Price and Volatility Linkages between International REITs and Oil Markets[#]

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Highlights

•Price and volatility transmissions between 19 REITs and oil analyzed.
•REITs markets at different stages of development;
•Analytical approach accounts for structural shifts as gradual processes
•Oil prices predict REITs prices in mature REITs markets, but the feedback is weak.
•Strong evidence of bidirectional volatility transmission in majority of markets.

Abstract

This study analyzes price and volatility transmissions between nineteen real estate investment trusts (REITs) and the oil markets. The REITs data represents a variety of countries at different stages of their development and the expanded analytical approach includes accounting for structural shifts as gradual processes – as opposed to strictly abrupt processes typically assumed in the literature. Oil prices are found to primarily predict REITs prices in mature REITs markets, but the feedback from REITs to oil prices is weak. From the perspective of volatility, strong evidence of bidirectional transmission in majority of the markets is observed. Our results are in general robust to a shorter common sample period of the various countries. This study further demonstrates the importance of accounting for gradual (smooth) structural shifts for price transmission analysis.

Keywords: REITs and oil markets; price and volatility spillovers; structural changes

JEL Codes: C32, Q02, R33

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1. Introduction

There is now widespread evidence that benefits can be derived by including real estate in mixed-asset portfolios (Hoesli et al., 2004; MacKinnon and Al Zaman, 2009; Hoesli and Reka, 2013; Bouri et al., 2018). But investing in the real estate market can be problematic because of the high unit value and illiquidity associated with properties. Hence, it is not surprising that the importance of the securitized real estate market, i.e., Real Estate Investment Trusts (REITs), which are exchange-traded funds that earn most of their income from investments in real estate, has grown substantially during the past decades, with a total market capitalization of US $ 1.7 trillion (Global REITs Market, EY Global Real Estate Report, 2018). Though the United States (US) continues to remain the leader in the REITs market (with a market capitalization of US $ 1.15 trillion), the number of countries now offering REITs as an investment vehicle has almost doubled in the last 10 years, and currently stands at $ 37 trillion. The ability of the REITs sector to attract investment capital is not surprising, since it is accessible to all investors irrespective of the portfolio size. Given the well-accepted importance of REITs in investment portfolios, an important question for investors is to understand what shocks drive this market. In addition, given the well-established role played by the real estate sector in the recent global financial crisis, and with REITs data available at high-frequency without measurement errors (unlike the housing market), as well as it being a good proxy for the overall real estate sector (Akinsomi et al., 2016), the early detection of the path that the sector takes following shocks, is a question of equal importance to policymakers as well (Gupta and Marfatia, 2018; Gupta et al., 2019).

In this regard, studies have primarily analyzed the role of monetary policy and macroeconomic news shocks in affecting the REITs market (see for example, Bredin et al.

(2007, 2011), Xu and Yang (2011), Claus et al. (2014), Kroencke et al. (2016), Marfatia et al., (2017), Nyakabawo et al., (2018)). With REITs shares trading as common stocks, and the large literature that exists involving the analysis of the importance of oil shocks on movements in prices and/or returns and volatility of international equity markets (see for example, Degiannakis et al., (2018), and Smyth and Narayan (2018) for detailed reviews), the lack of similar studies on REITs is quite perplexing. The two papers that we could find in this regard are that of Huang and Lee (2009) and Nazlioglu et al., (2016).[1] On one hand, Huang and Lee (2009) adopted the autoregressive conditional jump intensity model proposed by Chan and Maheu (2002) to capture the characteristics of the time-varying jump (i.e., sudden rather than smooth structural breaks) phenomenon, and investigated the influence of expected-and unexpected crude oil fluctuations on an overall REITs index of the US. The analytical results revealed that REITs returns rise in response to increase in expected oil price and provide a good partial hedge. Moreover, this paper also showed that oil has more impact on REITs than common stocks and the bond market. On the other hand, Nazlioglu et al., (2016) examined the role of oil price and volatility on the first and second-moments of six REITs categories of the US: Residential, Hotel, Healthcare, Retail, Mortgage and Warehouse/Industrial REITs. Econometrically, this study proposed a new causality approach by augmenting the Toda and Yamamoto (1995) method with a Fourier approximation to capture gradual or smooth shifts, which in turn does not require a prior knowledge regarding the number, dates, and form of structural breaks. Using this test, these authors find uni-directional causality running from oil prices to all REITs,

[1] There is a recent line of related research, whereby studies have pointed towards significant role of oil prices (shocks) on movements in international housing markets both for developed and emerging countries (see, Kaufmann et al., (2011), Antonakakis et al., (2016), Killins et al., (2017), and Salisu and Gupta (forthcoming)). However, it is worthwhile emphasizing that REITs are structurally different from house prices, with the former more closely related to the equity market in terms of its characteristics.

except for the mortgage REITs, with the causality running in the opposite direction in the latter case. In addition, based on a causality-in-variance test of Hafner and Herwartz (2006), Nazlioglu et al., (2016) indicate bi-directional volatility transmission between the oil market and all REITs. In sum these two studies showed significant impact of oil price on the first- and second-moments of US REITs, and also indicated of possible feedbacks.

The results from the works of Huang and Lee (2009) and Nazlioglu et al., (2016) point out that in the wake of the recent financialization of the oil market (Bahloul et al., 2018), the link between oil and financial markets, with the latter also including the REITs sector, has intensified. In other words, movements in these two markets are likely to affect each other, at the levels of both price and volatility, due to portfolio allocations carried out by investors (Tiwari et al., 2018). In addition, given that the price of a share in a (real estate) company is equal to the expected present value of discounted future cash flows (Huang et al., 1996), oil price shocks can affect REITs prices directly by affecting current and future cash flows or indirectly by affecting interest rates that are used to discount the future cash flows (Kaminska and Roberts-Sklar, 2018). Moreover, both oil and real estate markets are likely to be driven by common shocks associated with output, inflation and interest rate (Breitenfellner et al., 2015), resulting in indirect linkages in the first and second moments of oil and REITs.

Against this backdrop, we aim to extend the limited literature on the causal impact of prices and volatility involving the REITs and oil markets concentrated only on the US economy, to an international dimension (involving 19 countries) in the wake of the massive growth in the REITs sector worldwide, as discussed above. In this regard, based on data availability, we analyze multiple REITs markets that are at their different stages of development, and corresponds to the mature (US), the established (Australia, Belgium, Canada, France, Germany, Hong Kong, Japan, The Netherlands, New Zealand, Singapore and the UK), and the emerging (Ireland, Italy, Malaysia, Mexico, South Africa, Spain and Turkey) categories.

To achieve our objectives, from an econometric modelling perspective, we use the Fourier-based version of the Toda and Yamamoto (1995) test of causality in prices (as developed by Nazlioglu et al., (2016)), and the modified Hafner and Herwartz (2006) test of causality-in-variance with Fourier approximations (due to Pascalau et al., (2011) and Li and Enders (2018)). Both these models account for structural shifts, incorporated as gradual processes, in the relationships involving the movements in the first- and second moments of oil and REITs markets. Accounting for regime changes is of crucial importance, realizing that (high-frequency) data related to financial and commodity markets are subject to structural changes, and more importantly, the inability to model structural breaks would result in incorrect inferences (Kim et al., 2007; Salisu and Fasanya, 2013; Gil-Alana et al., 2016).

To the best of our knowledge, this is the first attempt to analyze price and volatility spillovers between the oil and international REITs markets based on tests of Granger causality with structural shifts.[2] Our paper can be considered to be an extension of the work of Huang and Lee (2009) from the perspective of going beyond the US, and looking at both first and second moment using methodological advancements to the standard tests of Granger causality for price and volatility. When compared to Nazlioglu et al., (2016), again we provide an international perspective, though unlike them we do not look at sector-specific REITs (due to lack of data across these countries) and concentrate on

[2] An application of these methods to the bond and oil markets can be found in Nazlioglu et al., (2020).

overall REITs. While like Nazlioglu et al., (2016) we use a first-moment test of causality accounting for smooth regime changes, we, unlike them, provide methodological innovation in accounting for structural breaks in a smooth manner when analyzing volatility spillover. In sum our analysis extends the literature in two dimension: international evidence and methodology. The remainder of the paper is organized as follows: Section 2 discusses the methodologies for testing causality in prices and volatility. Section 3 presents the data and its properties, as well as the results from the tests of causality. Finally, Section 4 concludes and draws implications of our results.

2. Econometric Methodology

2.1. Testing for price transmission with structural changes

In order to test for price transmission, we start with the basic "causality" model developed by Granger (1969). Granger define VAR(p) model as

$$y_t = \gamma + \Pi_1 y_{t-1} + \cdots + \Pi_p y_{t-p} + u_t \tag{1}$$

where y_t includes endogenous variables, γ is a vector of intercept terms, $\Pi = (\Pi_1, \ldots, \Pi_p)'$ are parameters and u_t are white-noise residuals. In our setting, y_t involves oil prices and international REITs. The null hypothesis of no Granger causality ($H_o\colon \Pi_1 = \cdots = \Pi_p = 0$) can be tested by the Wald statistic which has the chi-square distribution with p degrees of freedom. The Wald statistic for the null of no-Granger causality not only has a non-standard distribution if the variables in VAR model are integrated or co-integrated, but also depends on nuisance parameters (Toda and Yamamoto, 1995; Dolado and Lütkepohl, 1996). In order to overcome these drawbacks, Toda and Yamamoto (1995) (TY hereafter) estimates VAR(p+d) model with the level of variables where d is the maximum unit root degree of variables.

Equation (1) is based on the assumption of that there is no any structural breaks in y_t and the intercept terms γ are hence constant over time. Ventosa-Santaularia and Vera-Valdés (2008) prove an asymptotic result on that the Wald statistic rejects the null hypothesis if a structural break in data generating process is ignored in the estimations. This results is also substantiated via Monte Carlo simulations by Enders and Jones (2016). Authors indicate that ignoring structural breaks in a VAR model leads Granger causality test to have size distortions. They furthermore find out that it also tends to over-reject the null hypothesis unless breaks are properly modelled. Thereby, inferences from a standard Granger causality analysis may be misleading when structural breaks are ignored or improperly taken into account (Enders and Jones, 2016).

In a VAR specification, controlling for structural breaks and determining the original source of breaks is difficult because a break in one variable potentially causes shifts in other variables (Ng and Vogelsang, 2002; Enders and Jones, 2016). The dummy variable approach is traditionally employed for modelling breaks as a sharp process (for example, Perron, 1989; Zivot and Adrews, 1992; Lee and Strazicich, 2003). However, a significant portion of structural changes are gradual in nature. In order to partly remedy this issue, smooth transition approach is used (inter alia, Leybourne at al., 1998; Kapetanios et al., 2003). The core problem with both of these approaches is that they require to know the functional form and number of the breaks. To deal with these problems, Fourier approximation which is based on a variant of Flexible Fourier Form by Gallant (1981) is proposed for capturing structural shifts (see, Becker et al., 2006; Enders and Lee, 2012a and 2012b; Rodrigues and Taylor, 2012). The Fourier approximation does not require a prior knowledge on the form and number of breaks and captures structural shifts as a gradual/smooth process. By using this flexibility to simplify the determination of the form of shifts as well as estimation of the number and dates of breaks in a VAR framework, Enders and Jones (2016), Nazlioglu et al. (2016, 2019) and Gormus et al. (2018) employ Fourier approximation in recent papers.

Nazlioglu et al. (2016) extends the TY framework with Fourier approximation by relaxing the assumption of that the intercept terms γ are constant over time and define VAR*(p+d)* model as

$$y_t = \gamma(t) + \Pi_1 y_{t-1} + \cdots + \Pi_{p+d} y_{t-(p+d)} + u_t \tag{2}$$

where the intercept terms $\gamma(t)$ are the functions of time and denote any structural shifts in y_t. To capture structural shifts as a gradual process with an unknown date, number and form of breaks, the Fourier approximation is defined by

$$\gamma(\mathrm{t}) \cong \gamma_0 + \sum_{k=1}^{n} \gamma_{1k} sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} \gamma_{2k} cos\left(\frac{2\pi kt}{T}\right) \tag{3}$$

where n is the number of frequencies, γ_{1k} and γ_{2k} measures the amplitude and displacement of the frequency, respectively. By substituting equation (3) into (2), we obtain

$$y_t = \gamma_0 + \sum_{k=1}^{n} \gamma_{1k} sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} \gamma_{2k} cos\left(\frac{2\pi kt}{T}\right) + \Pi_1 y_{t-1} + \cdots + \Pi_{p+d} y_{t-(p+d)} + u_t. \tag{4}$$

It is worthwhile noting that a large value of n is most likely to be associated with stochastic parameter variation and decreases degrees of freedom. A single Fourier frequency, on the other hand, mimics a variety of breaks in deterministic components, hence one can also use a single frequency component (see, Becker et al., 2006). $\gamma(\mathrm{t})$ with a single frequency is defined as

$$\gamma(\mathrm{t}) \cong \gamma_0 + \gamma_1 sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 cos\left(\frac{2\pi kt}{T}\right) \tag{5}$$

where k denotes the frequency. In the single frequency case, we substitute equation (5) in equation (2) and obtain

$$y_t = \gamma_0 + \gamma_1 sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 cos\left(\frac{2\pi kt}{T}\right) + \Pi_1 y_{t-1} + \cdots + \Pi_{p+d} y_{t-(p+d)} + u_t. \tag{6}$$

In the Toda-Yamamoto framework, the null hypothesis of Granger non-causality is based on zero restriction on first p parameters ($H_o: \Pi_1 = \cdots = \Pi_p = 0$) on the variable of interest and the Wald statistic has the chi-square distribution with p degrees of freedom. The recent works in the causality literature use the bootstrap distribution in order to increase the power of test statistic in small samples as well as being robust to the unit root and co-integration properties of data (see Mantalos, 2000; Hatemi-J, 2002; Hacker and Hatemi-J, 2006; Balcilar et al., 2010). In addition to using the asymptotic chi-square distribution, we also obtain the bootstrap distribution of Wald statistic by employing residual sampling bootstrap approach originally proposed by Efron (1979).[3] Nazlioglu et al. (2019) conduct Monte Carlo simulations in order to compare the size and power properties of the Fourier TY approach with those of the TY test. The results shows that as the number of observations grows, while the difference between asymptotic and bootstrap distribution disappears, the importance of considering the structural shifts in causality analysis becomes more obvious. Moreover, while the TY test has severe size distortions in large samples, the Fourier TY test has good size properties.

Both equation (4) and (6) requires determining the number of Fourier frequency components and lag lengths. We follow the common approach to determine the optimal

[3] In order to save space, we omit the details of the bootstrap procedure here and refer an interested reader to Hatemi-J (2002) and Balcilar et al. (2010).

number of lags in a causality analysis. We first set the number of Fourier frequency and lags to a maximum scalar and pare down one-by-one up to one, then select the optimal Frequency and lag combination which minimizes information criterion such as Akaike or Schwarz.

2.2. Testing for volatility transmission with structural changes

We also investigate volatility interactions between the REITs and oil markets by employing the Lagrange multiplier (LM) volatility spillover test developed by Hafner and Herwartz (2006). Especially when international markets are analyzed, the LM test provides more accurate results compared to the Cheung and Ng (1996) and Hong (2001) methods (Gormus, 2016). In order to obtain the LM test, GARCH (1,1) is estimated for series *i* and *j*. The GARCH (1,1) specification for *i* is given by

$$y_{it} = x_{it}'c_i + \varepsilon_{it} \tag{7}$$

$$\sigma_{it}^2 = \omega_i + \alpha_i\varepsilon_{it-1}^2 + \beta_i\sigma_{it-1}^2 \tag{8}$$

where x_{it} is exogenous variables, ε_{it} is error terms that denotes the real-valued information, and σ_{it}^2 is conditional variance. $\omega_i > 0, \alpha_i, \beta_i \geq 0$ is established in order to ensure non-negativity of conditional variance as well as $\alpha_i + \beta_i < 1$ to ensure finite variance. Everything we assume for the series *i* hold for series *j* as well.

After the estimation of the GARCH (1,1) models for *i* and *j*, we define

$$\varepsilon_{it} = \xi_{it}\sqrt{\sigma_{it}^2(1 + z_{jt}'\pi)}, \qquad z_{jt} = \left(\varepsilon_{jt-1}^2, \sigma_{jt-1}^2\right)' \tag{9}$$

where ξ_{it} is standardized residuals of series *i*. ε_{jt}^2 and σ_{jt}^2 are squared disturbance term and volatility for series *j*, respectively. The null hypothesis of no-volatility transmission

($H_0\colon \pi = 0$) is tested against the alternative hypothesis of volatility transmission ($H_0\colon \pi \neq 0$). The LM statistic is defined as

$$\lambda_{LM} = \frac{1}{4T}\left(\sum_{t=1}^{T}(\xi_{it}^2 - 1)\, z_{jt}'\right)V(\theta_i)^{-1}\left(\sum_{t=1}^{T}(\xi_{it}^2 - 1) z_{jt}\right) \tag{10}$$

where

$$V(\theta_i) = \frac{\kappa}{4T}\left(\sum_{t=1}^{T} z_{jt}\, z_{jt}' - \sum_{t=1}^{T} z_{jt}\, x_{it}'\left(\sum_{t=1}^{T} x_{it}\, x_{it}'\right)^{-1}\sum_{t=1}^{T} x_{it}\, z_{jt}'\right), \kappa = \frac{1}{T}\sum_{t=1}^{T}(\xi_{it}^2 - 1)^2.$$

The number of misspecification indicators in z_{jt} affects the asymptotic distribution of the test statistic and λ_{LM} hence has the chi-square distribution with two degrees of freedom.

The conditional variance in equation (8) does not have any structural changes and is affected from the constant term ω_i, the ARCH term α_i, and the GARCH term β_i. The recent literature on the volatility modelling implies that the long-run volatility process can be also affected from the structural changes (see among others, Starica and Granger, 2005; Diebold and Inoue, 2013, Mikosch and Starica, 2004). If the volatility process has structural changes, then the conventional GARCH(1,1) model may not be sufficient to modelling the long-run volatility. Pascalau et al. (2011), Teterin et al. (2016), and Li and Enders (2018) more recently show that the structural changes in the conditional variance can be well approximated by Fourier approximation which does not require a prior information regarding the numbers, dates and form of variance shifts. Moreover, Fourier approximation may be more suitable for financial data since several breaks may occur in a long financial series where it might be difficult to identify (Li and Enders, 2018).

The conventional GARCH model can be re-defined to include breaks in the level of conditional variance (Pascalau et al., 2011; Li and Enders, 2018) as follows

$$\sigma_{it}^2 = \omega_i(t) + \alpha_i \varepsilon_{it-1}^2 + \beta_i \sigma_{it-1}^2 \tag{11}$$

where $\omega_i(t)$ now depends on time. To capture any shifts in volatility process, $\omega_i(t)$ is approximated by Fourier approximation and the equation (8) is re-written as

$$\sigma_{it}^2 = \omega_{0i} + \sum_{k=1}^{n} \omega_{1i,k} sin\left(\frac{2\pi k_i t}{T}\right) + \sum_{k=1}^{n} \omega_{2i,k} cos\left(\frac{2\pi k_i t}{T}\right) + \alpha_i \varepsilon_{it-1}^2 + \beta_i \sigma_{it-1}^2. \tag{12}$$

The test statistic in equation (10) can be obtained based on equation (12) and we label it as Fourier λ_{LM} $(F\lambda_{LM})$. Since using Fourier approximation does not change the number of misspecification indicators in z_{jt}, $F\lambda_{LM}$ follows an asymptotic chi-square distribution with two degrees of freedom.

The equation (12) requires determining the number of Fourier frequency components. As discussed in Pascalau et al. (2011), one can benefit from Akaike or Schwarz information criterion. We first define the maximum number of Fourier frequency and then we select the optimal frequency which minimizes information criterion.

3. Data and Empirical Results

3.1. Data

Our analysis utilizes daily observations of REITs indices of nineteen countries (Australia, Belgium, Canada, France, Germany, Hong Kong, Ireland, Italy, Japan, Malaysia, Mexico, The Netherlands, New Zealand, Singapore, South Africa, Spain, Turkey, the UK, and the US), and the oil price. The REITs data is sourced from the DataStream database of Thomson Reuters, with the real estate data corresponding to the S&P REITs indices for each country. As for the oil prices, we use the daily price of Brent Crude as it serves as a benchmark price for purchases of oil worldwide, and is used to price two thirds of the world's internationally traded crude oil supplies. The data is derived from the FRED database of the Federal Reserve Bank of St. Louis. To avoid the impact of exchange rate fluctuations, both the REITs and oil price data are in US dollar terms. A graphically plotted version of the data can be seen in Figure A1 and the descriptive statistics are summarized in Table A1 in the Appendix section. Expectedly the time span of REITs data varies across countries (as detailed in Table A1), with Ireland having the shortest sample (12/24/2013-03/11/2019), and the US covering the longest period (07/31/1989-09/13/2018). Besides the econometric "non-normality" of the oil and REITs prices, what is important to observe is that these variables have gone through multiple regime changes in a consistent manner over the sample of data considered. This fact further supports our decision of analyzing price and volatility transmissions using models that incorporate a variety of structural breaks.

In order to proceed with the TY approach to Granger-type price transmission analysis, one needs to determine the maximum integration number *(d)* of unit root of the variables. To accomplish this, we conduct the augmented Dickey & Fuller (ADF) test of Dickey and Fuller (1979), the ADF test with one structural break (ZA-ADF) developed by Zivot and Andrews (1992) and the ADF with a Fourier approximation (F-ADF) developed by Enders and Lee (2012b).[4] Table 1 reports the results from these unit root tests. While the unit root tests cannot reject the null hypothesis of unit root for the level of oil prices at the 1 percent level of significance, they strongly support the evidence on stationarity for the first difference of the oil prices. Similar findings are also observed for the REITs series.

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[4] In order to save space, we omit the details of unit root tests. An interested reader is referred to the cited articles. The unit root tests were conducted with the tspdlib library in GAUSS available at: https://github.com/aptech/tspdlib written by Saban Nazlioglu.

Accordingly, the maximum integration of the variables (d) is equal to one in VAR$(p + d)$ models.

Table 1: Results from unit root tests for oil prices and REITs

	Level						First Difference					
	ADF		ZA-ADF		F-ADF		ADF		ZA-ADF		F-ADF	
Oil prices	-1.453		-3.670		-3.571	*	-83.330	***	-83.365	***	-83.329	***
REITs												
Canada	-1.448		-2.865		-1.814		-33.362	***	-33.595	***	-33.476	***
Australia	-1.869		-4.804	*	-2.612		-32.705	***	-33.079	***	-32.788	***
France	-3.173	**	-3.401		-3.255		-59.935	***	-60.062	***	-59.972	***
Germany	-2.694	*	-3.478		-2.963		-21.061	***	-21.561	***	-21.133	***
Hong Kong	-0.142		-3.499		-0.334		-63.480	***	-63.540	***	-63.506	***
Japan	-2.219		-3.773		-2.255		-64.470	***	-64.475	***	-48.180	***
Netherlands	-1.644		-3.501		-2.726		-66.947	***	-67.014	***	-66.974	***
New Zealand	-1.369		-3.684		-1.925		-73.770	***	-73.848	***	-73.840	***
Singapore	-2.935	**	-3.185		-3.252		-41.817	***	-62.700	***	-41.901	***
UK	-2.754	*	-4.140		-2.682		-51.799	***	-52.222	***	-51.870	***
USA	-0.981		-4.155		-1.011		-100.335	***	-100.419	***	-100.368	***
Belgium	-1.740		-3.727		-2.664		-72.562	***	-72.585	***	-72.596	***
Ireland	-3.049		-4.922	**	-3.645	*	-38.391	***	-38.498	***	-38.425	***
Italy	-3.554	***	-4.869	**	-3.695	*	-27.533	***	-27.607	***	-27.645	***
Malaysia	-1.928		-3.321		-2.534		-59.969	***	-60.051	***	-60.016	***
Mexico	-0.876		-4.480		-2.075		-32.951	***	-33.123	***	-32.989	***
South Africa	-3.191	**	-4.049		-3.523	*	-52.376	***	-52.480	***	-52.376	***
Spain	-1.634		-4.749	*	-2.260		-45.450	***	-45.539	***	-45.464	***
Turkey	-0.963		-3.477		-1.653		-53.090	***	-53.272	***	-53.110	***

Notes: ADF: Augmented Dickey and Fuller (1979) unit root test. ZA-ADF: Zivot and Andrews (1992) ADF unit root test with a break. F-ADF: Enders and Lee (2012b) ADF unit root test with Fourier approximation. ADF test includes a constant term. ZA-ADF and F-ADF tests include structural shifts in the constant term. The optimal lag(s) were determined by Schwarz information criterion for augmented ADF and ZA-ADF tests by setting maximum number of lags to 5. The optimal frequency and lags were determined by Schwarz information criterion for F-ADF by setting maximum number of lags to 5 and of Fourier frequency to 3. ADF critical values are -3.433 (1%), -2.862 (5%), -2.567 (10%). ZA-ADF critical values are -5.34 (1%), -4.80 (5%), -4.58 (10%). The critical values for F-ADF test with one frequency are -4.31 (1%), -3.75 (5%), -3.45 (10%). *, ** and *** indicate statistical significance at 10, 5 and 1 percent, respectively.

3.2. Main Results

Table 2 reports the results of the price transmission analysis. In order to determine the optimal lags in the TY test and the optimal Fourier frequency and lags in the Fourier TY approach, we set the maximum number of frequency to 3 and lags to 5. The optimal frequency and lags are determined by minimizing the Akaike information criterion.[5]

[5] The causality tests were conducted with the tspdlib library.

Table 2: Results from price causality tests

	Panel A: No-shift				Panel B: Smooth shifts									
	TY				FTY with single frequency (k)					FTY with cumulative frequency (n)				
Oil ≠>REITs	*p*	Wald	p-val^{a}	p-val^{b}	*p*	*k*	Wald	p-val^{a}	p-val^{b}	*p*	*n*	Wald	p-val^{a}	p-val^{b}
Canada	5	1.812	0.874	0.872	5	3	1.882	0.865	0.880	5	3	1.854	0.869	0.846
Australia	5	9.368	0.095	0.099	4	2	6.995	0.136	0.154	4	3	6.864	0.143	0.145
France	1	0.901	0.342	0.322	1	2	0.890	0.346	0.339	1	3	0.885	0.347	0.301
Germany	5	6.507	0.260	0.237	5	1	6.504	0.260	0.266	5	3	6.490	0.261	0.261
Hong Kong	1	14.384	0.000	0.000	2	1	15.736	0.000	0.000	2	2	15.065	0.001	0.000
Japan	5	35.669	0.000	0.000	3	2	34.690	0.000	0.000	3	3	34.908	0.000	0.000
Netherlands	1	0.338	0.561	0.555	2	1	0.868	0.648	0.644	2	2	0.961	0.618	0.644
New Zealand	1	3.423	0.064	0.055	2	2	5.478	0.065	0.063	2	2	5.369	0.068	0.086
Singapore	2	18.744	0.000	0.000	3	2	19.660	0.000	0.000	3	2	18.745	0.000	0.000
UK	1	2.654	0.103	0.096	2	1	3.115	0.211	0.218	2	2	3.001	0.223	0.216
USA	1	1.548	0.213	0.199	2	1	3.073	0.215	0.204	2	2	3.078	0.215	0.234
Belgium	1	0.071	0.790	0.792	2	2	0.165	0.921	0.926	2	3	0.169	0.919	0.932
Ireland	2	7.300	0.026	0.027	2	2	8.229	0.016	0.020	2	2	7.560	0.023	0.028
Italy	4	12.557	0.014	0.021	5	1	12.402	0.030	0.036	5	3	12.014	0.035	0.039
Malaysia	2	43.878	0.000	0.000	3	1	44.681	0.000	0.000	3	2	43.305	0.000	0.000
Mexico	4	5.068	0.280	0.265	2	1	0.672	0.714	0.730	2	2	0.641	0.726	0.737
South Africa	1	2.106	0.147	0.152	2	1	2.152	0.341	0.348	2	2	2.351	0.309	0.314
Spain	2	2.531	0.282	0.261	3	1	2.567	0.463	0.456	3	3	1.919	0.589	0.582
Turkey	1	0.717	0.397	0.405	2	1	2.699	0.259	0.236	2	2	2.677	0.262	0.274
REITs ≠>Oil														
Canada	5	24.385	0.000	0.000	5	3	24.025	0.000	0.002	5	3	24.395	0.000	0.000
Australia	5	4.452	0.486	0.486	4	2	3.157	0.532	0.526	4	3	2.914	0.572	0.578
France	1	0.005	0.945	0.953	1	2	0.002	0.961	0.970	1	3	0.000	0.983	0.988
Germany	5	13.807	0.017	0.023	5	1	14.579	0.012	0.017	5	3	15.188	0.010	0.013
Hong Kong	1	1.573	0.210	0.214	2	1	1.885	0.390	0.392	2	2	1.824	0.402	0.381
Japan	5	26.263	0.000	0.000	3	2	1.260	0.739	0.743	3	3	1.346	0.718	0.715
Netherlands	1	0.030	0.861	0.860	2	1	0.327	0.849	0.850	2	2	0.396	0.820	0.833
New Zealand	1	0.971	0.324	0.319	2	2	1.409	0.494	0.485	2	2	1.413	0.493	0.488
Singapore	2	3.238	0.198	0.183	3	2	4.919	0.178	0.181	3	2	4.860	0.182	0.190
UK	1	0.198	0.656	0.669	2	1	0.772	0.680	0.679	2	2	0.873	0.646	0.651
USA	1	30.433	0.000	0.000	2	1	31.628	0.000	0.000	2	2	31.682	0.000	0.000
Belgium	1	1.558	0.212	0.213	2	2	4.403	0.111	0.119	2	3	4.370	0.112	0.111
Ireland	2	0.965	0.617	0.609	2	2	0.903	0.637	0.619	2	2	0.945	0.624	0.625
Italy	4	4.552	0.336	0.354	5	1	4.397	0.494	0.481	5	3	4.205	0.520	0.542
Malaysia	2	0.068	0.967	0.967	3	1	0.535	0.911	0.923	3	2	0.279	0.964	0.968
Mexico	4	6.354	0.174	0.157	2	1	5.668	0.059	0.052	2	2	5.580	0.061	0.073
South Africa	1	2.224	0.136	0.131	2	1	2.617	0.270	0.260	2	2	2.296	0.317	0.297
Spain	2	7.465	0.024	0.026	3	1	8.499	0.037	0.046	3	3	7.929	0.047	0.056
Turkey	1	1.221	0.269	0.265	2	1	1.422	0.491	0.493	2	2	1.422	0.491	0.484

Notes: ≠> signifies the null hypothesis of no-transmission. TY: traditional TY approach which does not account for structural breaks, FTY(k): Fourier TY approach with single frequency which is based on equation (6), and FTY(n): Fourier TY approach with cumulative frequencies is based on equation (4). Maximum *k/n* and *p* are respectively set to 3 and 5, then optimal *k/n* and *p* are determined by Akaike information criterion. p-val^{a} is the p-value based on the asymptotic chi-square distribution with p degrees of freedom. p-val^{b} is the p-value based on the bootstrap distribution with 1,000 replications. VAR(p+d) models are estimated with d equal to 1. Bivariate VAR models include oil prices and REITs variable.

The results from the TY test (see panel A of Table 2) show that the null hypothesis of no-price transmission from oil prices to REITs is rejected in nine countries (Australia, Hong Kong, Japan, New Zealand, Singapore, UK, Ireland, Italy, and Malaysia) (at least) at the 10 percent significance level according to the bootstrap distribution.[6] This results imply that there is an information transmission, and hence a predictive power from oil prices to REITs in these countries. The TY test is not able to take into account the role of possible structural shifts in a VAR model. It is well-known that the oil prices are characterized by a different trend and volatility dynamics after the 2007/2008 financial crisis. In order take into account the role of such structural shifts, one needs to know the date, number, and form of shifts which is challenge in practice for an applied research. A Fourier approximation is able to efficiently solve this problem because it does not require the knowledge of the date, number, and functional form of any break. The results from the Fourier TY causality analysis in panel B of Table 2 are in general similar to those of the TY approach with a few important exceptions. Specifically, the Fourier TY method does not provide evidence on the existence of a price transmission from oil prices to REITs in Australia and UK where the traditional TY approach showed there was.

As regards to a price transmission from REITs to oil prices, the TY test indicates that the null hypothesis of no-transmission is rejected for five countries (namely, Canada, Germany, Japan, USA, and Spain). When the structural shifts are taken into account in the estimations, even though the transmission results hold for Canada, Germany, USA, and Spain, it disappears in the case of Japan. The Fourier TY approach further shows a

[6] Note that the asymptotic distribution does not support price transmission for the UK.

transmission from REITs to oil prices for Mexico where the traditional TY method does not.

In essence, the price transmission between REITs and oil markets is primarily concentrated in established markets,[7] though some evidence is detected for emerging REITs markets such as Ireland, Italy, Malaysia, Mexico and Spain. Based on the suggestions of an anonymous referee, a graphical summary of these results have now been provided in Figure A2 in the Appendix of the paper.

If we look at the results closely, we find that for economies with matured and established REITs markets (and financial markets in general), which simultaneously also plays an important role in the oil market from the side of both exports and imports (for example, Canada, Germany, Japan, and the US), there is evidence of causality from the REITs sector to the oil market. The real estate sector is viewed as a leading indicators of the macroeconomy (Stock and Watson, 2003), and hence its impact on output, filters out into the oil market, which is known to be affected by economic activity (Gupta and Wohar, 2017). For the countries, which are relatively lesser of a player in the oil market but have somewhat established REITs sector, or for economies like Malaysia and Mexico which does have domestic oil reserves even with emerging REITs, the causality is observed from the oil market to the REITs sector. In these cases, oil market is possibly affecting the REITs market either through the influence of oil prices on the overall financial market (Balcilar et al., 2015) or on output (and even, inflation and interest rates (Gupta and

[7] Unlike Nazlioglu et al., (2016), we could not detect bi-directional price transmission between oil and REITs for the USA (and also we did not obtain evidence of causality from the oil to REITs as in Huang and Lee (2009)). But realizing that Nazlioglu et al., (2016) had used the West Texas Intermediate (WTI) oil price instead of the Brent crude. We hence re-conduct the causality test using WTI oil prices, and just as in Nazlioglu et al., (2016), are able to detect bi-directional spillovers between the oil and real estate markets. Complete details of these results have been presented in Table A2 in the Appendix of the paper.

Kotzé, 2017)), which in turn tends to affect a sector of the financial market like the REITs especially when it is matured, or via the economy for countries where oil revenues does play an important part of their income, respectively.

When we consider information transmission between markets, in addition to analyzing the data at level (mean price transmission), we also look at the risk transfer dimension (volatility transmission). Due to the econometric nature of the price transmission analysis, the identified interactions can be interpreted as a long-run phenomenon. However, volatility transmission analysis is related to the short-term. This analysis is especially important because not only hedging strategies require knowledge on volatility spillovers between asset classes, identification of risk interactions is even more relevant in the short-run since risk perceptions can change rapidly (Nazlioglu et al., 2016).

Table 3: Results from volatility spillover tests

	Oil ≠> REITs					REITs ≠> Oil				
	λ_{LM}	p-value	n	$F\lambda_{LM}$	p-value	λ_{LM}	p-value	n	$F\lambda_{LM}$	p-value
Canada	14.469	0.000	3	16.254	0.000	15.891	0.000	3	20.477	0.000
Australia	12.791	0.000	3	13.110	0.000	13.495	0.000	3	16.247	0.000
France	18.658	0.000	2	21.067	0.000	6.411	0.040	1	6.959	0.030
Germany	4.795	0.090	1	5.673	0.058	8.656	0.013	3	18.483	0.000
Hong Kong	13.019	0.001	1	13.107	0.001	14.571	0.000	2	16.862	0.000
Japan	10.425	0.005	3	12.454	0.001	11.788	0.002	3	14.328	0.000
Netherlands	14.324	0.000	3	14.361	0.000	8.290	0.015	3	10.233	0.005
New Zealand	2.369	0.305	3	1.506	0.470	15.817	0.000	3	15.118	0.000
Singapore	8.678	0.013	2	14.577	0.006	12.603	0.001	1	15.686	0.000
UK	4.660	0.097	3	5.611	0.060	3.085	0.213	3	3.798	0.149
USA	9.807	0.007	1	13.997	0.000	6.820	0.033	3	10.372	0.005
Belgium	10.492	0.005	3	13.902	0.000	13.222	0.001	3	15.410	0.000
Ireland	2.676	0.262	1	2.137	0.343	1.673	0.433	3	2.930	0.231
Italy	1.065	0.587	1	3.739	0.154	9.912	0.007	3	14.082	0.000
Malaysia	1.366	0.504	3	11.667	0.002	4.146	0.125	3	3.441	0.178
Mexico	1.646	0.438	3	1.860	0.394	10.091	0.006	3	10.316	0.005
South Africa	12.329	0.002	3	16.224	0.000	5.994	0.064	3	5.526	0.063
Spain	0.240	0.886	3	3.194	0.202	6.982	0.030	3	4.164	0.099
Turkey	11.412	0.003	3	7.453	0.024	7.064	0.029	3	7.949	0.018

Notes: ≠> signifies the null hypothesis of no-volatility spillover. λ_{LM}: Volatility spillover LM test which does not account for structural breaks is based on the variance equation (8). $F\lambda_{LM}$: Volatility spillover Fourier LM test is based on the variance equation (12). Maximum number of Fourier frequency n are set to 3 and then optimal n is determined by Akaike information criterion. The mean equation is based AR(1) model for the return of REITs and oil prices.

The results from the volatility transmission LM test by Hafner and Herwartz (2006) are reported in Table 3. Note that λ_{LM} is the volatility transmission test based on the variance equation (8) which does not account for structural breaks, and $F\lambda_{LM}$ is the volatility transmission Fourier LM test based on the variance equation (12) which accounts for structural breaks in the conditional variance of the REITs and oil returns.

The λ_{LM} test indicates test the null hypothesis of no volatility transmission from oil prices to REITs is rejected in thirteen cases (at least at the 10 percent level of significance), but cannot be rejected for six cases (New Zealand, Ireland, Italy, Malaysia, Mexico, and Spain). These results are also supported by the $F\lambda_{LM}$, except for the case of Malaysia, for which significant volatility transmission from the oil to REITs is evidenced. In relation to the volatility transmission from REITs to oil prices, the λ_{LM} test shows that the null hypothesis of no transmission cannot be rejected only for three cases – UK, Ireland, and Malaysia. In other words, volatility in REITs market impacts risk in oil market in sixteen countries (at least at the 10 percent level of significance). This evidence continues to hold even if we control for smooth shifts in the volatility process, since the $F\lambda_{LM}$ test reaches to the same conclusions. These findings therefore imply that there is a strong evidence of risk transmission between oil and REITs markets, and the interactions appear to work in both directions, as also detected by Nazlioglu et al., (2016) for the case of the USA. In other words, there exists a risk transmission feedback between oil markets and a significant portion of the international REITs we tested. Again, as with the price-level causality, based on the suggestions of an anonymous referee, a graphical summary of these results of volatility spillovers have now been provided in Figure A3 in the Appendix of the paper.

As we interpret the results of both price and volatility transmission tests together, we observe a stronger evidence of risk transmission between the REITs and oil markets (irrespective of the level of evolution of the real estate sector) compared to price interactions. This result of relatively stronger volatility or uncertainty spillovers in these two markets in both directions is not necessarily surprising. We say this since, oil market volatility is known to drive economic uncertainty (Hailemariam et al., 2019), which in turn impacts the volatility of REITs markets (Ajmi et al., 2015), just like overall financial markets (Chuliá et al., 2017). At the same time, uncertainty in real estate markets affects the overall macroeconomic uncertainty (Gabauer and Gupta, 2020), with each of these economies heavily related to the oil market as major exporters or importers, the general macroeconomic uncertainty spills over to the oil market volatility. Also note, REITs market uncertainty in a particular economy is likely to spillover to the REITs and equity of other economies (Hoesli and Reka, 2015), and that too irrespective of the stage of evolution the REITs markets are in (Bouri et al., 2019), given the interconnectedness of financial markets, which in turn, also affects uncertainty of the oil market, given the financialization of commodity markets (Bonato, 2019). In other words, volatility of REITs can affect the volatility of the oil market directly, or through international spillovers via other REITs market.

3.3. Robustness Check

Based on the suggestions of an anonymous referee, we repeated our analyses of price and volatility spillovers between the REITs and the oil markets using a common sample across all the countries. The results from the TY causality tests for the same sample period (December 24, 2013 – September 13, 2018) are reported in Table A3 in the Appendix of the paper. The null hypothesis of no-price transmission from oil prices to REITs is rejected in nine countries (Germany, Japan, Netherlands, New Zealand, Singapore, UK, Belgium, Ireland, and Malaysia) at least at the 10 percent significance level. The results from the Fourier TY causality analysis support these findings with the exception for Germany, Netherlands, and New Zealand. With respect to the price transmission from REITs to oil prices, the TY test indicates that the null hypothesis of no-transmission is rejected for six countries (namely, Canada, France, Germany, Japan, Mexico, and Spain). These findings (only an exception for Germany) is also supported with the Fourier TY approach. The findings from the TY causality tests for the same sample period are in general consistent with those from the TY causality tests for the country-specific sample periods as reported in Table 2. Only a few exceptions are Hong Kong, Belgium, and Italy for the causality from oil prices to REITs. Specifically, in the December 24, 2013 – September 13, 2018 period, even though the causal linkage disappears for Hong Kong and Italy, it appears for Belgium. For the causality from REITs to oil prices, while a causal linkage is observed for France, it again disappears for USA over the December 24, 2013 – September 13, 2018 period.

The results from the volatility transmission tests for the same sample period (December 24, 2013 – September 13, 2018) are reported in Table A4 in the Appendix of the paper. Note again that λ_{LM} test does not account for structural breaks and $F\lambda_{LM}$ test accounts for structural breaks in the conditional variance of the REITs and oil returns. The λ_{LM} test indicates that the null hypothesis of no volatility transmission from oil prices to REITs is rejected for nine cases (France, Germany, Hong Kong, Japan, Singapore, USA, Belgium, Mexico, and South Africa) at least at the 10 percent level of significance.

However, the $F\lambda_{LM}$ test supports this evidence only in three cases (Japan, Singapore, and USA). For the volatility transmission from REITs to oil prices, the λ_{LM} test shows that the null hypothesis of no transmission is rejected only for five cases – Germany, Hong Kong, Japan, USA, and Mexico at least at the 10 percent level of significance. But, this evidence continues to hold only for Japan and Mexico when we take into account the variance shifts. When we compare these findings with those in Table 3, the role of structural shifts in the volatility process is more pronounced during the December 24, 2013 – September 13, 2018 period, implying that the risk transmission mechanisms between oil and REITs markets can be characterized by gradual variance shifts. This is not surprising given the tumultuous behavior of the oil market during this period. But overall, we do tend to find evidence that volatility spillovers across these two markets is more important than price-level causal relationships.

4. Conclusions

The rapid growth of REITs in recent years has made it an important portfolio option. Furthermore, the role of the real estate sector in driving the recent financial crisis is also well-accepted. Just like any other investment vehicle, as the REITs market grows in size and impact, it becomes important for investors and policy makers to understand the outside drivers that impact the dynamics of that asset group. As commodity markets become more financialized (Henderson et al., 2014; Adams and Gluck, 2015), they tend to further interact with other financial markets - changing their portfolio and economic implications. Although energy markets are one piece of the overall commodity markets, numerous studies have suggested their strong impact – oil in particular – over the financial markets. Given these studies' findings and the growing impact of the REITs markets, it is important to evaluate the price and volatility sensitivity of REITs to fluctuations in the oil market.

In this paper, we evaluate nineteen international REITs markets which are at different stages of development. Furthermore, we try to verify the robustness of any suggested interaction with newly developed econometric techniques which minimize possible data and researcher-based biases. In the process, we aim to add to the limited literature which only concentrate on US REITs.

The results of our study suggest strong evidence of bidirectional volatility transmission between the REITs markets and the oil market, irrespective of the REIT market's state of evolution. In comparison, price-level transmissions are weak and primarily restricted to established and matured markets. For both the volatility and price transmission studies, accounting for gradual structural shifts suggested different results with some countries while confirmed the results with others. The basic story that volatility spillovers are more important than price-level causality continues to hold under a shorter common sample period of the various countries.

These findings have important implications for academics, investors and policymakers. As far as academic researchers are concerned, we show that to derive appropriate statistical inferences when analyzing interactions between REITs and oil markets, it is of paramount importance that gradual structural changes are incorporated into the modelling frameworks. The lack of this statistical control could easily yield incorrect inferences - particularly for the first-moment. From the perspective of REITs investors, understanding the interactions between these markets can improve both short and long-term portfolio strategies – especially in the established markets as our results suggest. In particular, volatility transmission results show decreasing diversification capacity of oil markets with portfolios containing REITs. Finally, the negative implications of a shock to either of the markets is likely to be prolonged due to the bi-directional feedback effect, and in turn, this could have long-term economical outcomes (Nguyen-Thanh, 2018; van Eyden et al., 2019). Hence, policymakers need to give increased attention to the interaction between these markets as even short-term shocks can be detrimental for the economy in the long-run as history has shown.

While our study suggests interesting interactions between these markets, the specific shock that drives the oil market are not analyzed, and is a limitation of our analysis. For example, the literature suggests that oil price movements due to different structural shocks, like, oil-specific supply, demand and inventory shocks, and demand shock due to changes in global economic activity tend to impact asset markets differently (Kilian, 2009; Kilian and Murphy, 2014). It would be interesting to analyze the impact of those various oil shocks, rather than aggregate oil price, on international REITs markets as part of future research. Moreover, since in-sample predictability does not guarantee out-of-sample gains, it would also be interesting to extend our analysis to a full-fledged forecasting exercise.

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APPENDIX:

Table A1. Summary Statistics

Country	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	*p*-value	Obs.
Australia	147.3570	138.2050	324.1300	49.1500	47.7130	1.3799	4.9134	2386.183	0.0000	5078 (11/09/1998-13/09/2018)
Belgium	124.0825	123.9450	195.3400	64.0700	26.7265	0.0426	2.8271	7.859	0.0197	5078 (11/9/1998 - 13/09/2018)
Brent	47.8614	33.5800	143.9500	9.1000	33.2263	0.8423	2.4584	964.188	0.0000	7390 (31/07/1989-13/09/2018)
Canada	225.9882	246.7300	380.6900	88.5800	82.7368	-0.1702	1.6704	398.568	0.0000	5078 (11/9/1998-13/09/2018)
France	278.0702	300.0100	424.1400	99.9100	71.0661	-0.7449	2.6221	373.320	0.0000	3793 (30/09/2003-13/09/2018
Germany	72.4603	73.9300	118.6200	17.5200	14.3852	-1.0132	5.2027	1027.156	0.0000	2752 (23/10/2007-13/09/2018)
Hong Kong	205.4961	172.9900	442.5000	74.6500	93.8902	0.6859	2.3087	354.000	0.0000	3600 (30/06/2004-13/09/2018)
Ireland	87.0077	87.5450	103.9400	66.6000	6.7290	-0.4323	2.8905	38.095	0.0000	1204 (24/12/2013-13/09/2018)
Italy	50.2774	48.4500	104.9300	25.8700	12.9934	1.1803	5.3852	1220.434	0.0000	2601 (2/6/2008-13/09/2018)
Japan	174.1351	182.7650	289.9300	78.3000	41.1975	-0.2521	2.7495	56.869	0.0000	4306 (28/09/2001-13/09/2018)
Malaysia	120.6988	121.6300	178.0600	80.0200	18.2406	0.4565	3.3674	120.930	0.0000	2997

										(31/10/2006-13/09/2018)
Mexico	110.3083	106.0500	172.5000	65.0200	27.6386	0.2084	1.7544	109.196	0.0000	1519 (25/09/2012-13/09/2018)
Netherlands	144.0335	133.8500	298.4000	71.6000	50.5057	0.8496	3.1611	616.320	0.0000	5078 (11/09/1998-13/09/2018)
New Zealand	140.0638	149.3700	223.1300	62.5300	37.9731	-0.3360	2.0657	280.213	0.0000	5078 (11/09/1998-13/09/2018)
South Africa	114.1545	114.2600	158.7600	53.0900	17.2292	-0.3881	3.0728	85.587	0.0000	3379 (09/05/2005-13/09/2018)
Singapore	269.0508	287.0800	401.6100	100.0000	71.2530	-0.6768	2.5952	320.983	0.0000	3859 (30/06/2003-13/09/2018)
Spain	117.4411	119.1300	157.3200	90.1900	12.3405	0.5396	4.2022	252.950	0.0000	2326 (06/07/2009-13/09/2018)
Turkey	43.7584	40.9600	102.6200	7.7400	17.9339	0.5863	2.7430	190.319	0.0000	3170 (28/02/2006-13/09/2018)
United Kingdom	42.4712	38.3800	108.4600	13.9300	16.5967	1.7991	6.4709	3056.644	0.0000	2935 (31/01/2007-13/09/2018)
United States	181.8762	150.0300	349.0300	74.2300	76.0220	0.4916	1.7850	752.216	0.0000	7390 (31/07/1989-13/09/2018)

Table A2: Results from causality analysis for USA with WTI prices

	WTI ≠> REITs			REITs ≠>WTI		
	TY	FTY(k)	FTY(n)	TY	FTY(k)	FTY(n)
Wald statistic	15.993	10.602	10.574	9.901	8.997	9.019
p-value[a]	0.007	0.031	0.032	0.078	0.061	0.061
p-value[b]	0.009	0.019	0.027	0.082	0.067	0.062
Frequency	-	1	2	-	1	2
Lags (p)	5	4	4	5	4	4

Notes: See Table 2.

Table A3: Results from causality tests for the same sample period (December 24, 2013 – September 13, 2018)

	Panel A: No-shift				Panel B: Smooth shifts									
	TY				FTY with single frequency (k)					FTY with cumulative frequency (n)				
Oil ≠>REITs	*p*	Wald	p-val[a]	p-val[b]	*p*	*k*	Wald	p-val[a]	p-val[b]	*p*	*n*	Wald	p-val[a]	p-val[b]
Canada	1	0.138	0.710	0.718	2	1	0.191	0.909	0.907	2	3	0.182	0.913	0.916
Australia	1	2.401	0.121	0.106	1	1	2.102	0.147	0.149	1	2	1.832	0.176	0.188
France	1	1.779	0.182	0.183	1	1	1.789	0.181	0.201	1	2	1.752	0.186	0.194
Germany	5	16.645	0.005	0.004	1	1	2.330	0.127	0.133	1	2	2.571	0.109	0.108
Hong Kong	1	0.061	0.804	0.816	1	1	0.020	0.888	0.888	1	2	0.012	0.915	0.909
Japan	1	5.671	0.017	0.025	2	2	6.805	0.033	0.036	2	3	6.254	0.044	0.041
Netherlands	1	2.782	0.095	0.076	2	1	3.182	0.204	0.199	2	3	3.678	0.159	0.163
New Zealand	1	2.748	0.097	0.102	1	1	2.494	0.114	0.111	1	3	2.189	0.139	0.123
Singapore	1	8.842	0.003	0.001	2	1	9.601	0.008	0.006	2	3	10.052	0.007	0.010
UK	5	10.045	0.074	0.096	5	1	9.924	0.077	0.074	5	2	9.459	0.092	0.092
USA	1	0.588	0.443	0.451	1	1	0.680	0.410	0.394	1	2	0.863	0.353	0.336
Belgium	1	3.714	0.054	0.059	1	1	3.339	0.068	0.075	1	2	3.034	0.082	0.095
Ireland	2	7.300	0.026	0.032	2	2	8.229	0.016	0.025	2	2	7.560	0.023	0.029
Italy	1	0.608	0.436	0.426	1	2	1.028	0.311	0.311	1	3	0.951	0.330	0.347
Malaysia	1	47.818	0.000	0.000	2	1	48.385	0.000	0.000	2	3	49.151	0.000	0.000
Mexico	1	0.355	0.552	0.565	2	1	1.868	0.393	0.375	2	3	2.025	0.363	0.383
South Africa	1	0.422	0.516	0.510	1	2	0.215	0.643	0.638	2	3	1.279	0.527	0.503
Spain	1	0.476	0.490	0.495	2	1	1.408	0.495	0.496	2	2	1.914	0.384	0.373
Turkey	2	2.102	0.350	0.372	3	1	2.207	0.531	0.513	3	2	2.192	0.533	0.541
REITs ≠>Oil														
Canada	1	3.355	0.067	0.083	2	1	7.056	0.029	0.038	2	3	6.965	0.031	0.028
Australia	1	1.663	0.197	0.214	1	1	1.461	0.227	0.212	1	2	1.274	0.259	0.247
France	1	2.908	0.088	0.071	1	1	3.044	0.081	0.079	1	2	3.133	0.077	0.066
Germany	5	15.577	0.008	0.008	1	1	1.698	0.193	0.191	1	2	1.932	0.165	0.168
Hong Kong	1	1.647	0.199	0.224	1	1	1.874	0.171	0.181	1	2	1.938	0.164	0.170
Japan	1	5.911	0.015	0.014	2	2	5.464	0.065	0.067	2	3	5.007	0.082	0.086
Netherlands	1	0.483	0.487	0.482	2	1	0.683	0.711	0.711	2	3	1.117	0.572	0.587
New Zealand	1	0.056	0.814	0.823	1	1	0.035	0.852	0.851	1	3	0.002	0.967	0.967
Singapore	1	0.131	0.717	0.709	2	1	0.332	0.847	0.863	2	3	0.262	0.877	0.896
UK	5	5.548	0.353	0.358	5	1	5.490	0.359	0.372	5	2	6.060	0.300	0.291
USA	1	0.057	0.812	0.816	1	1	0.075	0.785	0.779	1	2	0.147	0.702	0.728
Belgium	1	2.441	0.118	0.130	1	1	1.955	0.162	0.174	1	2	1.769	0.183	0.176
Ireland	2	0.965	0.617	0.621	2	2	0.903	0.637	0.642	2	2	0.945	0.624	0.616
Italy	1	2.092	0.148	0.162	1	2	2.665	0.103	0.115	1	3	2.503	0.114	0.115
Malaysia	1	1.045	0.307	0.328	2	1	0.937	0.626	0.606	2	3	0.875	0.646	0.642
Mexico	1	4.615	0.032	0.032	2	1	6.298	0.043	0.037	2	3	6.428	0.040	0.034
South Africa	1	0.882	0.348	0.339	1	2	1.099	0.295	0.298	2	3	1.519	0.468	0.440
Spain	1	5.618	0.018	0.022	2	1	4.768	0.092	0.095	2	2	5.181	0.075	0.069
Turkey	2	0.128	0.938	0.934	3	1	1.494	0.684	0.713	3	2	1.504	0.681	0.692

Notes: See Table 2.

Table A4: Results from volatility spillover tests for the same sample period (December 24, 2013 – September 13, 2018)

	Oil ≠> REITs					REITs ≠> Oil				
	λ_{LM}	p-value	n	$F\lambda_{LM}$	p-value	λ_{LM}	p-value	n	$F\lambda_{LM}$	p-value
Canada	3.064	0.216	3	1.099	0.577	3.001	0.223	3	1.607	0.448
Australia	2.050	0.359	3	0.526	0.769	0.388	0.824	3	0.063	0.969
France	8.368	0.015	3	0.384	0.825	0.665	0.717	3	0.071	0.965
Germany	5.908	0.052	2	1.302	0.521	9.056	0.011	3	4.056	0.132
Hong Kong	4.658	0.097	3	0.791	0.673	6.301	0.043	3	1.707	0.426
Japan	32.266	0.000	1	22.319	0.000	4.696	0.096	3	7.793	0.020
Netherlands	2.379	0.304	3	1.199	0.549	1.804	0.406	3	0.750	0.687
New Zealand	3.770	0.152	3	0.905	0.636	0.514	0.773	3	0.113	0.945
Singapore	15.510	0.000	2	11.514	0.003	2.898	0.235	3	1.950	0.377
UK	1.864	0.394	2	1.123	0.570	0.705	0.703	3	0.697	0.706
USA	13.106	0.001	3	7.522	0.023	6.807	0.033	3	3.233	0.199
Belgium	7.294	0.026	3	1.514	0.469	0.700	0.705	3	0.369	0.831
Ireland	2.676	0.262	1	2.137	0.344	1.673	0.433	3	2.930	0.231
Italy	3.112	0.211	2	2.903	0.234	2.876	0.237	3	2.519	0.284
Malaysia	1.890	0.389	3	1.026	0.599	0.121	0.941	3	0.339	0.844
Mexico	6.031	0.049	3	3.239	0.198	11.120	0.004	3	8.712	0.013
South Africa	6.802	0.033	3	3.114	0.211	1.926	0.382	3	0.698	0.705
Spain	0.139	0.933	2	0.671	0.715	1.351	0.509	3	0.583	0.747
Turkey	3.102	0.212	3	3.312	0.191	0.476	0.788	3	0.655	0.721

Notes: See Table 3.

Figure A1. Data Plot

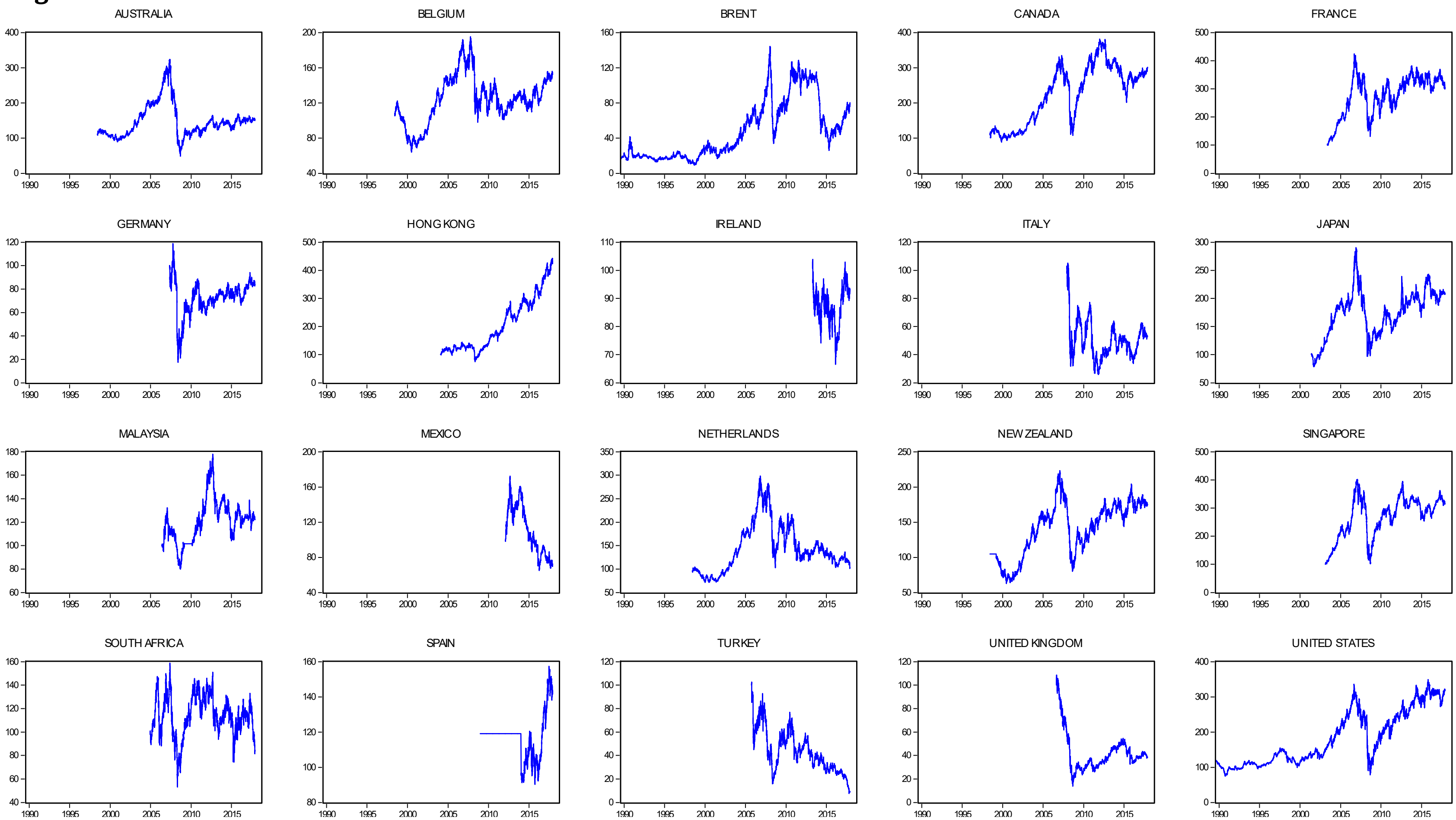


Figure A2(a). Graphical representation of results from price causality tests with no-shift

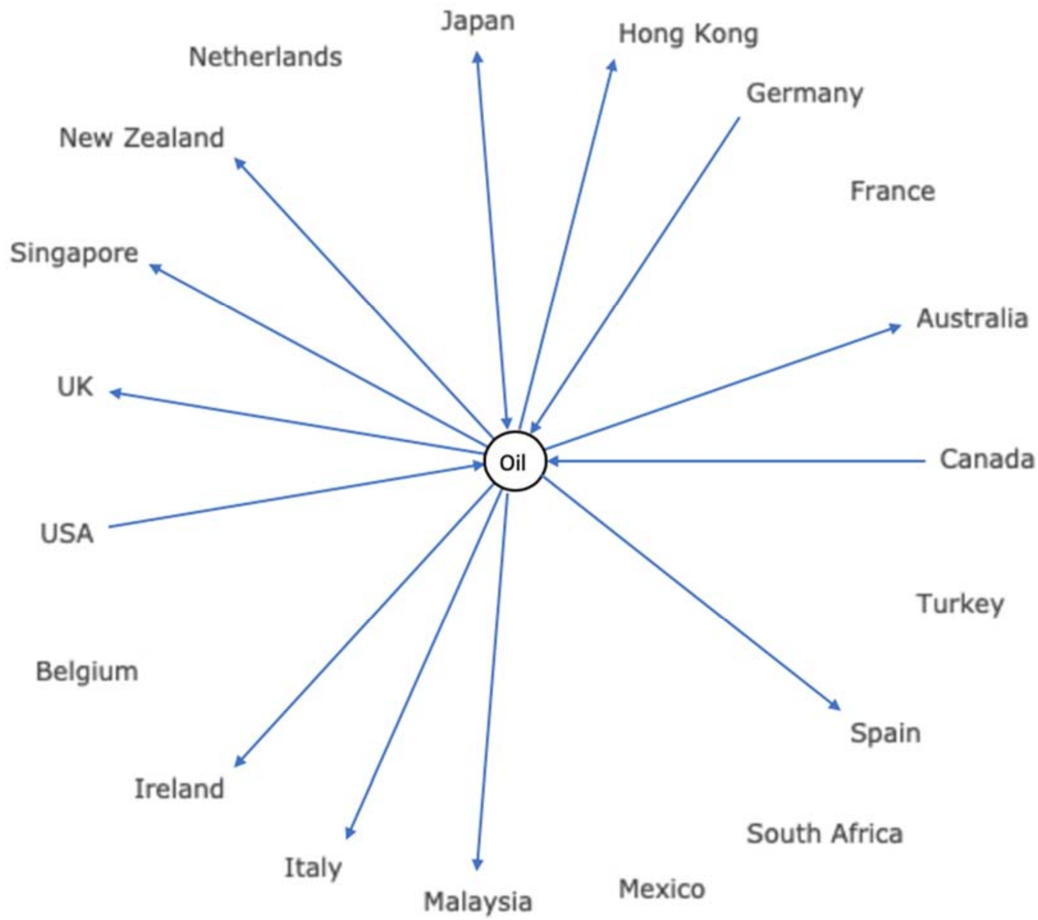
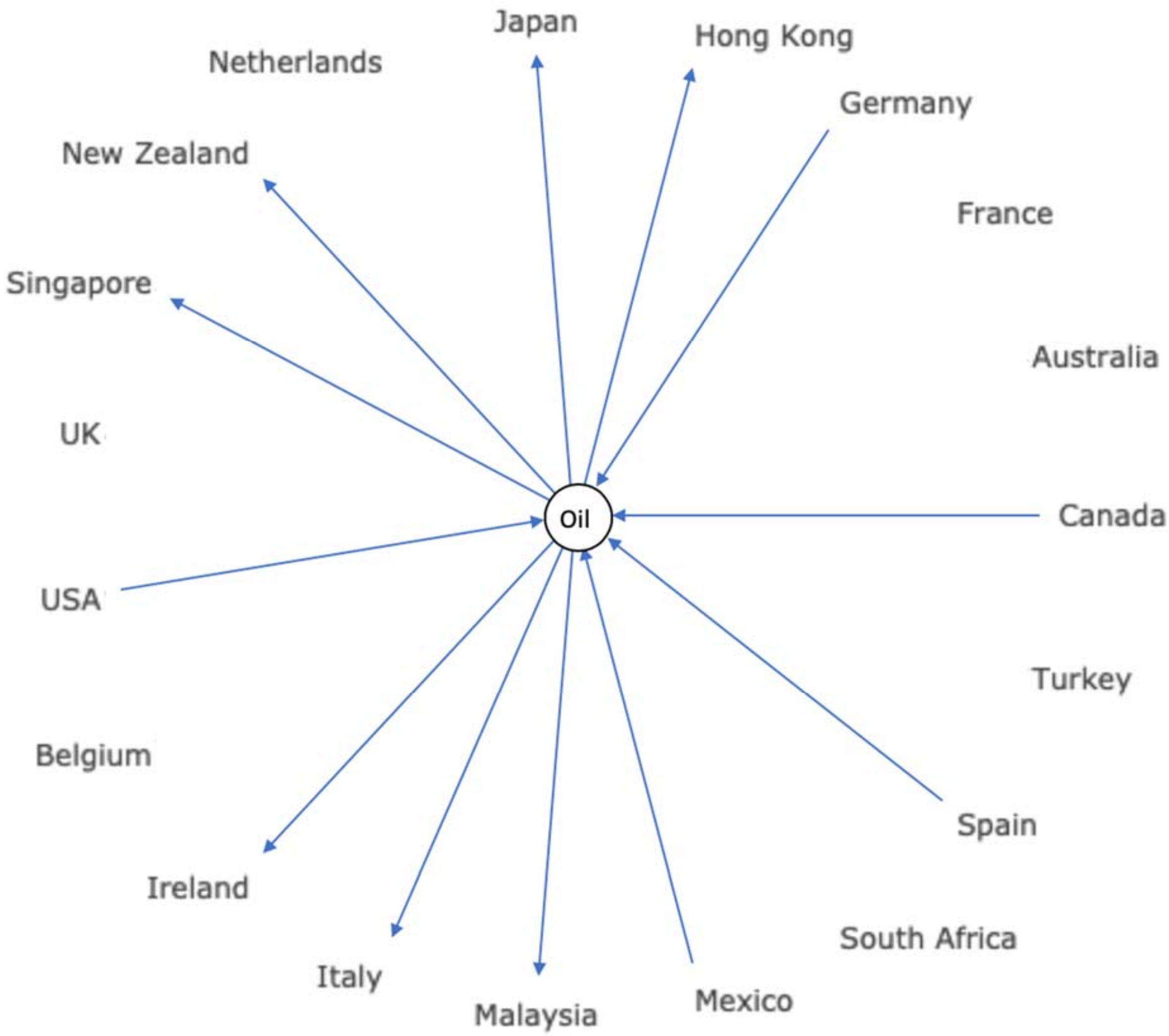


Figure A2(b). Graphical representation of results from price causality tests with smooth shifts



Note: See results in Table 2.

Figure A3(a). Graphical representation of results from volatility causality tests with no-shift

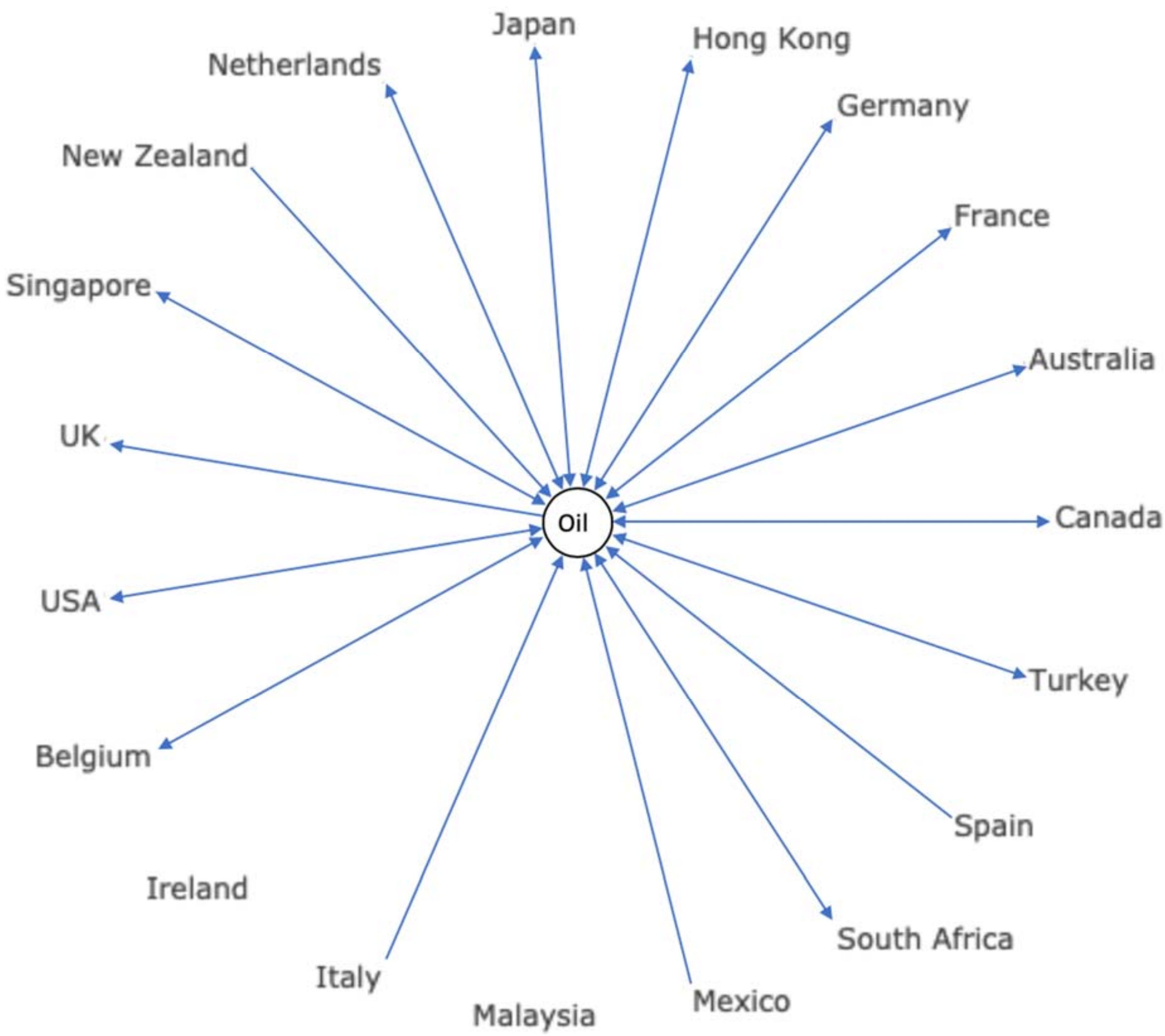
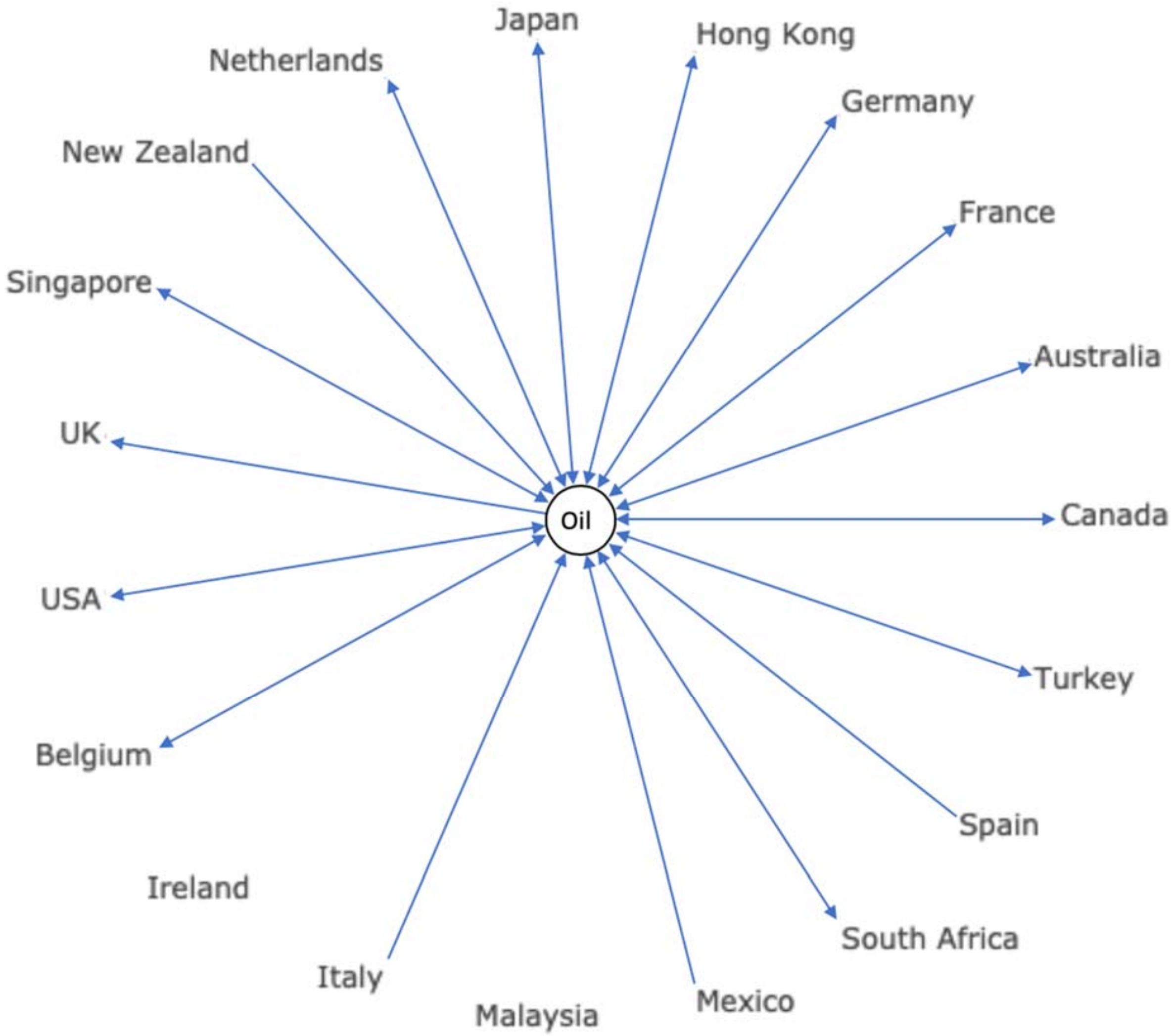


Figure A3(b). Graphical representation of results from price causality tests with smooth shifts



Note: See results in Table 3.