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Analyzing the relationship between global REITs and exchange rates: Fresh evidence from frequency-based quantile regressions

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Abstract

Purpose: This paper investigates the asymmetric dependence structure between real estate investment trusts (REITs) and currencies from Europe, North America, Asia, and Australasia.

Design/methodology/approach: The papers uses the Ensemble Empirical Mode Decomposition (EEMD) technique to decompose return series into short-term, medium-term, and long-term scales termed Intrinsic Mode Functions (IMFs) and further examines the asymmetric association between selected country REIT indices and their respective exchange rates (against the dollar) using both Quantile Regression Analysis (QRA) and Quantile-in-Quantile Regression (QQR) models.

Findings: Both QRA and QQR adequately capture the frequency-variant asymmetric link between REITs and exchange rates across different geographical locations. Associations are similar for Australia, Canada, France, and New Zealand as a group and for Germany, Hong Kong, Japan, and Singapore as another group in terms of direction, magnitude, and time horizons at which they occur. Positive and negative associations in Asia are the strongest across quantiles in the long-term.

Originality/value: The current literature on REITs-macroeconomic nexus is largely linear, asymmetric and does not address the impact on market noise. We contribute to the literature by employing a noise-reduction technique to the relationship between REITs and exchange rates. This approach reinforces the inefficient market hypothesis in the REITs-macroeconomic nexus. These are supported by the adaptive market hypotheses (AMH) and heterogeneous market hypotheses (HMH).

Practical implications: The study reveals the effect of exchange rates on the selected REITs market and the important role of currencies in international investors' decision-making process. The study reinforces the inefficient market hypothesis in the REIT-macroeconomic nexus. Further, this study engenders new insights into REIT investments in light of exchange rate fluctuations amidst market inefficiencies.

Keywords*:* empirical mode decomposition; exchange rates; REITs; quantile regressions; frequency-dependence; intrinsic mode function

JEL Classification: R1, R3, C1, E40

Paper type: Research paper

1. Introduction

One fundamental challenge that investors constantly face is selecting an investment that maximizes return and offers the least risk (Crosby et al., 2016; Ijasan et al., 2019). Investors can choose to invest directly through the acquisition of income-producing properties or indirectly through real estate investment trusts (REITs) (Ho et al., 2013). Compared to direct real estate investment (DREI), investors holding REITs do not suffer the burden associated with the management of real properties without jeopardizing regular income flow and capital appreciation, which are the main aspirations of every investor (Clayton & MacKinnon, 2001; Hoesli & Oikarinen, 2012). While international investors often encounter several challenges relating to regulation and knowledge of the market when investing directly in real estate, REITs offer them the opportunity to invest in any economy of their choice with a moderate degree of confidence (Ijasan et al., 2019). Moreover, as Hoesli and Oikarinen (2012) argued, REITs are characterized by their relatively low transaction costs, ease of conversion, and availability of smaller investible units. Stephen and Simon (2005) claim that these benefits combine to make REITs the preferred choice for many investors around the globe. Furthermore, REITs have been seen as substitutes for the real estate markets given the long-term relationship between the two (Hoesli & Oikarinen, 2012). The substitutability provides flexibility for investors to switch between these assets depending on which one is more profitable. This has been evidenced by cointegrating dynamics between them (see Boudry et al., 2012; Eng, 1995; Oikarinen et al., 2011; Yunus et al., 2012).

However, the investment market is not limited to the real estate sector alone, and investors must be conversant with the wider investment universe and leverage opportunities beyond the real estate investment markets (Yunus et al., 2012). To maximize return and minimize risk, rational investors strategically create investment portfolios by combining investments of opposing characteristics in terms of returns, risks, and volatility (Geiger et al., 2013). For indirect real estate investment, diversification benefits can be derived by investing in REITs and other investment options such as direct real estate and stocks (Caporale et al., 2014; Hoesli & Oikarinen, 2012). With the opportunities offered by foreign exchange markets (Tang et al., 2016; Rajput, Ghumro, & Anjum, 2019) and the increasing global attention given to REITs, Ngo (2017) argues that they have induced considerable attention from relevant stakeholders as a potential investment portfolio mix. Beyond their individual potential, investors now pay due attention to the diversification benefits of investing in REITs and trading in currencies.

Nonetheless, while REIT equities are becoming more "attractive as a trading avenue to add real estate exposure to a portfolio because of their historically high returns and high dividends," as argued by Ijasan et al. (2019, p. 3), they are equally vulnerable to their respective national economic environments (Sumer & zorhon, 2020). The susceptibility of REITs to shocks emanating from the domestic economy makes it imperative to explore the connection between them and provide a clear understanding of how REITs interact with key macroeconomic indicators and changes in the exchange rate market (Owusu Junior et al., 2018; Tangjitprom et al., 2016). For rational investment decisions and optimal portfolio creation, it is important to understand the nature and degree of the relationship between REITs and exchange rates over different time horizons. Studies on diversification potential have focused on REITs and DREIs on one hand (Hoesli & Oikarinen, 2012; Yunus et al., 2012) and between REITs and stocks on the other (Lee Stevenson, 2005; Tangjitprom et al., 2016).

Given the effects of foreign exchange rate changes on REITs (Ngo, 2017) and other macroeconomic variables (Sadhwani et al., 2019; Marfatia et al., 2020, 2020a; Gupta & Marfatia, 2018; Marfatia et al., 2017; Nguyen, Huynh & Wong, 2021; etc.), there is an increasing appetite for the combination of REITs and currencies in a single investment portfolio. In particular, Nyakabawo et al. (2018) examined the surprise impact of U.S. monetary policy and macroeconomic variables on the returns and volatility of the local housing market. While macroeconomic surprises did not affect housing returns, monetary policy had a much greater impact on returns across different periods (see also, Wang & Hartzell, 2020; Feng & Wu, 2021; Marfatia et al., 2021; Cohen & Burinskas, 2020; Mansur et al., 2020; Wang & Zong, 2020; Victor & Razali, 2019; etc.). According to Aye and Gupta (2019), even macroeconomic uncertainties can influence buying versus renting in the United States, affecting the performance of REITs. It has also become crucial for new research to explore possible interactions between the two investment options to aid in diversification and risk management (see Coşkun et al., 2017; Liow & Huang, 2018; etc.).

While some studies have ventured to explore the relationship between REITs and macroeconomic variables (e.g., Chiang, Lean & Wong, 2008; Kola & Kodongo, 2017; Ngo, 2017; Pierdzioch et al., 2019; Reddy & Wong, 2018; Wong & Reddy, 2018; etc.), many of these studies fail to account for the asymmetric nexus between them and the adaptive nature of the markets and their participants. Other studies (e.g., Caraiani et al., 2021; Gupta et al., 2019; Khan & Siddiqui, 2019; Lin et al., 2021; Liu & Mei, 1998; Liu et al., 2012; etc.) have also recognized the adaptive and time-varying dynamics in the market for REITs and macroeconomic components. Nonetheless, these studies assume that all market participants operate rationally, which is mostly not the case, especially under stressed market conditions (Gestel et al., 2001). It is clear from the literature that the link between REITs and exchange rates, for instance, is not one-to-one and thus non-linear and asymmetric. It is further established in the extant literature that the behavior patterns of investors usually vary across time. The adaptive market hypothesis (AMH) (Lo, 2004) and the heterogeneous market hypothesis (HMH) (Müller et al., 1993) support these dynamics in contrast to the efficient market hypothesis (EMH) (Fama, 1970, 1991). Cornell (2018) further argues that these produce varying shades of rationality (and irrationality) that are state-dependent across time and investors (see also, Acevedo et al., 2021). Unlike the aforementioned studies, this paper accounts for these complexities as a way of addressing the gaps in the REITs-exchange rates nexus literature. In so doing, we employ techniques that can examine non-linearity, asymmetries, adaptiveness, and reduce noise in the series.

We use the Ensemble Empirical Mode Decomposition (EEMD) technique to decompose return series into short-, medium-, and long-term scales (Müller et al., 1993) as well as reduce noise (Wu & Huang 2009). The decomposition into time scales accounts for the adaptive and non-homogeneous patterns in investor behavior and asset returns (Owusu Junior et al., 2021; Asafo-Adjei, Owusu Junior & Adam, 2021). Noise reduction also enhances the accuracy of results and analysis (Hassani, Dionisio, & Ghodsi, 2010; Owusu Junior et al., 2021a). In addition, we use quantile regression and quantile-in-quantile regressions to account for the non-linear and asymmetric link between REITs and exchange rates for more detailed revelations (Koenker, 2005; Koenker & Bassett, 1978; Koenker & Hallock, 2001; Chi et al., 2014; Sim & Zhou, 2015; Ng, Wong, & Xiao, 2017). This paper also follows the increasing importance of the quantile regression approach in the literature to examine asymmetric relationships (Al-Yahyaee et al., 2021; Caporin et al., 2021; Ngene et al., 2020; Ngene et al., 2017; etc.).

We analyse the link between REITs and exchange rates in the context of how appreciation or depreciation of currencies affects investments in REITs. The analysis is predicated on the assumption that REITs and stocks are similar and are likely to be influenced by the same exchange rates and broader country-level macroeconomic indicators (Huang et al., 2011; Owusu Junior et al., 2018).study is important for the following reasons: first, understanding the currency markets in the various countries as well as the potential and risks they present can serve as a framework for decision-making. Second, this understanding would serve as a guide for international investors and fund managers in the determination of which REITs and currencies to invest in and how to select assets for portfolio purposes in the face of currency risks. Third, the EEMD technique employed for the analysis can decompose price return series into short-, medium-, and long-term scales (Müller et al., 1993). According to Wu and Huang (2009), the technique is versatile for "extracting signals from data generated in noisy non-linear and non-stationary processes" (Wu & Huang, 2009; p. 1). Noise in time series data leads to inaccurate analysis and distorted results. The use of EEMD, therefore, helps to tackle these problems for better inferences. In total, our study is relevant for both policymakers and investors who desire to assess the fine-tuned relationship between REITs and exchange rates as well as other macroeconomic variables. The detailed asymmetric and non-linear results imply that decisions should be tailor-made for specific portions of the return distribution of REITs and macroeconomic variables, as well as for specific countries. In addition, policies and investment decisions need to account for the irrationality of participants, especially during turbulent market periods. This implies that decisions may have to be as adaptive as the behavior in the market for them to be useful. In this sense, policies to stabilise or incentivise investors will not be lost in the noise that usually plagues the markets where macroeconomic surprises and private investment decisions meet.

In the end, this paper makes some contributions to the literature. First, we contribute to the empirical application of the adaptive market and heterogeneous market hypotheses. The frequency-based quantile regressions address non-linearity, asymmetry, time-horizon dependent, and non-homogeneous relationships in the markets espoused by both AMH and HMH. Second, by employing the EEMD as a noise-reduction technique in the relationship between REITs and exchange rates, we contribute to the inefficient market hypothesis. This approach reinforces the inefficient market hypothesis by extracting the noise produced by the irrational behavior of investors due to fear and uncertainty concerning the REIT-macroeconomic nexus. Third, our findings corroborate a plethora of studies that question the entrenched EMH (see, Asafo-Adjei et al., 2021a; Asafo-Adjei, Adam & Darkwa, 2021; Boateng, Adam & Owusu Junior, 2021). Four, the study advances existing empirical evidence on the interaction between REITs and currencies in the context of portfolio investment and diversification. While studies have evaluated interrelationships among REITs in various countries and the role of economic indicators, including exchange rates, limited attention has been given to the diversification potential of having REITs and currencies in a single portfolio (Liu et al., 2012; Mull & Soenen, 1997). Kroencke and Schindler (2012) assessed the contribution of international REITs to an internationally diversified mixed-asset portfolio and found that there are significant diversification benefits for global bond and stock portfolios from investing in international REITs. They also noted that "accounting for currency risk exposure of international assets is helpful to separate the true diversification benefits from global bonds, stocks, and real estate" (Kroencke & Schindler, 2012; p. 1865). Despite being considered a critical imperative to the analysis of international diversification benefits, currency risk exposure is often neglected in empirical studies, and this is one of the gaps this study aims to fill.

Furthermore, the data used in this study and the analytical technique employed make it unique and clearly distinguishable from the existing literature. Findings from this study will be useful to international investors and their advisors in making decisions regarding when, where, and how to allocate investable funds, especially to portfolios involving REITs and currencies. Since economic factors affect exchange rates, the study will help in evaluating how the macroeconomic landscape affects the performance of REITs.

1.2 Global REITs context

The REIT market has gained momentum since 1999 (EPRA, 2019), with the US leading the chart as compared to Europe and other markets. The US REIT market keeps its lead due, in part, to its resilience. The US commercial property market was one of the hardest hit by the GFC and the quickest to rebound in the aftermath (Marzuki & Newell, 2017). Due to the desirable properties of REITs, there has been rapid growth and potential in the REIT markets for late-comers such as Belgium and South Africa (Akinsomi et al. 2017; Marzuki & Newell, 2019).

When it comes to the global index of REITs, every other market is small relative to the United States (US), which weighs about 65%. For instance, Japan is the second-largest after the US, with an 8.23% proportion of the Global REIT Index (EPRA, 2019). The various percentages of the Global REIT Index used in this study are Japan (8.23), Australia (5.91), the UK (4.79), Canada (3.23), Singapore (2.26), Hong Kong (2.25), France (1.77), The Netherlands (1.83), Germany (0.25), and New Zealand (0.12). Our selection is also based on the availability of data, size, and representativeness of the REIT markets in each region. The EPRA classifies REIT regions as Europe, the Americas, Asia-Pacific, and Africa and the Middle East. Countries in each of these regions are selected in the study according to their size and characteristic representation of the region, except for Africa and the Middle East. While South Africa enjoys 1.8% of the global REIT market, the remaining markets in the region are insignificant. The global proportions are as follows: Turkey (0.04%), the Kingdom of Saudi Arabia (0.02%), Israel (0.00%), and the United Arab Emirates (0.00%). The inclusion of the South African REITs into the REITs becomes an isolated case; there will not be another country to compare with in the region. As stated earlier, the momentum of the REIT market started in 1999 (EPRA, 2019). That is why our earliest data is from 2000 and the latest is from 2015. All these choices of data are further motivated by the fact that this study examines the relationship between REITs and exchange rates. Hence, we select sample data for matching periods for the two variables.

Our empirical results indicate that quantile and quantile-in-quantile regressions adequately capture the frequency-varying asymmetric link between REITs and exchange rates across different geographical locations. The relationships are similar for Australia, Canada, France, and New Zealand as a group and Germany, Hong Kong, Japan, and Singapore as another group in terms of direction, magnitudes, and frequencies. Findings from this study engender new insights into REIT investments in light of exchange rate fluctuations in the different regions and countries of REIT markets. The remainder of the paper is as follows: Section 2 presents models and methodologies. Section 3 details the data and preliminary presentations of the study, followed by detailed analysis and discussion of the outputs. Section 5 concludes the study with directions for future research.

2. Models and methodologies

This study partly reproduces the methods employed by Owusu Junior and Tweneboah (2020), Owusu Junior et al. (2020), and Owusu Junior et al. (2020). The main idea is to investigate the asymmetric relationship between the selected RETs and exchange rates. But we also employ data that accounts for the heterogeneous investor preferences. To achieve this, we employ the EEMD and quantile regression analysis (QRA), and Quantile-in-Quantile Regression (QQR) techniques in a two-step approach. We use the noise-reducing method of

EEMD to extract intrinsic mode functions (IMFs) from the selected currencies and REITs which identify with different time horizons. The IMFs represent different time scales of the original time series while the QRA and QQR address the asymmetry in the relationships. Both techniques help to address the complexity of stylised facts of the time series which we deem important to this study (Ivanov, 2013). The EEMD sifts through the original series with a sufficient number of iterations. In the process, white noise is added to provide a uniform reference in the frequency domain (Wu and Huang, 2009).

2.1 Ensemble empirical mode decomposition (EEMD)

As a successor to empirical mode decomposition (EMD), the EEMD builds on the EMD objective to further reduce noise. The specific details are described in Wu & Huang (2009) and followed in this study.

The EEMD defines the IMF components as the mean of an ensemble of trials, where each is made of the signal (data) and white noise of finite amplitude. In generic terms, all data $x(t)$ are a sum of signal (i.e., actual data,$s(t)$) and noise $n(t)$ so that

$$x(t) = s(t) + n(t) \tag{1}$$

The EEMD adds white noise to remove weak signals and keep the true signal. This is based on inspirations from Flandrin, Rilling, & Goncalves (2004) and Gledhill (2003). The cancellation (effects) principle[1] associated with an ensemble of noise-added cases to improve results. From Eq. (1), an i^{th} synthetic observation, $x_i(t)$ in Eq. (2) is obtained by adding a white noise of different realisations, $\omega_i(t)$ which avoid mode mixing with a relatively uniform reference scale distribution to facilitate EMD.

$$x_i(t) = x(t) + \omega_i(t) \tag{2}$$

The development of EEMD relies on the properties of EMD of Huang et al. (1998) and Huang, Shen, & Long (1999) in the following manner:

1. add white noise to the targeted data to arrive at $x_i(t)$
2. decompose $x_i(t)$ into IMFs
3. iterate 1 and 2 with varying white noise series and
4. obtain the (ensemble) means of corresponding IMFs of the decomposition as the result.

[1] See de Cheveigné (2005) for further details.

The important final feature is that the mean IMFs reside within the natural dyadic filter windows to evades the mode mixing problem. The largest number of IMFs s_i (and one residual r) of a data set is approximately $log_2 N$ where N represents the total number of data points. Thus, r can be represented as $s_i - (s_i - 1)$.

2.2 Quantile-in-Quantile Regression (QQR)

The QQR technique is the non-parametric version of the QRA. There are no parameters to examine the adequacy of the estimates hence an approximation between the QRA and QQR is the empirical justification of the conditional quantile relationship between the variables. The QQR technique seems appropriate to study the rising and/or declining market relationship between currencies and REITs since quantiles can describe the asymmetry between the high and low returns of price patterns. Thus, we can see the relationship between currency depreciation/appreciation and REITs. It starts with the nexus below as:

$$RR_t = \beta^{\theta}(ER_t) + u_t^{\theta} \tag{3}$$

where RR_t and ER_t denote the log-returns of the selected REITs and domestic currency[2] at period *t*, θ is the θth quantile of the conditional distribution of RR_t and u_t^{θ} is the error quantile whose θth conditional quantile is made up to be zero, and $\beta^{\theta}(\cdot)$ represents the slope of this relationship. By expanding (3) through the order Taylor rule, the quantile of ER^{τ} is given as:

$$\beta^{\theta}(ER_t) \approx \beta^{\theta}(EXR^{\tau}) + \beta^{\theta'}(ER^{\tau})(EX_t - ER^{\tau}) \tag{4}$$

where $\beta^{\theta'}$explains the partial derivative of $\beta^{\theta}(ER_t)$ which represent the marginal effect. We see that θ is the functional form of $\beta^{\theta}(ER^{\tau})$ and $\beta^{\theta'}(ER^{\tau})$ while τ is the functional form of ER and ER^{τ}, hence θ and τ are the functional forms of $\beta^{\theta}(ER^{\tau})$ and $\beta^{\theta'}(ER^{\tau})$. If we represent $\beta^{\theta}(ER^{\tau})$ and $\beta^{\theta'}(ER^{\tau})$ by $\beta_0(\theta,\tau)$ and $\beta_1(\theta,\tau)$, respectively, then (5) can suffice

$$\beta^{\theta}(ER_t) \approx \beta_0(\theta,\tau) + \beta_1(\theta,\tau)(ER_t - ER^{\tau}). \tag{5}$$

By substituting (5) into (3), we arrive at the (6) as:

$$RR_t = \underbrace{\beta_0(\theta,\tau) + \beta_1(\theta,\tau)(ER_t - ER^{\tau})}_{(*)} + u_t^{\theta} \tag{6}$$

where (*) gives the conditional quantile of θth of REITs returns. Furthermore, it reveals the actual association between the quantile of currency returns (θth) and the quantile of REITs

[2] Exchange rates are given in their respective local currency to the US dollar and REITs are denominated in US dollars.

returns (τth) of parameters β_0 and β_1 with indices of θ and τ. A similar minimization in the ordinary least squares framework results in

$$\min_{b_0,b_1} \sum_{i=1}^{n} \rho_\theta \left[ER_t - b_0 - b_1\left(\widehat{ER}_t - \widehat{ER}^\tau\right)\right] K\left(\frac{F_n(\widehat{ER}_t)-\tau}{h}\right) \quad (7)$$

where $\rho_\theta(u)$ is the quantile loss function represented as $\rho_\theta(u) = u\big(\theta - I(u < 0)\big)$, i is the function of indicator, $K(\cdot)$ is the kernel density function and h denotes kernel density function bandwidth parameter. The kernel function weights the observations of ER^τ where the minimal weights are negatively related to the distribution function of $\widehat{ER}_t$ as $F_n\big(\widehat{ER}_t\big) = \frac{1}{n}\sum_{k=1}^{n} I(\widehat{ER}_k < \widehat{ER}_t)$. In the spirit of Sim and Zhou (2015), we use the quantile bandwidth of $h = [0.05\ to\ 0.95]$ for empirical analysis (see also, Koenker, 2005; Koenker & Bassett, 1978; Koenker & Hallock, 2001).

By using QRA and QQR and IMFs as inputs, we are able to quantify the relationship between currency and REITs in a way that captures their frequency-dependent, non-linear, and non-stationary link. Furthermore, this allows us to infer the nexus during upward and downward market episodes in the short-, medium-, and long-terms. This study is novel as it provides fresh insights concerning how REITs and foreign exchange can be combined to create investment portfolios that satisfy profit-maximization and risk-minimization goals.

3. Data and preliminary results

We used daily frequency data from REITs and exchange rates for this study. These and their corresponding IMFs are presented in Table 1. The REITs are selected based on their proportion of the global REIT index, matching available data for respective exchange rates. Furthermore, we have selected sample periods for REITs based on the available data for each country. This explains why sample periods are not the same for all countries and why they do not match the history of REITs in each country. We gleaned all the data from Bloomberg Terminal. The US REITs are excluded because all REITs are denominated in USD and the local currency is given as the local currency against the USD. Thus, it will not be useful to examine the currency-REIT nexus for the US. We use direct quotations of exchange rates in this study. We further note that rising (bear market) values indicate depreciation of the local or domestic currency, while falling (bull market) rates signify the appreciation of the local currency.

One strength of the EEMD is that it endogenously decomposes series into many IMFs depending on the length of the series to represent time horizons. In the literature, IMF 1, IMF 5/IMF 6, and IMF Residual[3] are taken as representing short-, medium-, and long-term dynamics, in that order (see Table 1).

Table 1. Details of sampled data

Market	Period	No. of IMFs
Australia	30/11/2012 – 18/02/2019	10
Canada	30/11/2012 – 15/02/2019	10
France	09/07/2015 – 18/02/2019	9
Germany	30/11/2012 – 15/02/2019	10
Hong Kong	30/11/2012 – 18/02/2019	10
Japan	01/04/2003 – 22/02/2019	11
The Netherlands	03/01/2000 – 18/02/2019	11
New Zealand	30/11/2012 – 18/02/2019	10
Singapore	13/03/2006 – 18/02/2019	11
United Kingdom	02/01/2007 – 18/02/2019	11

Table 2 presents summary statistics of the variables for this study. The skewness and excess kurtosis are confirmed by the Shapiro-Wilk test for normality. The log-return series and their IMFs are asymmetric and leptokurtic. The asymmetry implies that there is not a direct correspondence between the amount and direction of changes in the currencies and REITs' returns. Furthermore, in terms of leptokurtosis, there is a tendency for extremely high or low returns to occur in the data for the study period. These occurrences have been observed in REITs in all the countries in this study and are typical of REITs in general (see Abuzayed et al., 2020; Akinsomi et al., 2014; Chang & Chen, 2014; Ling & Naranjo, 2015; Nazlioglu et al., 2020). This signals to investors to be wary of the price movements in both REITs and exchange rates as they affect the rewards of investments in either or both of these assets. Moreover, extreme returns tend to have leverage effects, pulling subsequent REITs or exchange rate returns in an unfavourable direction for investors. Investors are better off with returns that taper around the average for safety in investments. At a higher level, to model such extreme returns, it is important to apply techniques that capture these patterns very well. This strongly supports the use of quantile-based regressions to analyse the global currency-

[3] IMFs 5 is chosen to represent medium term for markets with a total of 10 IMFs, such as France.

REITs link. The time series plots presented in Figure 1 (in the Appendix) also show volatility clusters and thus indicate the frequency-varying risk levels in the series. This also suggests that IMFs are useful regression models.

Table 2. Summary of return series and IMFs

Statistic	RR	ER	RR_IMF1	RR_IMF6	RR_IMFR	ER_IMF1	ER_IMF6	ER_IMFR
	Australia							
Obs.	3901	3901	3901	3901	3901	3901	3901	3901
Mean	0.0003	0.000	-0.0001	0.000	0.0003	0.000	0.000	0.0001
Std. Dev.	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00
Skewness	-0.01	0.07	-0.06	0.15	1.29	0.03	-0.13	1.15
Kurtosis	8.24	4.42	5.85	1.47	0.59	0.98	0.02	0.26
Normtest.W*	0.91	0.96	0.95	0.98	0.81	0.99	1.00	0.84
	Canada							
Obs.	1606	1606	1606	1606	1606	1606	1606	1606
		-						
Mean	0.0001	0.0002	0.0003	-0.0001	-0.0002	0.000	0.000	-0.0001
Std. Dev.	0.023	0.005	0.024	0.001	0.000	0.004	0.001	0.000
Skewness	16.568	0.120	0.448	0.434	-0.030	0.030	0.046	0.405
Kurtosis	725.952	0.985	219.123	3.443	-1.034	-0.122	0.083	-1.050
Normtest.W*	0.240	0.992	0.230	0.900	0.970	0.995	0.995	0.935
	France			**				
Obs.	941	941	941	941	941	941	941	941
Mean	0.000	0.000	0.000	-0.0001	-0.0002	-0.0001	0.000	0.0001
Std. Dev.	0.012	0.005	0.009	0.002	0.002	0.004	0.001	0.000
Skewness	-0.321	0.231	-0.001	-0.021	0.355	-0.026	0.188	-0.600
Kurtosis	2.629	2.411	0.285	4.398	-1.087	0.064	0.921	-0.909
Normtest.W*	0.975	0.980	0.996	0.936	0.939	0.990	0.982	0.901
	Germany							
Obs.	1604	1604	1604	1604	1604	1604	1604	1604
		-						
Mean	0.0002	0.0001	0.000	0.000	0.0004	0.000	0.000	0.000
Std. Dev.	0.010	0.005	0.008	0.001	0.000	0.004	0.000	0.000
Skewness	-0.036	0.145	0.003	0.060	1.319	-0.022	0.011	-0.792
Kurtosis	1.363	2.310	-0.414	-0.368	0.970	0.392	0.041	-0.409
Normtest.W*	0.984	0.979	0.994	0.992	0.837	0.993	0.990	0.896

	Hong Kong							
Obs.	1606	1606	1606	1606	1606	1606	1606	1606
Mean	0.0005	0.000	-0.0001	0.000	0.0006	0.000	0.000	0.000
Std. Dev.	0.011	0.000	0.009	0.001	0.001	0.000	0.000	0.000
Skewness	0.110	0.609	-0.009	-0.001	0.857	-0.081	-0.049	0.281
Kurtosis	1.682	32.423	-0.292	-0.725	-0.514	12.664	1.400	-1.333
Normtest.W*	0.981	0.742	0.996	0.987	0.859	0.836	0.977	0.917
	Japan							
Obs.	3901	3901	3901	3901	3901	3901	3901	3901
Mean	0.0003	0.000	-0.0001	0.000	0.0003	0.000	0.000	0.0001
Std. Dev.	0.01	0.01	0.01	0.000	0.000	0.01	0.000	0.000
Skewness	-0.01	0.07	-0.06	0.15	1.29	0.03	-0.13	1.15
Kurtosis	8.24	4.42	5.85	1.47	0.59	0.98	0.02	0.26
Normtest.W*	0.91	0.96	0.95	0.98	0.81	0.99	1.00	0.84
	The Netherlands							
Obs.	4990	4990	4990	4990	4990	4990	4990	4990
Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Std. Dev.	0.006	0.003	0.005	0.001	0.000	0.002	0.000	0.000
Skewness	0.310	0.049	0.001	0.109	0.528	0.012	-0.017	0.959
Kurtosis	4.837	1.522	1.942	0.261	-0.969	-0.109	1.260	-0.375
Normtest.W*	0.935	0.986	0.981	0.995	0.916	0.995	0.986	0.830
	New Zealand							
Obs.	1606	1606	1606	1606	1606	1606	1606	1606
Mean	0.0001	-0.0001	0.000	0.000	0.000	0.000	0.000	-0.0001
Std. Dev.	0.011	0.007	0.009	0.001	0.000	0.005	0.001	0.000
Skewness	-0.172	-0.029	-0.019	-0.185	-0.721	0.009	-0.003	0.706
Kurtosis	2.219	0.904	0.131	-0.052	-0.657	-0.343	-0.820	-0.778
Normtest.W*	0.978	0.993	0.996	0.987	0.894	0.995	0.985	0.881
	Singapore							
Obs.	3364	3364	3364	3364	3364	3364	3364	3364
Mean	0.0002	0.0001	0.000	0.000	0.000	0.000	0.000	0.0001
Std. Dev.	0.015	0.004	0.012	0.002	0.001	0.003	0.000	0.000
Skewness	1.718	-0.001	-0.390	0.068	-1.016	-0.012	-0.110	0.860
Kurtosis	57.471	4.035	48.234	4.560	-0.255	0.782	0.232	-0.555
Normtest.W*	0.796	0.961	0.804	0.928	0.822	0.994	0.996	0.847
	United Kingdom							
Obs.	3157	3157	3157	3157	3157	3157	3157	3157
Mean	-0.0002	-0.0001	0.000	0.000	-0.0003	0.0001	0.000	-0.0003
Std. Dev.	0.019	0.007	0.015	0.001	0.001	0.005	0.001	0.001
Skewness	-0.603	2.532	0.085	0.271	-1.182	0.112	-1.188	1.224
Kurtosis	10.657	79.711	6.450	1.122	0.262	4.151	20.148	0.410
Normtest.W*	0.901	0.843	0.936	0.982	0.825	0.971	0.812	0.824

Note: Normtest.W indicates Shapiro-Wilk test of normality which is rejected for all levels of significance. RR - RREITs returns, ER - FOREX return, IMF.R - IMF Residual. **For France column 5 is IMF5.*

4. Asymmetric regression results

4.1 Quantile Regression Analysis (QRA)

The QRA estimates the respective local currency returns on REITs. Almost all the coefficients are significant at the conventional[4] levels of significance. We choose to plot these coefficients as shown in Figure 2 (see lines in wine color) for greater clarity. The plots in Figure 2 provide pictorial representations of the REITs-currency connection in terms of magnitude and direction and provide a basis of correspondence between QRA and QQR estimates (vertical axes are the coefficients of QRA and QQR). The lower quantiles are indicative of appreciating local currencies, whereas the upper quantiles denote depreciating local currencies. For Australia, we see positive associations in the short-and medium-terms but negative links in the long-term from the 55th quantile onwards. It is clear that positive links are stronger in the short-term, but inverse links are about twice as much. However, Canada shows only positive associations across all time horizons and quantiles, but they are stronger in the long-term than in the short-term. Similarly, in the short and medium-term, France portrays mostly positive relations. In the long-term, the links are stronger, with the lower and upper 50% of the distribution showing positive and negative relations, respectively. Similar analogies can be made for the nexus in Germany as well. The Netherlands and Germany have similar patterns in the short-term, but in the medium-term, they are not so similar. Their patterns are very different from those of the other European REITs in the long-term. Nonetheless, we may allude to their short-term similarities to the Euro and their geographical proximity.

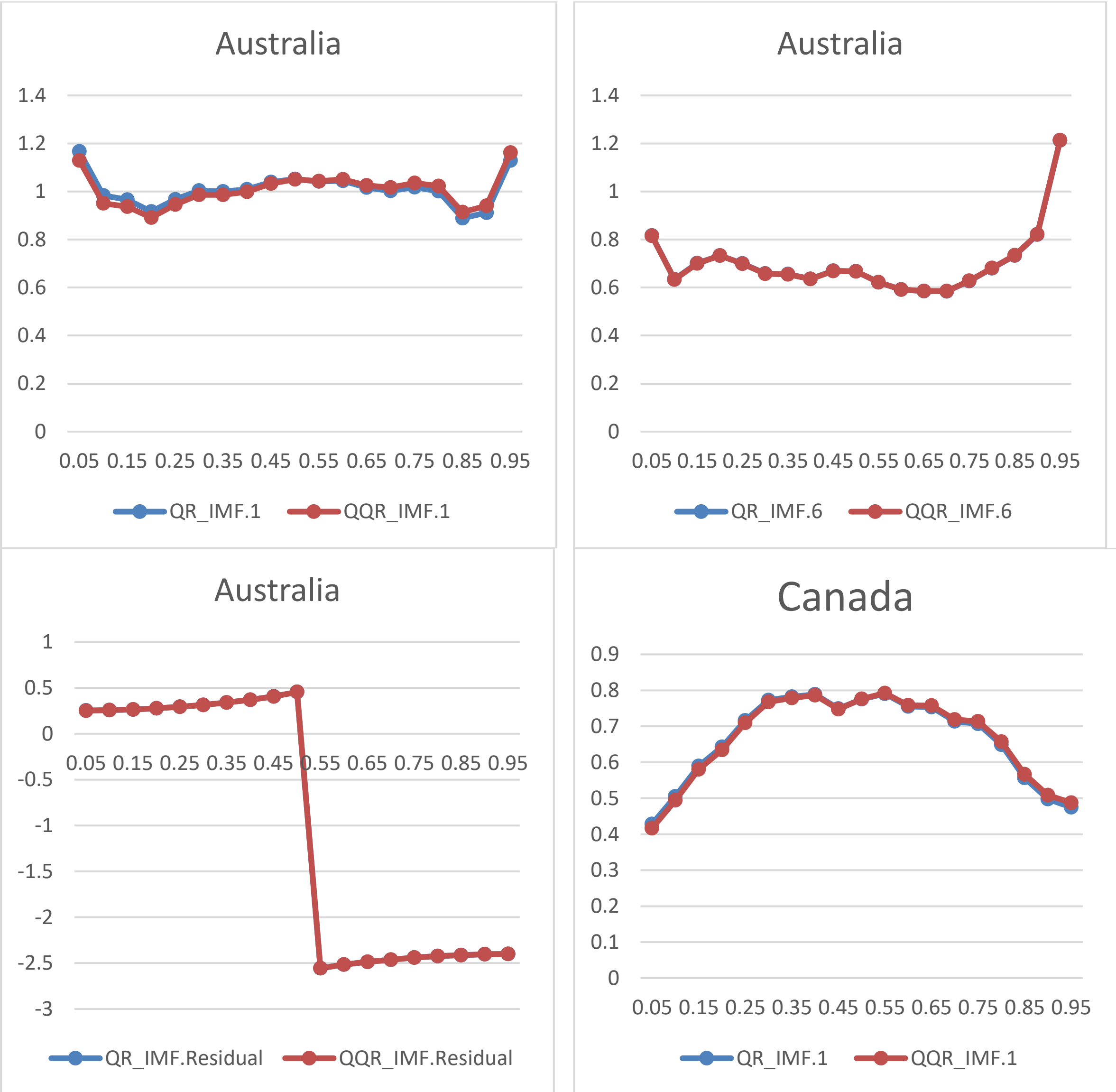
Hong Kong shows compositely increasing values with quantiles, mostly positive in the short and medium-terms. The long-term associations are negative and increasing, and they have larger coefficients than all other markets combined. For Japan, medium-term associations are similar to those of Hong Kong but weaker for Japan. Short-term associations are positive across the board, like in Hong Kong, but long-term links are positive all the way through and smaller, as compared to Hong Kong. Like in Hong Kong (and unlike Japan), long-term relationships are inverse and stronger than short-and medium-term relationships, which are positive for Singapore. It also appears that, for Singapore, the strength of associations increases across time but in opposite directions.

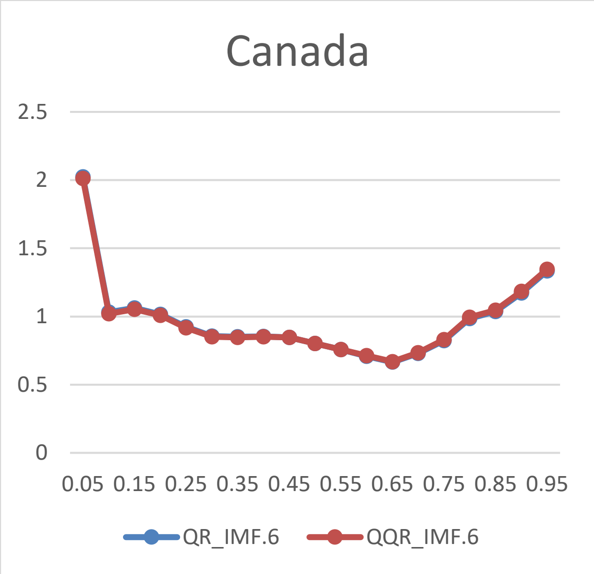
[4] That is 1%, 5%, and 10% significance levels. QQR table is not presented for brevity reasons. It is available upon request to the corresponding author.

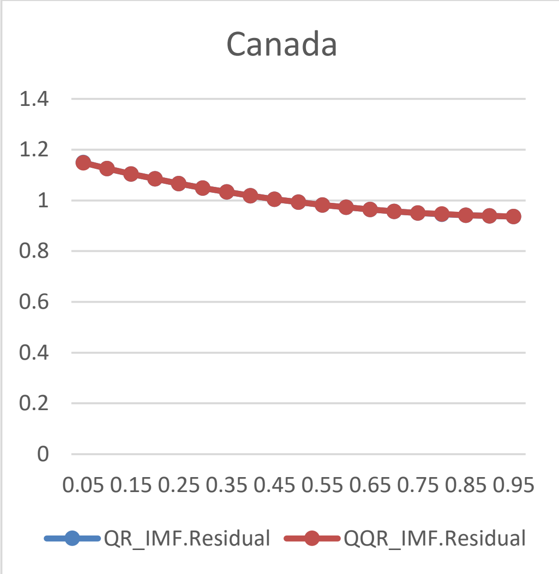
The dynamics in the UK are also similar to those in Hong Kong and Singapore. All long-term quantile associations are negative, albeit weaker than those of Hong Kong and Singapore. We find the strongest direct relationships in the short-term and the weakest medium-term direct links are in the UK market. New Zealand also has direct associations in the short (stronger) and long-terms across all quantiles, with the exception of the lower tails up to 0.15.The medium-term associations are also inverse across all quantiles.

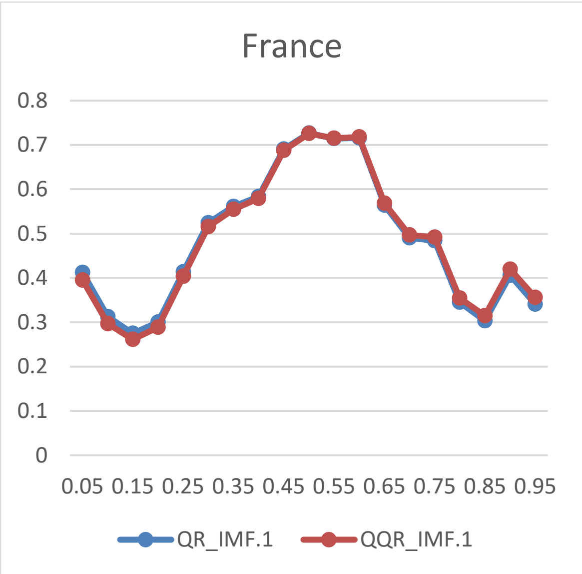
Except in a few cases, short- and medium-term local currency appreciation and depreciation have a direct relationship with REITs in the respective markets. For returns of daily periodicity, we can argue that it takes some time for investors to adjust their portfolios according to the changes in the foreign exchange market. However, this contradicts the assertion by Liu et al. (2012) that because REITs are exchange-traded financial instruments, they quickly reflect new information. Also, investors may not be keen on observing the marginal changes in their portfolios as we have done here (i.e., at each 5th quantile of the return distribution). This implies that, for portfolio diversification purposes, currencies and REITs may not provide a perfect combination or portfolio, since they move in the same direction. We can relate this to the findings of Kola and Kodongo (2017) that found a positive link between REITs and the real economy of the US. Khan and Siddiqui (2019) also show evidence of similar relations in the Malaysian market. But we observe inverse relationships at the lower 10–40th and upper 85–95th quantiles in the medium-term for France, Hong Kong, and Japan. Thus, when currency appreciation and depreciation are extreme, REIT investors react in opposite directions. That is to say, at extreme levels of currency appreciation, there are resulting disinvestments in REITs, but at extreme levels of currency depreciation, there are corresponding increases in REIT investments. Ngo (2017) also documents that dollar appreciation adversely affects US REITs (see also, Mull & Soenen, 1997). These corroborate the notion that REITs can act as a hedge against currency depreciation, as found in Coşkun et al. (2017) for Turkish REITs.

Nonetheless, we see the inverse currency-REIT nexus as dominant in the long-term for large parts of the distribution, notably in France, Australia, Germany, Hong Kong, New Zealand, Singapore, and the UK, where investors can adjust their portfolios accordingly in the long-term when the effects of currency fluctuations are hard to miss. At this time horizon, we corroborate the findings from the study by Liu and Mei (1998) that exchange rate risk may account for a larger portion of real estate-related asset return fluctuation than is relative to common stocks. For these countries, exchange rates and REITs act as potential hedges for each other, whether currencies are appreciating or depreciating (see Baur & Lucey, 2010; Baur & McDermott, 2010). This enables investors to construct a portfolio consisting of currencies and REITs without the need to constantly monitor the performance of currencies.




Canada
2.5
2
1.5
1
0.5
0
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.6
QQR_IMF.6


Canada
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.Residual
QQR_IMF.Residual


France
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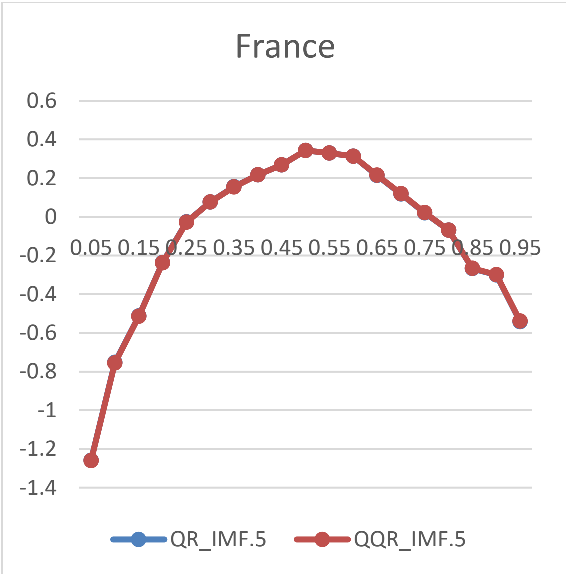
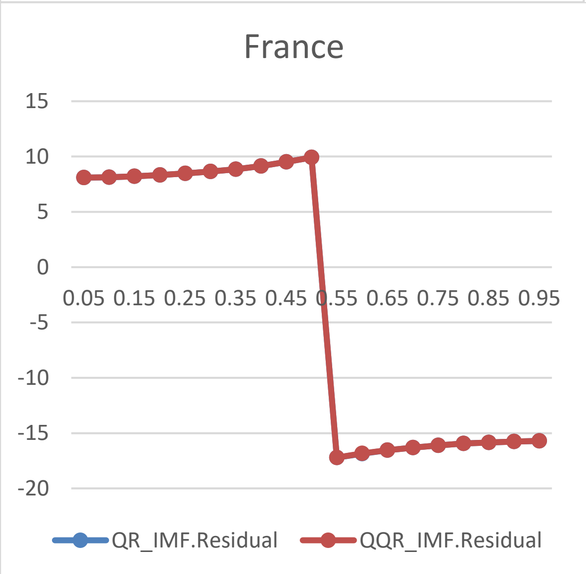
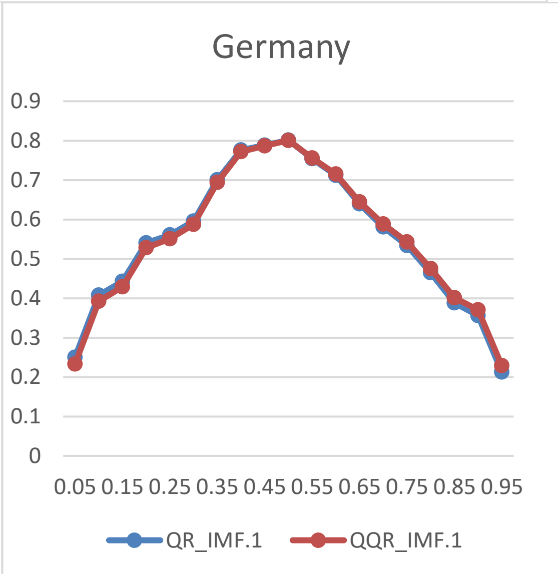
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.1
QQR_IMF.1


France
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.5
QQR_IMF.5


France
15
10
5
0
-5
-10
-15
-20
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.Residual
QQR_IMF.Residual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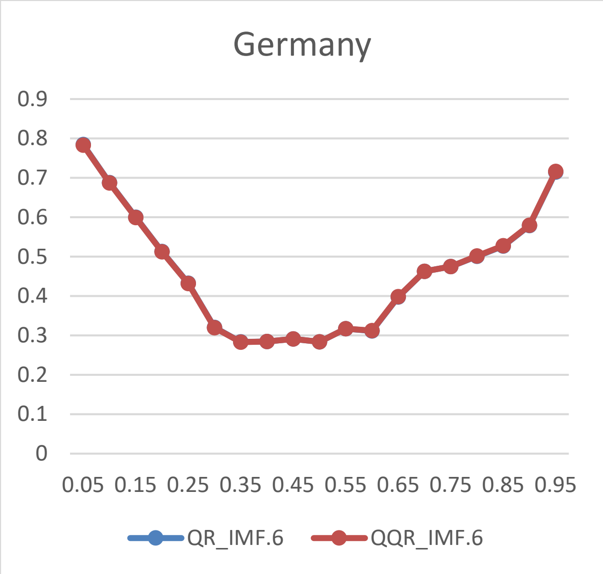
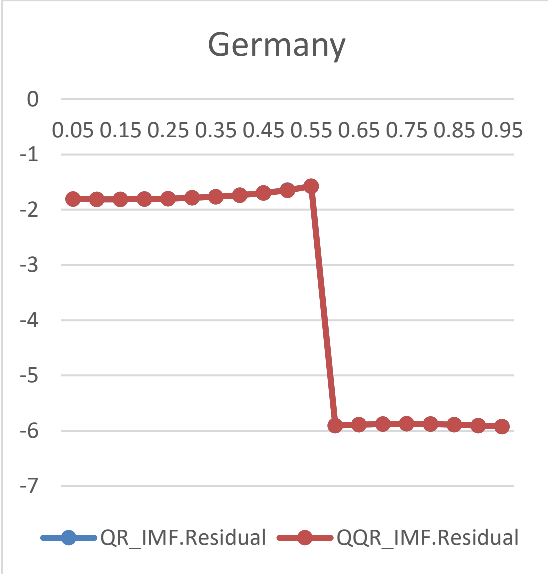
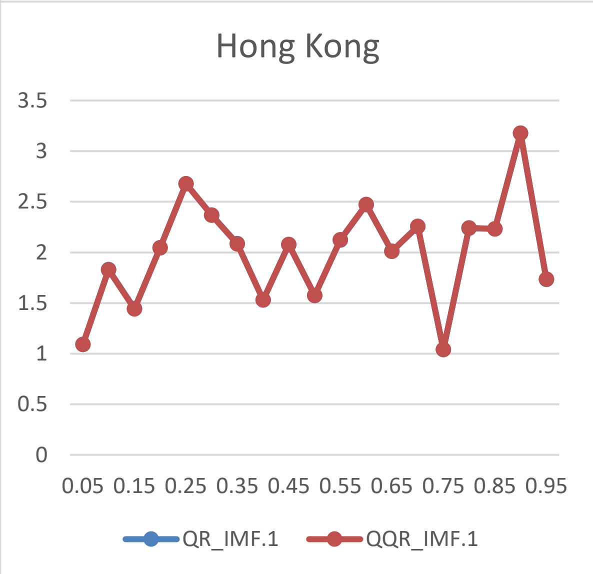
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.1
QQR_IMF.1


Germany
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.6
QQR_IMF.6


Germany
0
-1
-2
-3
-4
-5
-6
-7
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.Residual
QQR_IMF.Residual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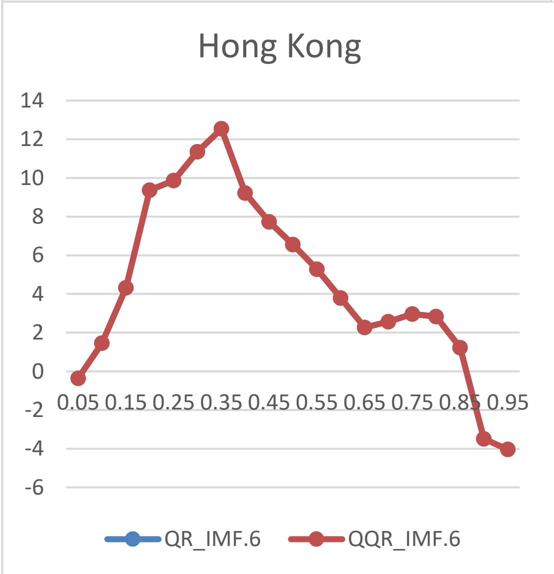
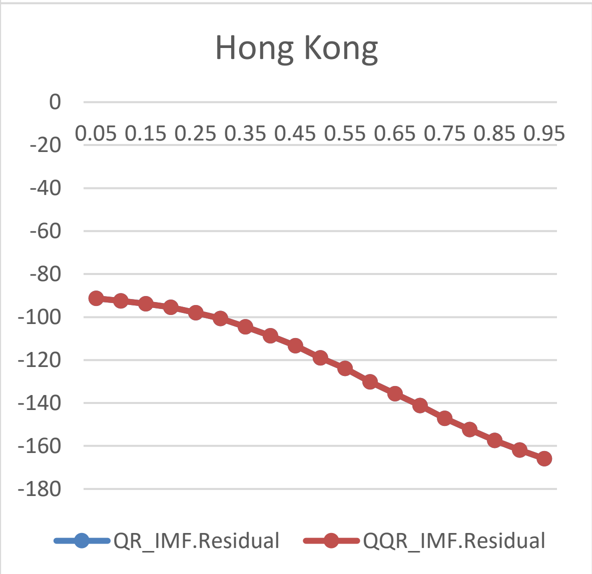
3.5
3
2.5
2
1.5
1
0.5
0
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.1
QQR_IMF.1


Hong Kong
14
12
10
8
6
4
2
0
-2
-4
-6
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.6
QQR_IMF.6


Hong Kong
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-20
-40
-60
-80
-100
-120
-140
-160
-180
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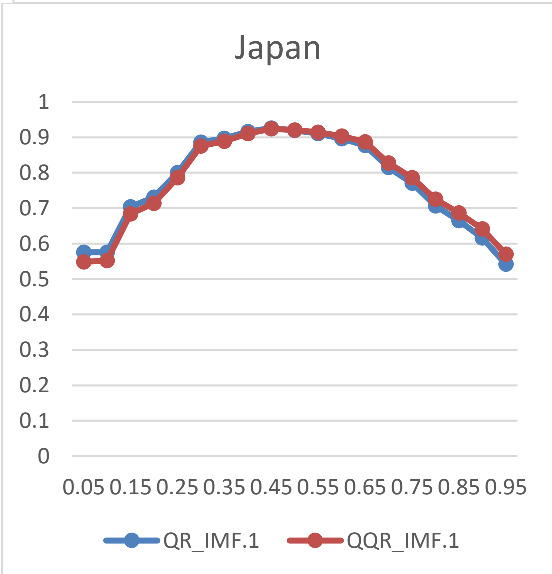
QR_IMF.Residual
QQR_IMF.Residual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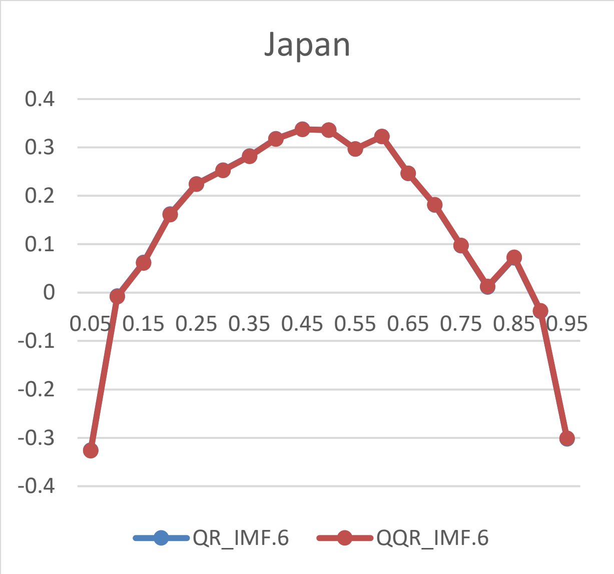
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.1
QQR_IMF.1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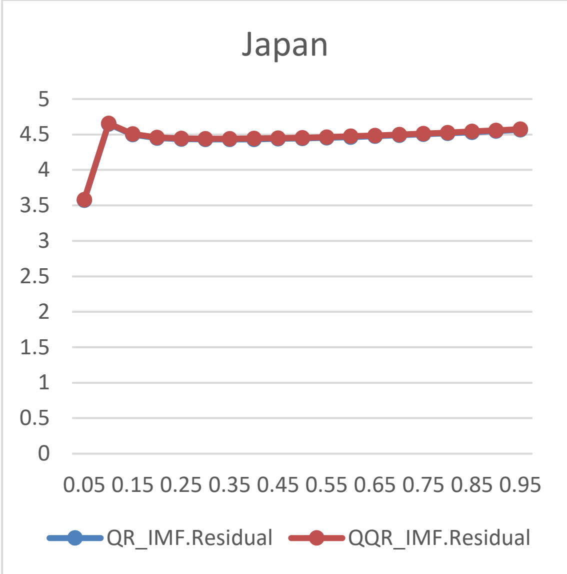
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.6
QQR_IMF.6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4
3.5
3
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2
1.5
1
0.5
0
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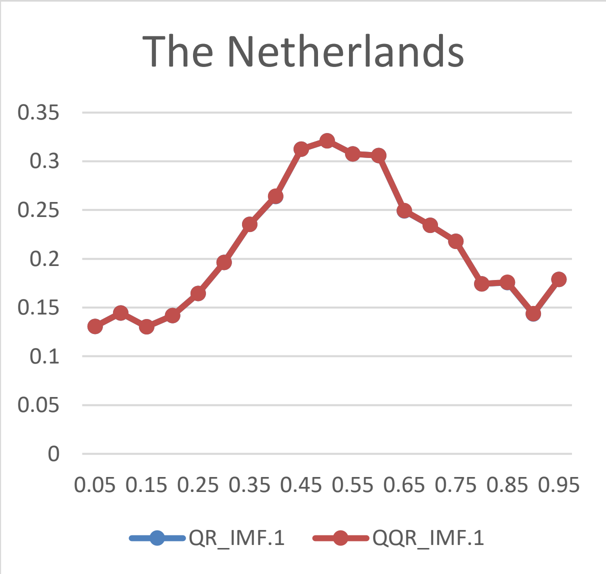
QR_IMF.Residual
QQR_IMF.Residual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0
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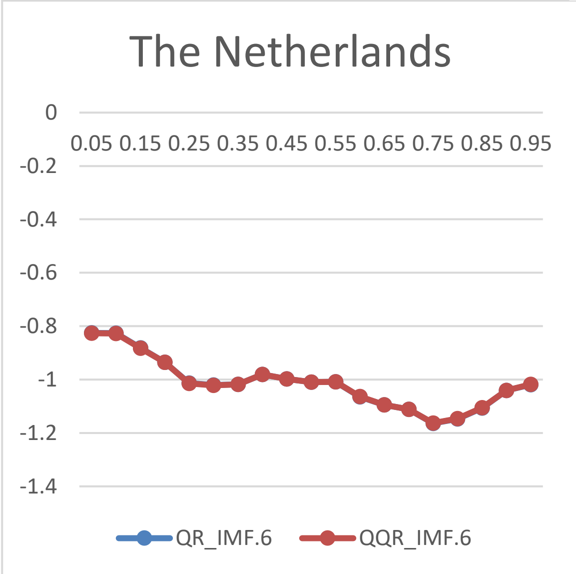
QR_IMF.1
QQR_IMF.1


The Netherlands
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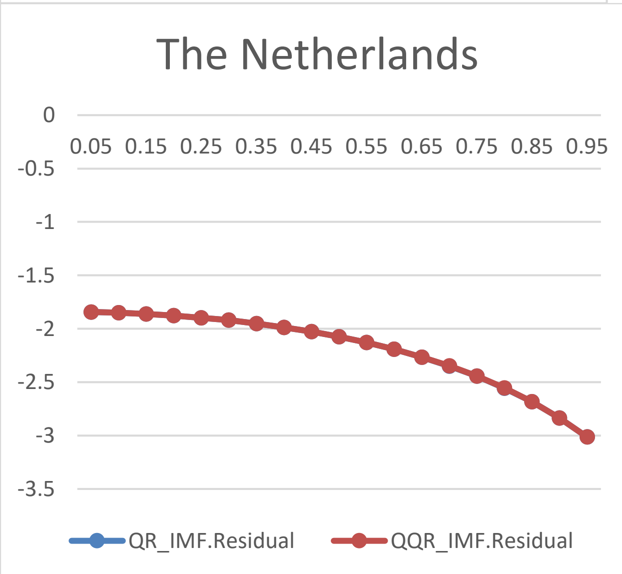
-0.4
-0.6
-0.8
-1
-1.2
-1.4
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.6
QQR_IMF.6


The Netherlands
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-1
-1.5
-2
-2.5
-3
-3.5
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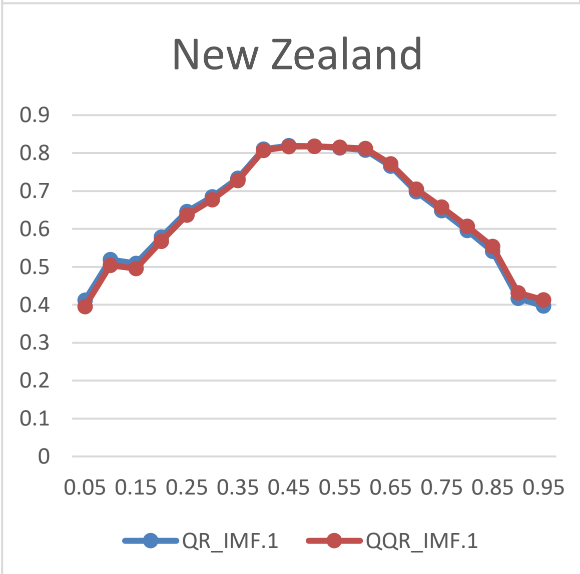
QR_IMF.Residual
QQR_IMF.Residual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0.3
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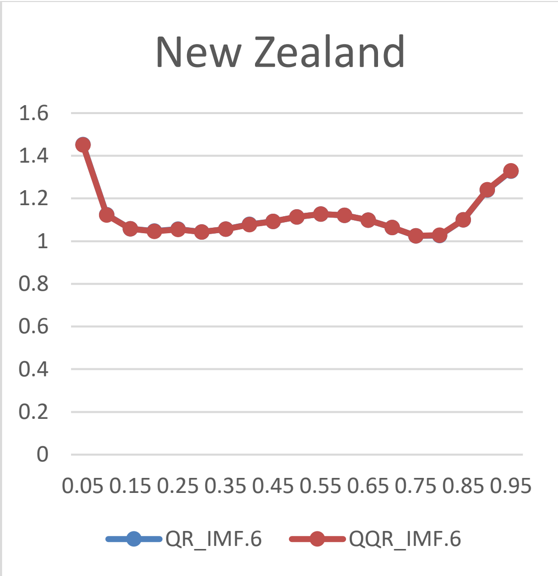
QR_IMF.1
QQR_IMF.1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1.2
1
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0.6
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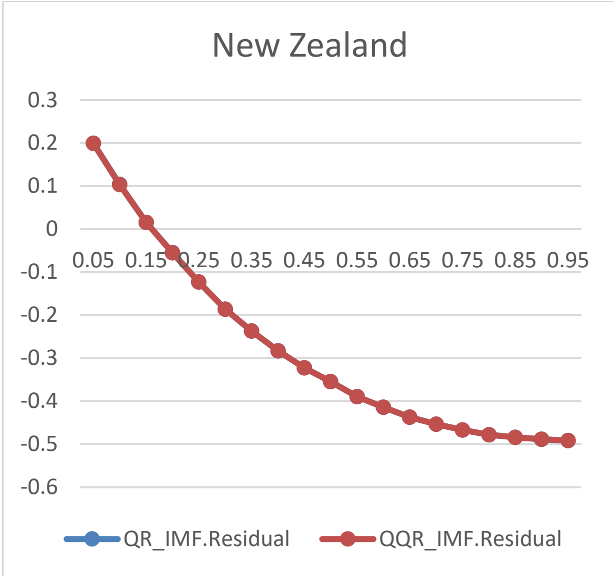
QR_IMF.6
QQR_IMF.6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0
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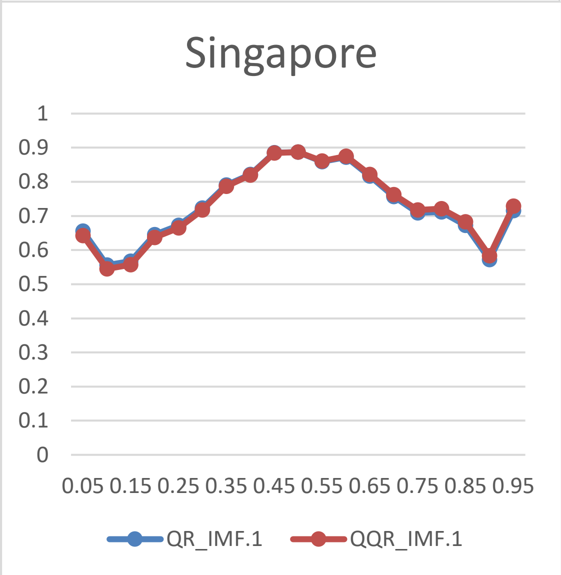
-0.2
-0.3
-0.4
-0.5
-0.6
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.Residual
QQR_IMF.Residual


Singapore
1
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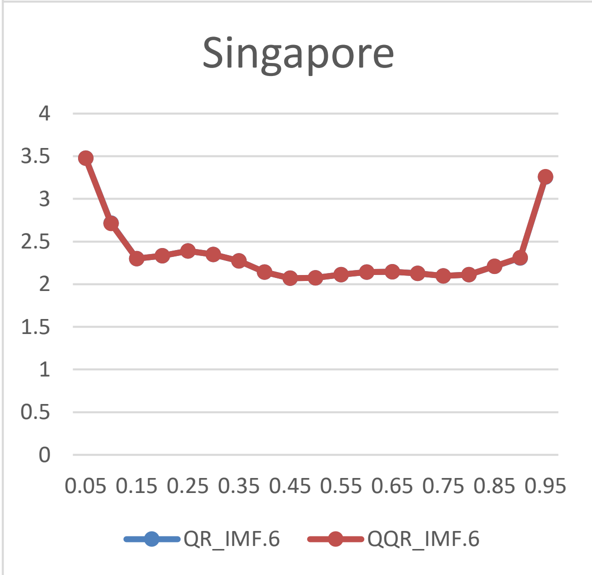
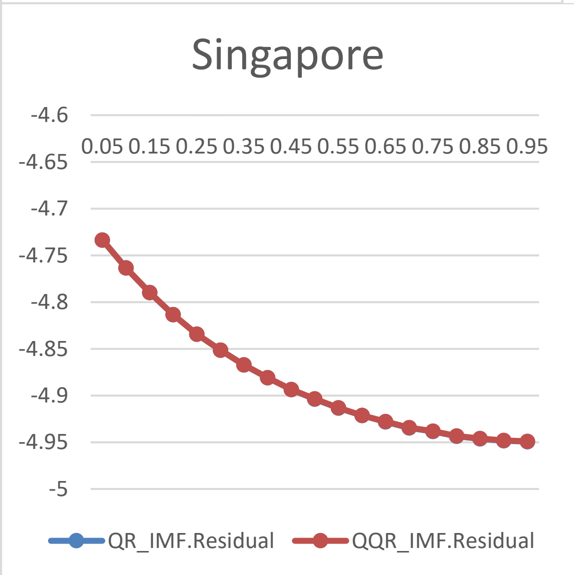
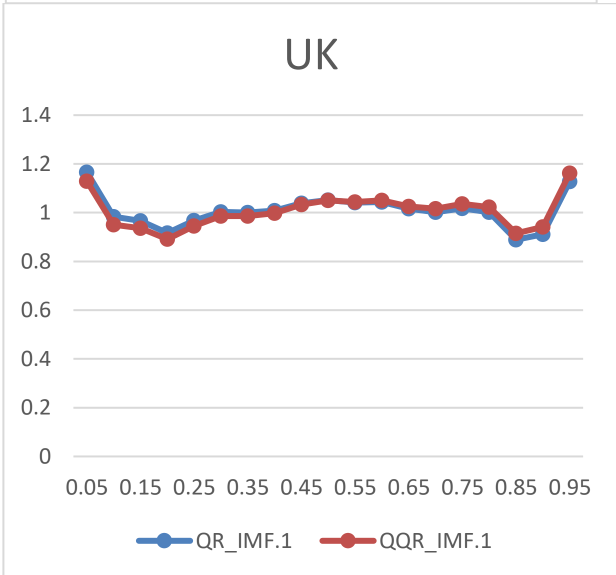
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.1
QQR_IMF.1


Singapore
4
3.5
3
2.5
2
1.5
1
0.5
0
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.6
QQR_IMF.6


Singapore
-4.6
-4.65
-4.7
-4.75
-4.8
-4.85
-4.9
-4.95
-5
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.Residual
QQR_IMF.Residual


UK
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1.2
1
0.8
0.6
0.4
0.2
0
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
QR_IMF.1
QQR_IMF.1

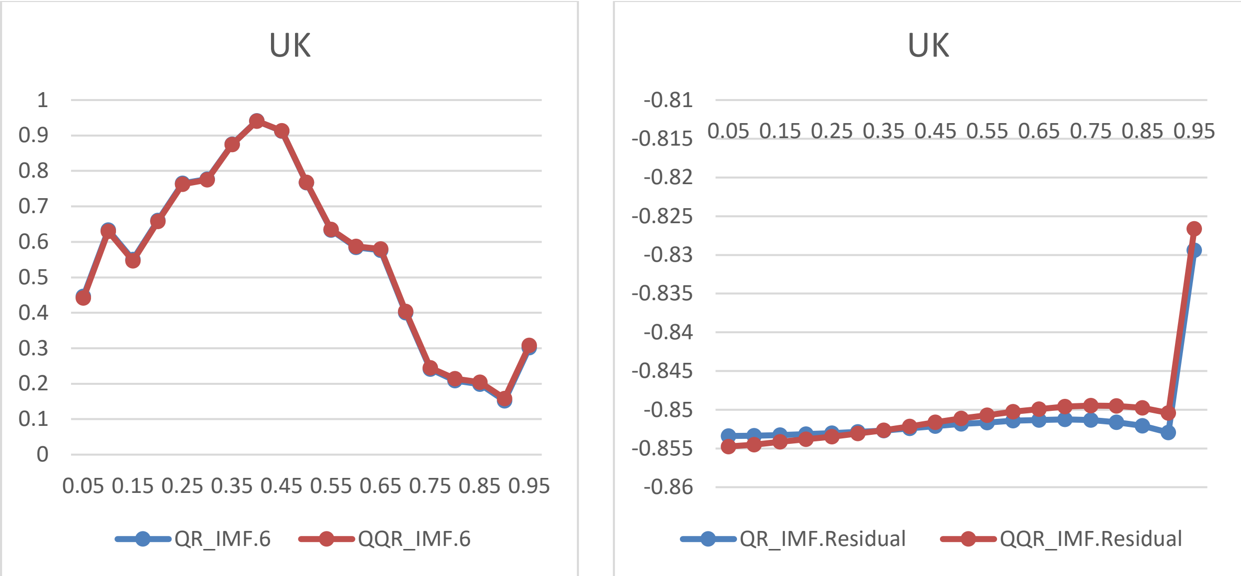

Figure 2. QRA and QQR coefficient plots of REITs and local currency nexus
Note: QRA and QQR coefficients are in the vertical axes.

4.2 Quantile Regression Analysis (QRA) results

We can infer the REITs' exchange links via QQR from those of QRA if we can compare them. The QQR is a non-parametric model, and hence the significance of coefficients is not available. However, the QQR approach "decomposes" the QRA estimates into the specific quantiles of the explanatory variables (Bouri et al., 2017). Thus, the closeness of QQR and QRA can be used as a validating tool for QQR[5]. These can also be observed from the line plots of QRA and QQR coefficients in Figure 2, as explained earlier. We observe that QRA estimates largely confirm those of QQR across quantiles and time horizons. Moreover, the results show that the magnitudes and directions of QQR estimates are particularly close to those of QRA. We find that blue and wine lines almost perfectly overlap. Hence, the QQR is a good technique to quantify the frequency-dependent asymmetric relations between local currencies and REITs, and its estimates are also synchronous with those of the QRA approach.

5. Conclusions

This study examined the asymmetric frequency-dependent association between exchange rates and REITs in nine global REIT markets. We discover that both QRA and QQR are valid models to examine the relationship between currencies and global REITs at different time-

[5] Table of QQR estimates is not presented for brevity reasons. They are available upon request to the corresponding author.

frequency scales. Our frequency decomposition technique also has the unique feature of reducing noise in the time series, which could otherwise fault our analysis.

In the short and medium-terms, both local currency appreciation and depreciation have a direct relationship with REITs in many of the markets. However, we observe that France, Hong Kong, and Japan, in the medium-term, have inverse relationships at the extreme lower and upper tails of the distribution. While we surmise that it may take some time for investors to adjust their REIT portfolios for returns of daily periodicity, this cannot be said of France, Hong Kong, and Japan. Furthermore, it may be hard for investors to observe the changes at each 5th quantile of the return distribution. However, in the long-term, there are far more inverse currency-REITs that link bullish and bearish currency returns. Thus, at extreme levels of currency appreciation, there are resulting disinvestments in REITs, but at extreme levels of currency depreciation, there are corresponding increases in REIT investments for France, Australia, Germany, Hong Kong, New Zealand, Singapore, and the UK. There is better diversification potential in the long-term than in the short and medium-terms, which implies that in the long-term, local currencies and REITs may act as hedges but not as safe havens for each other.

This study has contributed to the application of both AMH and HMH. This is seen in the use of time-horizon dependent quantile regressions to examine the non-linear, asymmetric, and diverse relationships between global REITs and exchange rates. Moreover, our study reinforces the inefficiency in the markets by employing the EEMD technique to reduce the noise in the relationship between REITs and exchange rates. This ensures that our findings are refined for better policy and investment decision making.

Our findings are in line with those that find a positive link between local currencies and REITs, but also between REITs and macroeconomic variables in general. Our finding corroborates HMH as we find that the connection between currencies and REITs is frequency dependent. We also confirm the stylised facts of time-varying and asymmetric returns in financial assets. These are seen through the different magnitude estimates at the various quantiles. Thus, both investment and policy decisions will work better if they are based on the direction of the foreign exchange market and target specific time horizons.

This study is beneficial to fund managers and other practitioners with an interest in international REITs since they are exposed to currency risks. The evidence illuminates our understanding of how different economies or markets behave differently due to exchange rate fluctuations within the framework and the implications it provides for international portfolio dynamics. This comes as no surprise given that these countries operate flexible exchange rate regimes such that the dynamics are dictated by the peculiar market forces in each country. Different markets have unveiled different perspectives and distinctive potentials concerning hedging and diversification at different time and frequency domains. It is, therefore, important to appreciate the individual economies for risk management, diversification, and fund management practices in the absence of a universal exchange rate regime or currency. This creates an avenue to expand this study to encompass these aspects (see Akinsomi et al., 2021).

Furthermore, given the COVID-19 pandemic has affected almost every fabric of the economic, social, and public health system, including food prices (see Agyei et al., 2021), it would be interesting to update the data for the study to include the pandemic period. This will reveal the extreme non-linearities and asymmetries between REITs and exchange rates that are garnered by the uncertainties presented by the pandemic. Moreover, further insights can be gleaned from studying this relationship in a bi-directional manner and through the application of non-linear causality tests at the time-horizons and the various quantiles (see Antonakakis et al., 2018). Similarly, various GAS and GARCH models were subjected to the Model Confidence Set technique in order to reveal volatility transmission between variables (Owusu Junior, Tiwari, Tweneboah, & Asafo-Adjei, 2021). This will lead to a deeper understanding of these relationships.

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Conflict of Interest

None to declare.

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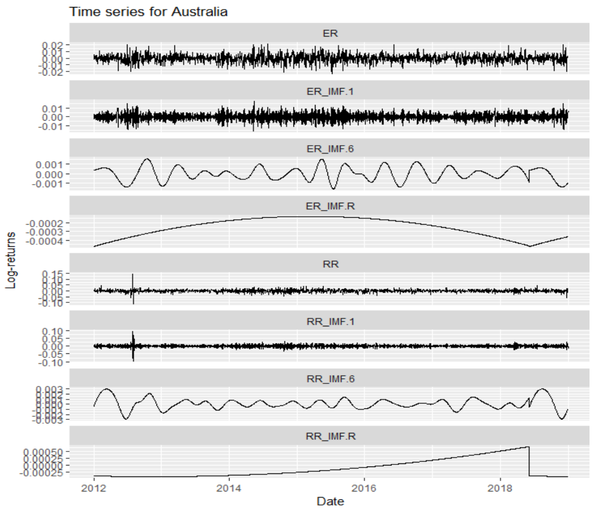
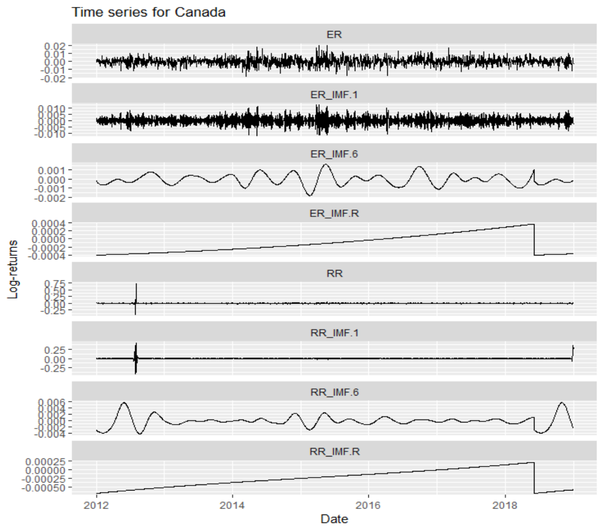
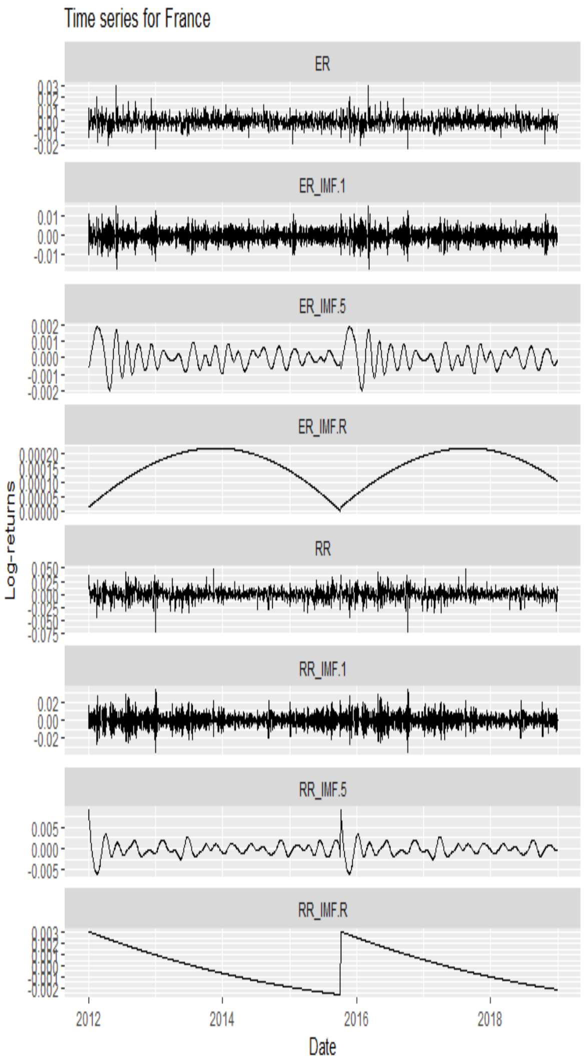
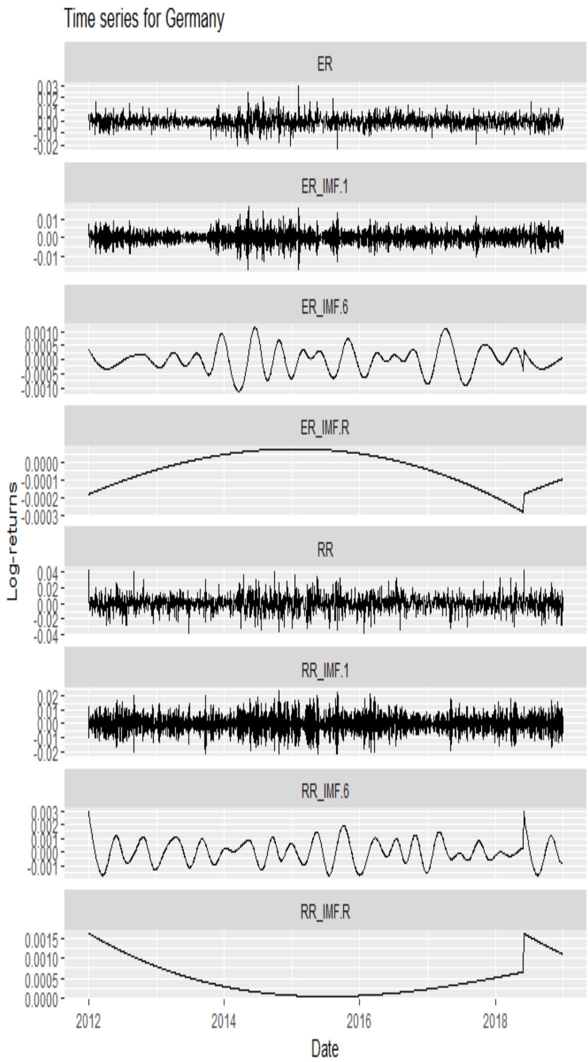
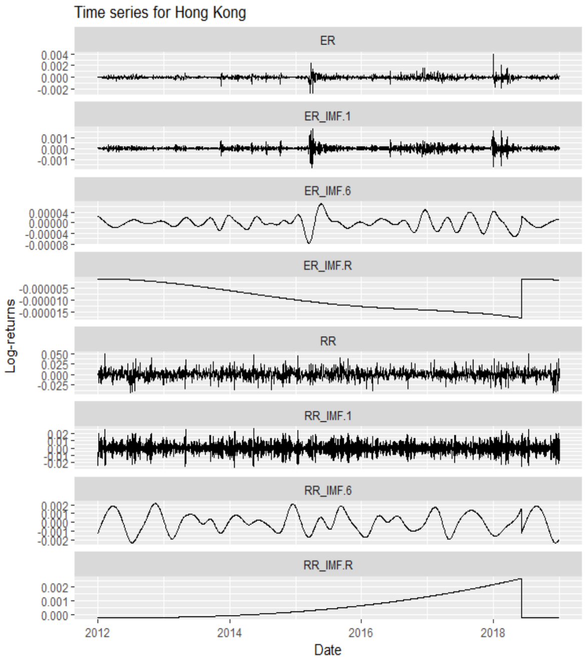
Appendix: Log-return and IMF plots

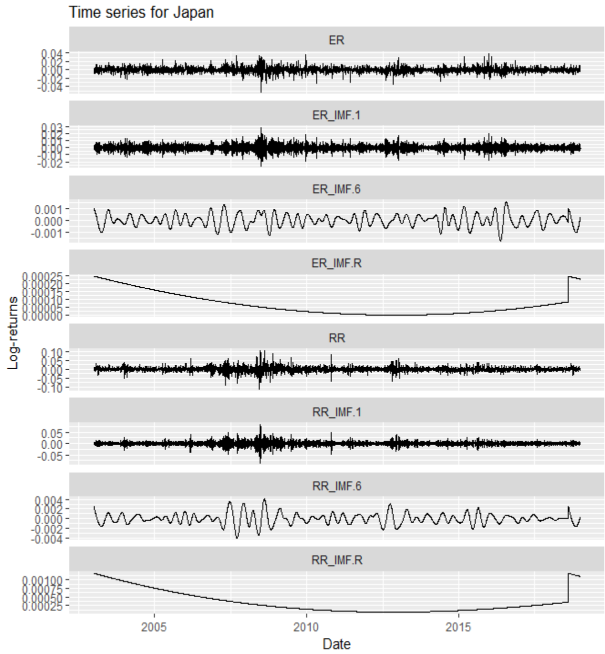


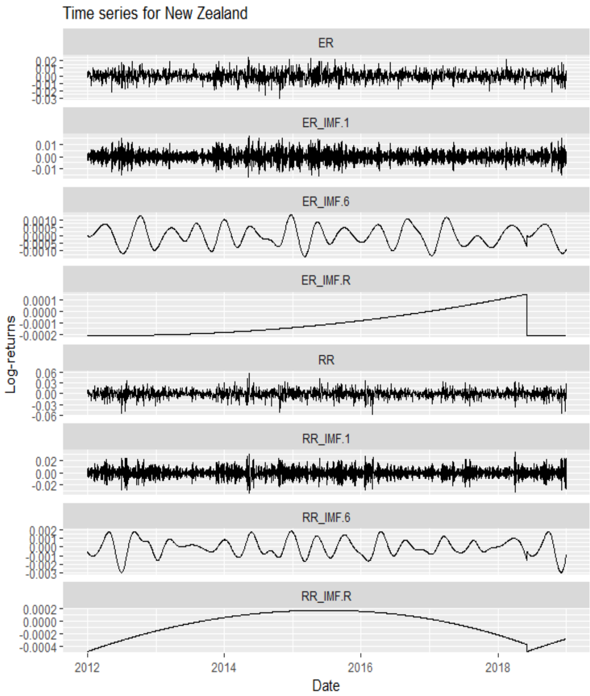


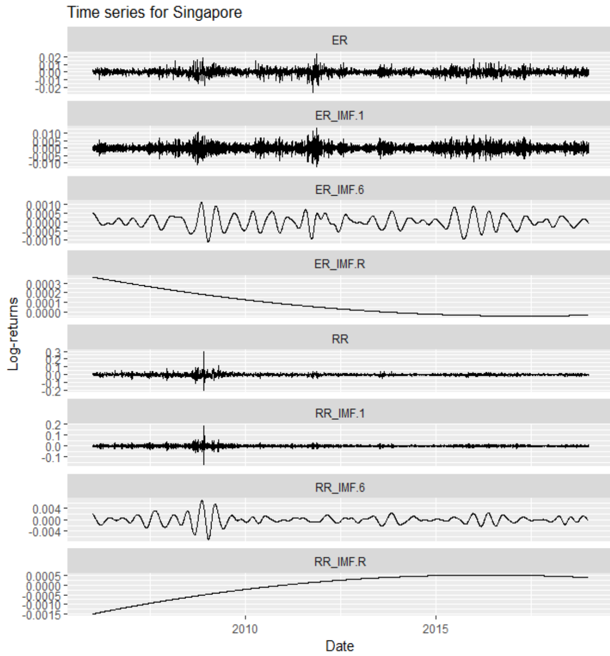





Time series for Hong Kong
ER
ER_IMF.1
ER_IMF.6
ER_IMF.R
RR
RR_IMF.1
RR_IMF.6
RR_IMF.R
Log-returns
Date
2012
2014
2016
2018


Time series for Japan
ER
ER_IMF.1
ER_IMF.6
ER_IMF.R
RR
RR_IMF.1
RR_IMF.6
RR_IMF.R
Log-returns
Date
2005
2010
2015


Time series for New Zealand
ER
ER_IMF.1
ER_IMF.6
ER_IMF.R
RR
RR_IMF.1
RR_IMF.6
RR_IMF.R
Log-returns
Date
2012
2014
2016
2018


Time series for Singapore
ER
ER_IMF.1
ER_IMF.6
ER_IMF.R
RR
RR_IMF.1
RR_IMF.6
RR_IMF.R
Log-returns
Date
2010
2015

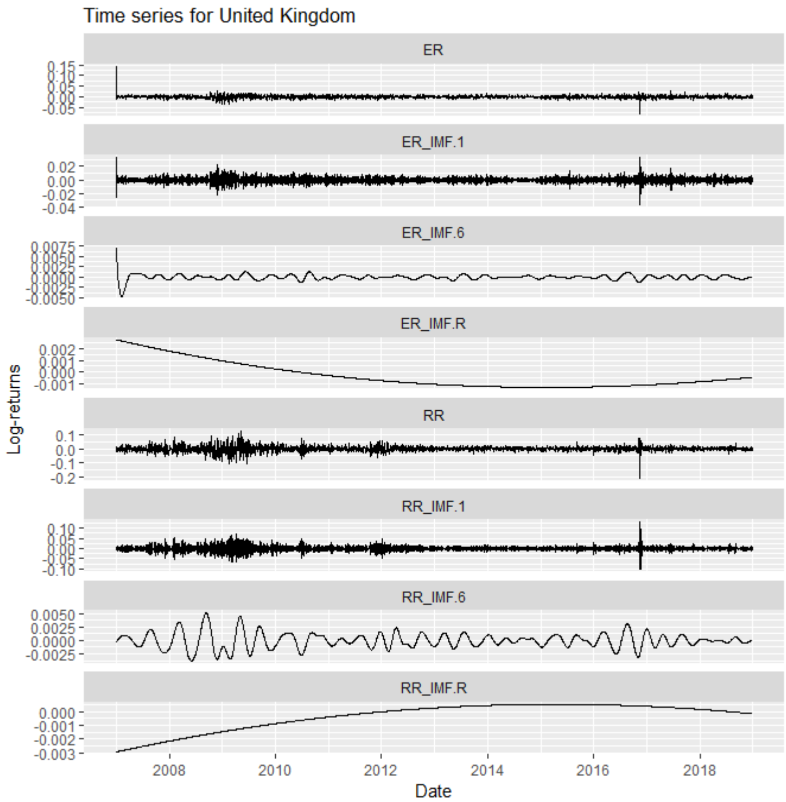


Figure 1. Log-return and IMF plots of selected local currency and REITs markets