51E-02 | 2.59E-02 | 1.96E-02 | 1.98E-02 | 2.05E-02 |
| Germany | -9.15E-04 | -7.07E-04 | -3.28E-04 | 6.04E-03 | 6.60E-03 | 7.01E-03 | 1.34E-03 | 1.54E-03 | 2.00E-03 |
| Greece | -1.52E-01 | -1.40E-01 | -1.21E-01 | 7.67E-02 | 7.44E-02 | 6.78E-02 | 7.93E-02 | 7.62E-02 | 7.10E-02 |
| India | -5.97E-03 | -6.32E-03 | -6.30E-03 | -5.44E-03 | -5.61E-03 | -5.08E-03 | -7.39E-03 | -7.48E-03 | -7.04E-03 |
| Ireland | 7.80E-04 | 5.42E-04 | 2.94E-04 | 5.77E-03 | 5.59E-03 | 5.99E-03 | 1.47E-02 | 1.47E-02 | 1.48E-02 |
| Italy | 7.28E-03 | 7.29E-03 | 7.62E-03 | 1.03E-02 | 1.04E-02 | 1.12E-02 | 1.67E-02 | 1.68E-02 | 1.75E-02 |
| Japan | -1.34E-02 | -1.29E-02 | -1.35E-02 | -2.25E-02 | -2.14E-02 | -2.29E-02 | -2.22E-02 | -2.15E-02 | -2.26E-02 |
| Mexico | -2.95E-03 | -2.95E-03 | -2.39E-03 | -4.06E-03 | -3.66E-03 | -3.22E-03 | -7.65E-03 | -7.36E-03 | -6.71E-03 |
| Netherlands | -6.31E-03 | -6.33E-03 | -6.45E-03 | -7.72E-03 | -7.70E-03 | -7.50E-03 | -4.90E-03 | -4.85E-03 | -4.78E-03 |
| New Zealand | -4.94E-03 | -4.69E-03 | -5.36E-03 | -5.16E-03 | -4.76E-03 | -5.25E-03 | -7.53E-03 | -7.00E-03 | -7.61E-03 |
| Pakistan | -1.46E-02 | -1.45E-02 | -1.44E-02 | 1.85E-03 | 1.72E-03 | 1.83E-03 | 2.01E-03 | 1.94E-03 | 1.94E-03 |
| Russia | 2.69E-02 | 2.72E-02 | 2.77E-02 | 2.76E-02 | 2.77E-02 | 2.83E-02 | 2.87E-02 | 2.89E-02 | 2.94E-02 |
| Singapore | 2.34E-03 | 3.67E-03 | 4.11E-03 | 1.83E-02 | 2.02E-02 | 2.09E-02 | 1.69E-02 | 1.85E-02 | 1.90E-02 |
| Korea | -3.72E-02 | -3.65E-02 | -3.59E-02 | -2.95E-02 | -2.84E-02 | -2.76E-02 | -3.25E-02 | -3.15E-02 | -3.06E-02 |
| Spain | 1.73E-02 | 1.74E-02 | 1.83E-02 | 3.36E-02 | 3.46E-02 | 3.57E-02 | 2.80E-02 | 2.88E-02 | 3.01E-02 |
| Sweden | -4.48E-03 | -4.07E-03 | -3.89E-03 | 8.46E-04 | 1.72E-03 | 1.87E-03 | -1.07E-03 | -3.00E-04 | -4.14E-05 |
| UK | 1.55E-02 | 1.57E-02 | 1.64E-02 | 3.06E-02 | 3.17E-02 | 3.32E-02 | 2.64E-02 | 2.75E-02 | 2.92E-02 |

(*continued on next page*)

**Table A3** (*continued*)

| Country | Country-Specific EUI Versus Realized Volatility | | | Global EUI [Equally weighted] Versus Realized Volatility | | | Global EUI [GDP-Weighted] Versus Realized Volatility | | |
|---|---|---|---|---|---|---|---|---|---|
| | $h=1$ | $h=5$ | $h=10$ | $h=1$ | $h=5$ | $h=10$ | $h=1$ | $h=5$ | $h=10$ |
| USA | 3.64E-02 | 3.69E-02 | 3.85E-02 | 6.80E-02 | 6.92E-02 | 7.19E-02 | 6.58E-02 | 6.69E-02 | 6.97E-02 |
| Vietnam | 1.43E-02 | 1.16E-02 | 9.59E-03 | 3.57E-02 | 3.32E-02 | 3.19E-02 | 3.52E-02 | 3.26E-02 | 3.17E-02 |

**Note:** The Campbell-Thompson (CT) test statistics compare each GARCH-MIDAS-EUI-based model with the GARCH-MIDAS-RV (benchmark) model. Positive statistics indicate higher precision of the former over the latter.

**Table A4**
Out-of-Sample Forecast Evaluation using Campbell Thompson Test (Comparison among the EUI-based Models).

| Country | Global EUI (Equally weighted) Versus Country-Specific EUI | | | Global EUI (GDP-Weighted) Versus Country-Specific EUI | | | Global EUI [Equally Weighted] Versus Global EUI [GDP-Weighted] | | |
|---|---|---|---|---|---|---|---|---|---|
| | $h=1$ | $h=5$ | $h=10$ | $h=1$ | $h=5$ | $h=10$ | $h=1$ | $h=5$ | $h=10$ |
| Australia | 6.64E-03 | 7.65E-03 | 8.21E-03 | 7.30E-03 | 8.48E-03 | 9.24E-03 | -6.67E-04 | -8.33E-04 | -1.04E-03 |
| Belgium | 1.57E-03 | 1.55E-03 | 1.80E-03 | 6.90E-03 | 6.82E-03 | 6.93E-03 | -5.36E-03 | -5.31E-03 | -5.17E-03 |
| Brazil | 1.12E-02 | 1.17E-02 | 1.28E-02 | 1.34E-02 | 1.42E-02 | 1.54E-02 | -2.23E-03 | -2.49E-03 | -2.62E-03 |
| Canada | 7.31E-02 | 7.50E-02 | 7.91E-02 | 7.00E-02 | 7.17E-02 | 7.58E-02 | 3.35E-03 | 3.62E-03 | 3.55E-03 |
| Chile | 7.15E-03 | 7.47E-03 | 7.73E-03 | 1.02E-02 | 1.07E-02 | 1.11E-02 | -3.04E-03 | -3.25E-03 | -3.44E-03 |
| China | 4.38E-03 | 4.49E-03 | 4.14E-03 | -7.49E-04 | -7.88E-04 | -9.46E-04 | 5.12E-03 | 5.27E-03 | 5.08E-03 |
| Colombia | -2.11E-03 | -2.15E-03 | -2.21E-03 | 3.59E-03 | 3.76E-03 | 4.07E-03 | -5.72E-03 | -5.94E-03 | -6.30E-03 |
| Croatia | -3.32E-03 | -3.78E-03 | -4.72E-03 | -8.86E-04 | -1.41E-03 | -2.32E-03 | -2.43E-03 | -2.37E-03 | -2.39E-03 |
| Denmark | 2.02E-03 | 2.11E-03 | 2.58E-03 | 9.77E-03 | 9.88E-03 | 1.02E-02 | -7.82E-03 | -7.85E-03 | -7.72E-03 |
| France | 1.21E-02 | 1.28E-02 | 1.32E-02 | 7.44E-03 | 7.49E-03 | 7.73E-03 | 4.67E-03 | 5.38E-03 | 5.52E-03 |
| Germany | 6.95E-03 | 7.30E-03 | 7.34E-03 | 2.25E-03 | 2.25E-03 | 2.33E-03 | 4.71E-03 | 5.06E-03 | 5.02E-03 |
| Greece | 1.99E-01 | 1.88E-01 | 1.69E-01 | 2.01E-01 | 1.90E-01 | 1.72E-01 | -2.84E-03 | -2.00E-03 | -3.52E-03 |
| India | 5.26E-04 | 7.03E-04 | 1.21E-03 | -1.41E-03 | -1.16E-03 | -7.40E-04 | 1.94E-03 | 1.86E-03 | 1.94E-03 |
| Ireland | 4.99E-03 | 5.06E-03 | 5.70E-03 | 1.39E-02 | 1.41E-02 | 1.45E-02 | -9.05E-03 | -9.21E-03 | -8.91E-03 |
| Italy | 3.08E-03 | 3.16E-03 | 3.61E-03 | 9.44E-03 | 9.53E-03 | 9.92E-03 | -6.42E-03 | -6.44E-03 | -6.38E-03 |
| Japan | -8.94E-03 | -8.42E-03 | -9.26E-03 | -8.70E-03 | -8.52E-03 | -8.91E-03 | -2.41E-04 | 1.01E-04 | -3.46E-04 |
| Mexico | -1.10E-03 | -7.08E-04 | -8.31E-04 | -4.68E-03 | -4.40E-03 | -4.31E-03 | 3.56E-03 | 3.67E-03 | 3.46E-03 |
| Netherlands | -1.40E-03 | -1.36E-03 | -1.05E-03 | 1.41E-03 | 1.48E-03 | 1.66E-03 | -2.81E-03 | -2.84E-03 | -2.71E-03 |
| New Zealand | -2.24E-04 | -7.45E-05 | 1.05E-04 | -2.58E-03 | -2.30E-03 | -2.24E-03 | 2.35E-03 | 2.22E-03 | 2.34E-03 |
| Pakistan | 1.62E-02 | 1.60E-02 | 1.60E-02 | 1.63E-02 | 1.62E-02 | 1.61E-02 | -1.54E-04 | -2.16E-04 | -1.09E-04 |
| Russia | 6.79E-04 | 5.69E-04 | 6.05E-04 | 1.85E-03 | 1.77E-03 | 1.75E-03 | -1.18E-03 | -1.20E-03 | -1.14E-03 |
| Singapore | 1.60E-02 | 1.66E-02 | 1.68E-02 | 1.46E-02 | 1.49E-02 | 1.50E-02 | 1.47E-03 | 1.78E-03 | 1.92E-03 |
| Korea | 7.39E-03 | 7.79E-03 | 8.00E-03 | 4.52E-03 | 4.83E-03 | 5.14E-03 | 2.88E-03 | 2.97E-03 | 2.87E-03 |
| Spain | 1.66E-02 | 1.75E-02 | 1.78E-02 | 1.08E-02 | 1.16E-02 | 1.21E-02 | 5.82E-03 | 5.97E-03 | 5.79E-03 |
| Sweden | 5.31E-03 | 5.76E-03 | 5.74E-03 | 3.39E-03 | 3.76E-03 | 3.83E-03 | 1.92E-03 | 2.01E-03 | 1.92E-03 |
| UK | 1.52E-02 | 1.63E-02 | 1.71E-02 | 1.10E-02 | 1.21E-02 | 1.29E-02 | 4.24E-03 | 4.31E-03 | 4.16E-03 |
| USA | 3.28E-02 | 3.36E-02 | 3.47E-02 | 3.05E-02 | 3.12E-02 | 3.24E-02 | 2.40E-03 | 2.51E-03 | 2.37E-03 |
| Vietnam | 2.17E-02 | 2.18E-02 | 2.25E-02 | 2.12E-02 | 2.12E-02 | 2.23E-02 | 5.17E-04 | 5.81E-04 | 2.39E-04 |

**Note:** The figures in Columns 2–4 and Columns 5–7 are the Campbell-Thompson (CT) statistics that compare the GARCH-MIDAS model that is respectively based on global EUI (equally-weighted) and global EUI (GDP-Weighted) with the GARCH-MIDAS that is based on country-specific EUI (benchmark) model. Columns 8–10 are the CT statistics that compare the GARCH-MIDAS model that is based on global EUI (equally-weighted) with the GARCH-MIDAS model that is based on global EUI (GDP-Weighted), where the latter is the benchmark. For Columns 2–7, positive CT statistics imply that the GARCH-MIDAS model based on the global EUI variants is preferred over the GARCH-MIDAS-RV model based on country-specific EUI; negative CT statistic indicates a preference for the benchmark GARCH-MIDAS model with country-specific EUI. For Columns 8–10, positive CT statistics imply that the GARCH-MIDAS based on the global EUI (equally-weighted) variants is preferred over the GARCH-MIDAS model with global EUI (GDP-weighted), while negative CT indicates the converse.

## References


Abiad, A., & Qureshi, I. A. (2023). The macroeconomic effects of oil price uncertainty. *Energy Economics, 125*(C), Article 106389.

Afkhami, M., Cormack, L., & Ghoddusi, H. (2017). Google search keywords that best predict energy price volatility. *Energy Economics, 67*, 17–27.

Ahir, H., Bloom, N., Furceri, D. (2022). The World Uncertainty Index. In: National Bureau of Economic Research Working Paper Series, No. 29763.

Bańbura, M., Giannone, D., & Reichlin, L. (2011). Nowcasting. In P. Michael, & D. F. Hendry (Eds.), *Oxford Handbook on Economic Forecasting* (pp. 63–90). Oxford University Press.

Bernanke, B. S. (1983). Irreversibility, uncertainty, and cyclical investment. *Quarterly Journal of Economics, 98*(1), 85–106.

Bloom, N. A. (2009). The impact of uncertainty shocks. *Econometrica, 77*(3), 623–685.

Bollerslev, T. (1986). Generalized Autoregressive Conditional Heteroskedasticity. *Journal of Econometrics, 31*(3), 307–327.

Bollerslev, T. (2023). The story of GARCH: A personal odyssey? *Journal of Econometrics, 234*, 96–100 (Supplement).

Campbell, J. Y. (2008). Viewpoint: estimating the equity premium. *Canadian Journal of Economics, 41*(1), 1–21.

Campbell, J. Y., & Thompson, S. B. (2008). Predicting excess stock returns out of sample: Can anything beat the historical average? *The Review of Financial Studies, 21*(4), 1509–1531.

Clements, M. P., & Galvão, A. B. (2008). Macroeconomic forecasting with mixed-frequency data. *Journal of Business and Economic Statistics, 26*(4), 546–554.

Colacito, R., Engle, R. F., & Ghysels, E. (2011). A component model for dynamic correlations. *Journal of Econometrics, 164*(1), 45–59.

Cross, J., Nguyen, B. H., & Tran, T. D. (2022). The role of precautionary and speculative demand in the global market for crude oil. *Journal of Applied Econometrics, 37*(5), 882–895.

Cross, J., & Nguyen, B. H. (2018). Time-varying macroeconomic effects of energy price shocks: a new measure for China. *Energy Economics, 73*, 146–160.

Dang, T. H.-N., Nguyen, C. P., Lee, G. S., Nguyen, B. Q., & Le, T. T. (2023). Measuring the energy-related uncertainty index. *Energy Economics, 124*, Article 106817.

Degiannakis, S., Filis, G., & Arora, V. (2018). Oil prices and stock markets: A review of the theory and empirical evidence. *The Energy Journal, 39*(5), 85–130.

Diebold, F. X., & Mariano, R. S. (1995). Comparing predictive accuracy. *Journal of Business & Economic Statistics, 13*(3), 253–263.

Dutta, A., Bouri, E., Saeed, T., & Vo, X. V. (2020). Impact of energy sector volatility on clean energy assets. *Energy, 212*, Article 118657.

Engle, R. F. (1982). Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation. *Econometrica, 50*(4), 1987, 1007.

Engle, R. F., Ghysels, E., & Sohn, B. (2013). Stock market volatility and macroeconomic fundamentals. *The Review of Economics and Statistics, 95*(3), 776–797.

Feng, J., Wang, Y., & Yin, L. (2017). Oil volatility risk and stock market volatility predictability: Evidence from G7 countries. *Energy Economics, 68*, 240–254.

Ghani, M., & Ghani, U. (2023). Economic policy uncertainty and emerging stock market volatility. *Asia-Pacific Financial Markets*. DOI: https://doi.org/10.1007/s10690-023-09410-1.

Ghysels, E., Plazzi, A., Valkanov, R., Rubia, A., & Dossani, A. (2019). Direct versus iterated multi-period volatility forecasts. *Annual Review of Financial Economics, 11*, 173–195.

Ghysels, E., & Valkanov, R. (2012). Forecasting volatility with MIDAS. In L. Bauwens, C. Hafner, & S. Laurent (Eds.), *Handbook of volatility models and their applications* (pp. 383–401). Hoboken, New Jersey, United States: John Wiley & Sons, Inc.

Gong, X., Zhang, W., Xu, W., & Li, Z. (2022). Uncertainty index and stock volatility prediction: evidence from international markets. *Financial Innovation, 8*, 57.

Harvey, D., Leybourne, S., & Newbold, P. (1997). Testing the equality of prediction mean squared errors. *International Journal of Forecasting, 13*(2), 281–291.

Jurado, K., Ludvigson, S. C., & Ng, S. (2015). Measuring uncertainty. *American Economic Review, 105*(3), 1177–1216.

Kilian, L. (2008). The economic effects of energy price shocks. *Journal of Economic Literature, 46*(4), 871–909.

Li, D., Zhang, L., & Li, L. (2023). Forecasting stock volatility with economic policy uncertainty: A smooth transition GARCH-MIDAS model. *International Review of Financial Analysis, 88*, Article 102708.

Liu, Z., Ye, Y., Ma, F., & Liu, J. (2017). Can economic policy uncertainty help to forecast the volatility: A multifractal perspective. *Physica A: Statistical Mechanics and Its Applications, 482*, 181–188.

Liu, L., & Zhang, T. (2015). Economic policy uncertainty and stock market volatility. *Finance Research Letters, 15*, 99–105.

Ludvigson, S. C., Ma, S., & Ng, S. (2021). Uncertainty and Business Cycles: Exogenous Impulse or Endogenous Response? *American Economic Journal: Macroeconomics, 13*(4), 369–410.

Megaritis, A., Vlastakis, N., & Triantafyllou, A. (2021). Stock market volatility and jumps in times of uncertainty. *Journal of International Money and Finance, 113*, Article 102355.

Melichar, M. (2016). Energy price shocks and economic activity: which energy price series should we be using? *Energy Economics, 54*, 431–443.

Nguyen, B. H., Okimoto, T., & Tran, T. D. (2022). Uncertainty and sign-dependent effects of oil market shocks. *Journal of Commodity Markets, 26*(C), Article 100207.

Poon, S.-H., & Granger, C. W. J. (2003). Forecasting volatility in financial markets: A review. *Journal of Economic Literature, 41*(2), 478–539.

Qin, P., & Bai, M. (2022). Does oil price uncertainty matter in stock market volatility forecasting? *PLoS One, 17*(12), Article e0277319.

Rapach, D. E., Strauss, J. K., & Wohar, M. E. (2008). Forecasting stock return volatility in the presence of structural breaks, in Forecasting in the Presence of Structural Breaks and Model Uncertainty. In D. E. Rapach, & M. E. Wohar (Eds.), *of Frontiers of Economics and Globalization* (Vol. 3, pp. 381–416). Bingley, United Kingdom: Emerald.

Salisu, A. A., Cunado, J., Isah, K., & Gupta, R. (2021). Oil price and exchange rate behaviour of the BRICS. *Emerging Markets Finance and Trade, 57*(7), 2042–2051.

Salisu, A.A., Demirer, R., and Gupta, R. (Forthcoming a). Technological Shocks and Stock Market Volatility Over a Century: A GARCH-MIDAS Approach. Journal of Empirical Finance.

Salisu, A. A., Demirer, R., & Gupta, R. (2022a). Financial turbulence, systemic risk and the predictability of stock market volatility. *Global Finance Journal, 52*, Article 100699.

Salisu, A. A., Demirer, R., & Gupta, R. (2023). Policy uncertainty and stock market volatility revisited: the predictive role of signal quality. *Journal of Forecasting, 42*(8), 2307–2321.

Salisu, A. A., Gupta, R., Bouri, E., & Ji, Q. (2022b). Mixed-frequency forecasting of crude oil volatility based on the information content of global economic conditions. *Journal of Forecasting, 41*(1), 134–157.

Salisu, A. A., & Gupta, R. (2021). Oil Shocks and Stock Market Volatility of the BRICS: A GARCH-MIDAS. *Global Finance Journal, 48*, Article 100546.

Salisu, A.A., Gupta, R., Cepni, O., and Caraiani, P. (Forthcoming b). Oil Shocks and State-Level Stock Market Volatility of the United States: A GARCH-MIDAS Approach. Review of Quantitative Finance and Accounting.

Schwert, G. W. (1989). Why does stock market volatility change over time? *Journal of Finance, 44*(5), 1115–1153.

Segnon, M., Gupta, R., & Wilfling, B. (2024). Forecasting stock market volatility with regime switching GARCH-MIDAS: the role of geopolitical risks. *International Journal of Forecasting, 40*(1), 29–43.

Shiller, R. J. (1981a). Do stock prices move too much to be justified by subsequent changes in dividends? *American Economic Review, 71*(3), 421–436.

Shiller, R. J. (1981b). The use of volatility measures in assessing market efficiency. *Journal of Finance, 36*(2), 291–304.

Smyth, R., & Narayan, P. K. (2018). What do we know about oil prices and stock returns? *International Review of Financial Analysis, 57*, 148–156.

Wang, J., Gupta, R., Çepni, O., & Ma, F. (2023a). Forecasting international REITs volatility: the role of oil-price uncertainty. *The European Journal of Finance, 29*(14), 1579–1597.

Wang, J., Ma, F., Bouri, E., & Zhong, J. (2022). Volatility of clean energy and natural gas, uncertainty indices, and global economic conditions. *Energy Economics, 108*(C), Article 105904.

Wang, L., Ma, F., Liu, J., & Yang, L. (2020). Forecasting stock price volatility: new evidence from the GARCH-MIDAS model. *International Journal of Forecasting, 36*(2), 684–694.

Wang, L., Wu, R., Ma, W., & Xu, W. (2023b). Examining the volatility of soybean market in the MIDAS framework: The importance of bagging-based weather information. *International Review of Financial Analysis, 89*(C), Article 102720.

Xiao, J., Fenghua, W., Yupei, Z., & Xiong, W. (2021). The role of US implied volatility index in forecasting Chinese stock market volatility: Evidence from HAR models. *International Review of Economics & Finance, 74*, 311–333.

Yu, X., Huang, Y., & Xiao, K. (2021). Global economic policy uncertainty and stock volatility: evidence from emerging economies. *Journal of Applied Economics, 24*(1), 416–440.