Do green investments react to oil price shocks? Implications for sustainable development

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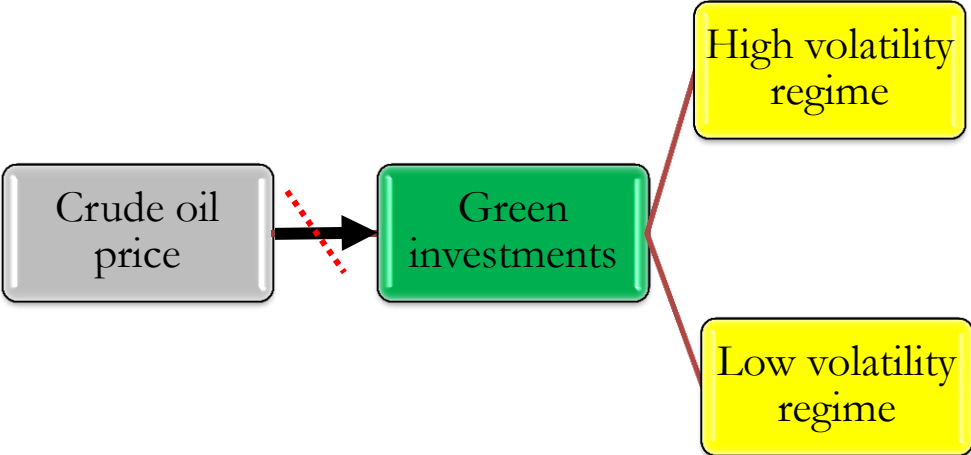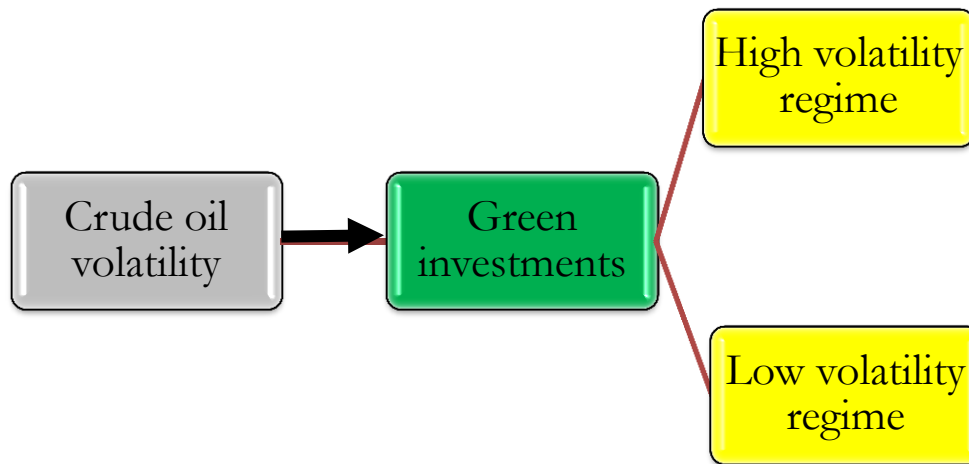# Do Green Investments React to Oil Price Shocks? Implications for Sustainable Development

Abstract

This study investigates whether green investments are connected to oil price shocks. While earlier papers mainly investigate the linkage between clean energy stock and crude oil prices, we consider recently introduced environmental indexes consisting of companies that use eco-friendly production processes and develop green infrastructures. Using the Markov regime switching regression approach, we observe that the effect of crude oil prices on environmental investments appears to be statistically insignificant, albeit positive in most of the cases. One possible reason behind such a finding is that the oil-dependence is limited to the case of eco-friendly firms. The results further indicate switching between low and high volatility regimes implying that there exist high and low volatility states for green assets. Given that growing concerns about climate change and energy security would inspire market participants shift towards ethical investments, our results could be of interest to investors aiming at decarbonizing their portfolios by including more environmental assets. One important finding of our empirical analysis is that green assets are found to be more susceptible to oil market volatility rather than to oil price fluctuations. This is a novel finding given that prior literature focusing on the association of oil sectors and green assets mainly consider the information on oil prices rather than oil volatility. Hence, our study aims to conceal an important void in the exiting literature.

Keywords: Green investments; Environmental assets; Oil price shocks; Regime shifts; Sustainable development.

Graphical abstract

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                                            │  High volatility │
                                            │      regime      │
                                            └──────────────────┘
┌──────────────┐      ┌──────────────┐     ╱
│  Crude oil   │─────▶│    Green     │────
│  volatility  │      │ investments  │────
└──────────────┘      └──────────────┘     ╲
                                            ┌──────────────────┐
                                            │  Low volatility  │
                                            │      regime      │
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1. Introduction

With the growing perception of the significance of sustainability, investors are shifting towards green investments. More specifically, investors now tend to form portfolios that include eco-friendly companies. Such firms are gaining popularity as they produce and support environment-friendly goods and services. Schaeffer et al. (2012), for instance, argue that eco-friendly firms have recently received enormous attention from investors, policymakers, and society for providing green services. On the whole, green investments or environmental assets are of paramount interest to market participants.

In this study, we examine whether green investments respond significantly to oil price shocks. Such an investigation could be critical for policymakers to comprehend the impact of oil prices on environmental investments and develop appropriate strategies for promoting eco-friendly business. For example, when the oil market experiences a downturn, the incentives for

environmentally friendly investors will decrease, and hence, there could be a drop in environmental asset prices. In contrast, when oil prices go up, incentives will be increasing, which causes the equity prices of eco-friendly firms to grow.

A number of studies (Bondia et al., 2016; Dutta, 2017; Xia et al., 2019) claim that an upsurge in oil prices encourage green investments. Bondia et al. (2016), for instance, show that rising energy prices motivate the investors to shift towards green energy companies due to higher incentives for such action. Dutta (2017) also argues that oil price volatility (OVX) has an inverse influence on clean energy stocks, implying their movement in the samilar direction.

This study is different from the other studies in two major ways. Firstly, we examine the association between crude oil and green investments across different economic regimes by resorting to the Markov regime switching (MRS) approach. The existing studies focusing on the association between ethical investments and other financial assets mostly employ the ordinary least squares (OLS) regression, albeit the linkage amongst financial markets is prone to recurrent changes as a consequence of recessions, terrorist attacks, natural disasters, etc. Therefore, the fixed parameter assumption of the least squares method is too restrictive, and hence the applied model could be misspecified. To this end, adopting the MRS regression is beneficial as such specification allows its coefficients to swing across a distinct number of states (Uddin et al., 2018). For instance, employing this approach, we can explore how green assets react to oil price shocks in case of high and low volatility states.

Secondly, we consider recently introduced environmental indexes, which consist of companies that use eco-friendly production processes and develop green infrastructure. These indexes include the MSCI global environment index and MSCI global green building index. According to MSCI.com, '*Global Environmental indexes are designed to maximize exposure to clean*

technologies. They include companies that generate the majority of their revenues from goods and services that contribute to a more environmentally sustainable economy. The index stock selection process utilizes MSCI ESG Sustainable Impact Metrics'. To the best of our knowledge, this is the maiden research to study these green assets, whereas earlier papers mainly examine the linkage between oil and clean energy stock prices.

The remainder of the paper is structured as follows: Section 2 presents the literature review. Section 3 presents the data and methodology. Section 4 mummarizes the empirical findings. Section 5 concluds the paper.

2. Literature review

This section briefly reviews the literature on stock prices of environmentally friendly companies and international crude oil prices.

Henriques and Sadorsky (2008) employ a vector autoregression (VAR) model to examine the connection amongst oil, alternative energy, and some other variables. Stock prices of clean energy firms movement is found to be explained to some extent by the remaining three variables. Sadorsky (2012a) contends that surging oil prices proliferate clean energy equity risks. Another study by Sadorsky (2012b) demonstrates that oil prices emit volatility to clean energy stock markets. Considering oil price shocks, Kumar et al. (2012) study firm-level sensitivity of renewable energy stock prices. Wen et al. (2014) find the average value and volatility transmission relationship of Chinese renewable energy and fossil fuel companies. Employing a copula approach, Reboredo (2015) reports empirical evidence of time-evolving dynamic dependence of oil prices on clean energy stock.

Bondia et al. (2016) find associations between of energy equity and oil markets. They further confirm that the commodity market Granger causes the stock market and not vice-versa. Reboredo et al. (2017) uses wavelets and find the existence of weak short-run co-movements between clean energy and energy stock prices. Nevertheless, the relationship becomes coherent in a long-run. Ahmad (2017) confirms the co-movement of renewable energy stock returns and oil prices. This finding essentially implies that an upsurge in energy prices might stimulate the green energy stock prices. Dutta et al. (2018) shows that clean energy stocks can be hedged using information on carbon emission prices. Bouri et al. (2019) find that crude oil and gold act as safe-haven assets for clean energy stocks during the episodes of extreme market movements. Xia et al. (2019) document that variations in electricity, oil, and coal prices are the major drivers of clean energy stock returns. A recent work by Kocaarslan and Soytas (2019) indicates that the US dollar appreciation is one of the important drivers of the time-varying linkage of clean energy stock and oil prices.

The other segment of literature is concerned with oil volatility index (OVX) to investigate its impact on clean energy stock indexes. In this regard, Dutta (2017) opines a positive relationship between OVX and the renewable energy stocks realized volatility. Ahmad et al. (2018) report a negative correlation between clean energy equities and OVX. Hence, the risks associated with clean energy equities can be minimized by including the OVX in the portfolio. Dutta (2019) investigates whether the information on oil, gold, and silver implied volatility indexes impact solar energy firms equity prices. The findings demonstrate that higher risks are transmitted from oil VIX (OVX), as compared to silver VIX and gold VIX to the alternative energy stocks. Dutta et al. (2020) show that OVX appears to be an appropriate tool for hedging the downside risk linked to clean energy stock prices.

The review of literature suggests that the above articles deal with time-series displaying structural breaks. Mostly, conventional OLS regression models are used for investigating the relationship of oil and clean energy stock prices. The findings of such models could be misleading (Kim et al., 2008). Consequently, regime-switching models would better perform than the traditional regime-independent models (Hamilton, 1990; Fong and See, 2002; Lee and Chen, 2006).

3. Data and methodology

3.1. Data

In addition to two different green indexes, WTI crude oil prices are taken into account as a representative of the global oil market. Our sample period ranges from September 2010 to December 2018. We employ daily data in our empirical analyses. The data source is Thomson Reuters DataStream.

The time-trends of the considered time-series are shown in Figure 1. We may observe that the Environment and Green Building indexes depict persistent growth trends. The crude oil price dynamics, represented by the WTI index, exhibit some noticeable fluctuations until mid-2014. A steep fall in oil price is observed by onset mid-2014, followed by some frequent price oscillations. Another sharp price drop is evident in mid-2015. Nevertheless, the prices have recovered to some extent since then.

3.2. Markov regime switching (MRS) approach

The MRS model receives massive attention in prior literature[1]. Many researchers including Liu et al. (2012), Balcilar and Ozdemir (2013), Balcilar et al. (2015), Basher et al. (2016), and Uddin

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[1] Several studies find the MRS approach suitable for exploring the impacts of oil price shocks on financial assets. Bhar and Hammoudeh (2011) observe that oil price shocks are regime-dependent on different financial variables.

et al. (2018), among others. For example, Uddin et al. (2018) claim that financial time-series are nonlinear, and therefore, it is important to use econometric models that take into account the asymmetric association amongst the financial time-series. We, therefore, employ the MRS model as it can capture such asymmetry and also allows model parameters to vary across different economic regimes. In this study, the MRS approach assumes the following form:

(1)
$$R_{i,t} = \alpha_{i,r_t} + \beta_{i,r_t} R_{t-1} + \gamma_{i,r_t} WTIRET_{t-1} + u_{i,t}$$

In Equation (1), $R_{i,t}$ is the log return for environmental stocks, r_t refers to a discrete state variable, α_{i,r_t} is the state-dependent intercept, β_{i,r_t} and γ_{i,r_t} are regime-dependent slope coefficients and WTIRET indicates the log return of WTI oil prices. At time $(t + 1)$, the probability of transmission to state m from state 1 is fully dependent on time t state. The stochastic regime switching process may be written as:

(2)
$$p_{jk} = \Pr(r_{t+1} = k | r_{t+1} = j), p_{jk} \geq 0, \sum_{k=1}^{M} p_{jk} = 1$$

where M is the number of regimes.

Equation (1) is estimated in two regimes to evaluate the regime-dependent parameters. Following previous studies (Ang and Bekaert, 2002; Uddin et al., 2018), estimation of the regime classification measure (RCM) is considered to gauge the precision of the MRS model:

(3)
$$RCM(r) = 100r^2(1/T) \sum_{t=1}^{T} \prod_{i=1}^{r} \hat{p}_{i,t}$$

Balcilar and Ozdemir (2013) evidence the regime prediction power of oil price for the equity market of the USA. Charlot and Marimoutou (2014) document that precious metal returns react differently in high and low volatility regimes to oil price shocks. Basher et al. (2016) report similar results when analyzing the effect of oil price shocks on exchange rates using the MRS approach.

The RCM statistics range from 0 to 100, where 0 implies that the adopted approach classifies the regimes accurately, while 100 indicates that the method fails to do so.

4. Empirical findings

4.1. Summary statistics

Table 1 reports the summary statistics, which shows the maximum volatility of the WTI oil market, negative skewness of all the return series, and leptokurtic. So, the considered time series are non-normal. This is also validated through the Jarque-Bera test.

4.2. Unit root tests

Table 2 exibits the unit root tests results. The Phillips-Perron (PP) (Phillips and Perron, 1988) and Augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1979; 1981) tests are employed for verifying the stationarity of the stock prices. They provide necessary stationarity conditions for modeling the returns using the autoregressive process (Dutta et al., 2018). These tests report the stationarity of all the return series. However, all the price level series are nonstationary. The study of Perron (1989) advocates that when a time series has structural breaks, the conventional unit root tests may lead to misleading results. Accordingly, we preer the Zivot-Andrews unit root test (Zivot and Andrews, 1992). Table 3 shows the corresponding results. It confirms that all the return indexes are stationary.

One noticeable finding is that the WTI oil price index remains stationary even at levels when the Zivot-Andrews unit root test is used. Table 2 results show that the WTI oil price index follows a non-stationary process at levels. This finding simply indicates the importance of taking the structural breaks into account when testing for the stationary condition of a financial time series.

4.3. Results of MRS model

Table 4 displays the findings of our MRS regression approach. Panel A presents the estimates of the MRS model, whereas Panel B shows the transition probabilities and expected durations. Some notable findings have come out from our empirical analyses. First, the effect of crude oil prices on environmental investments appears to be statistically insignificant, albeit positive in most of the cases. One possible explanation could be that the degree to which a stock index is sensitive towards oil price movements is determined by the oil-dependence of the underlying industrial sector (Arouri et al., 2012). The oil-dependence is limited to the case of eco-friendly firms. For instance, companies that provide ecological services typically use solar, wind, and other clean energies, and hence they are dependent upon natural resources such as sunlight, wind, and water-bodies, respectively. These natural resources are rarely related to oil prices.

Second, the sigma coefficient, which refers to the level of volatility for each state, appears to be higher for regime 2 than regime 1. This finding implies that regime 1 (regime 2) is the low (high) volatility regime. For both indexes, we report similar findings. Moreover, the sigma parameters appear to be different from zero, which indicates swapping between low and high volatility states. Therefore, we conclude that there exist low and high volatility states for green assets. The chi-square tests further show that state variances are unequal for each stock index.

Third, the DU1 and DU2 statistics, which measure the possible durations for occupying a specific regime, suggest that the MSCI global green building index, in comparison to the environment index, has a higher probability of living in a specific state. Additionally, based on the smoothed probability for each stock index, both regimes seem to be highly persistent as the values of p_{11} and p_{22} are close to 1 in most of the cases.

Forth, the RCM values reveal that the MRS regression fits well for each of the equity indexes used. Figures 2 depict smooth probabilities of belonging in a high volatility regime. Consistent with the RCM statistics reported in Table 4, a strong switching pattern is observed for both environmental assets.

4.4. *Effects of oil volatility shocks*

So far, the findings suggest a positive and insignificant linkage between the prices of green assets and global crude oil. Earlier studies focusing on the association of oil sectors and clean energy consider the information on oil prices rather than oil volatility. However, the exposure of financial market participants to the volatility of their investments plays an important role in portfolio formulation, hedging decisions, and risk management, particularly through derivatives and option pricing (Shahzad and Caporin, 2020). Green business is not an exception either. Given that crude oil volatility is increasingly important for the global economy, exploring the connectivity between crude oil volatility and equity prices of eco-friendly firms could be of paramount significance to investors when hedging the risk of such assets.

Here, the effects of oil price volatility on green assets are reported. We consider the OVX as a proxy for energy market volatility[2]. We estimate Equation (1) after replacing RETWTI by ΔOVX. The results of this estimation are provided in Table 5. It is evident from these findings that crude oil

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[2] A number of recent studies have used the information on OVX while testing the impact oil price volatility on different financial assets. Ji and Fan (2016), for example, document an inverse association between OVX and WTI oil price indexes. Dutta et al. (2017) find that OVX exerts a significant effect on the Middle East and African stock prices. In addition, Lv (2018) shows that OVX has a significantly positive impact on crude oil futures volatility. Ahmad et al. (2018) demonstrate that the information on OVX is useful for hedging clean energy stock market risk. Besides, Dutta (2018) finds that OVX has an asymmetric influence on both precious and industrial metal price indexes. While examining the effects of oil market volatility on the US ethanol prices, Dutta et al. (2018) report that the US biofuel prices react significantly to OVX shocks. Xiao et al. (2019) reports that the impact of the OVX changes on the VXFXI changes appears to be positive and that such effect would be more in a bearish market. In addition, Shahzad and Caporin (2019) show that crude oil volatility, measured by OVX, predicts the volatility of tourism sector stocks.

volatility influence significantly on the returns of environmental investments. Therefore, changes in the price levels of these assets are more sensitive to oil market volatility rather than to oil price shocks. This result is not surprising. The volatility is more important than prices of oil for both policymakers, investors, consumers, traders, and producers.

It is also observed that the effect of OVX is negative, suggesting an inverse relationship between OVX and green assets. These findings are aligned with those documented by Dutta (2017), Ahmad et al. (2018), Dutta (2019), and Dutta et al. (2020). All these articles show that OVX has a negative impact on the alternative energy sector stock indexes. However, our findings differ from the above studies in that none of these articles has scrutinized how green assets react to oil market uncertainty in case of high and low volatility states. In this study, we show that the effects of OVX are different for high and low volatility states. More specifically, these findings reveal that the returns of the environmental assets are more sensitive to OVX in regimes with high volatility than the low volatility. Conducting chi-square tests also confirms that state variances are significantly different from each other.

The negative association between OVX and environmental assets has important implications for investors, given that such linkage indicates hedging opportunities for market participants. Baur and Lucey (2010) show that any financial asset can be considered to be a hedge if it is negatively correlated or uncorrelated with an asset on the average. Hence, OVX may be considered as a useful financial instrument in hedging the downside risk of green assets.

It is noteworthy that a "hedge does not have the property of reducing losses in times of market stress or turmoil since the asset could exhibit a positive correlation in such periods and a negative correlation in normal times with a negative correlation on average" (Baur and Lucey, 2010). Future research can be carried out to verify whether OVX can offset the loss during the periods of

recession. In such cases, OVX can be considered to be a safe haven for portfolios consisting of environmental assets.

4.5. Additional analyses

We further our analyses by investigating how the equity prices of green companies behave during the periods of oil price downturn. To serve this purpose, we consider the period from December 2014 to March 2016. In this period, the oil market experiences a depression which creates several jumps in OVX (Figure 4). There could be several reasons for such a stress in the global oil market. Majorly, it is due to declining demand, strengthing of the US dollar, and the Iran nuclear deal (Dutta, 2018).

Table 6 shows the outcomes of this sub-period. They are consistent with the previous estimates. For example, the impact of crude oil prices on environmental investments is statistically insignificant and positive in each case. Besides, the sigma parameters appear to be different from zero, which indicates swapping between low and high volatility states. Hence it can be concluded that there appear low and high volatility states for green assets. The chi-square tests further show that state variances are unequal for each stock index. Thus, the results are robust as they are not sensitive to the sample periods used.

4.6. Discussion and implications for sustainable development

Over the last decade, there have been several articles focusing on the association between returns on ethical investments and oil price changes. These studies mostly adopt conventional regression models to explore the association among the markets mentioned above. In sum, prior literature has relied on regime-independent approaches to modeling the linkage between energy and environmental asset prices. Kim (2008), however, argues that as financial time-series often

experience structural breaks, the use of orthodox regression models could be distorted. In such a context, regime-switching models are assumed to perform better than the traditional regime-independent processes. Employing the Markov regime switching model, this present research work aims to conceal a significant void in the existing literature. Our analyses reveal that green assets, like conventional asset classes (stocks, oil, gold, etc.), also switch between low and high volatility states, which further confirms the suitability of regime-dependent approaches to modeling the stock prices of green companies. This is a new finding given that previous articles do not focus on the regime-switching property of ethical investments. Another major finding of this study is that green investments are immune to variations in global oil prices. Also, oil prices and green equities are positively correlated, and hence, oil price increase will positively impact the green energies (Ahmad et al., 2018; Bouri et al., 2019; Dutta et al., 2020). Thus, we provide empirical evidence that green assets are more susceptible to oil market volatility rather than to oil price fluctuations.

More importantly, oil volatility impacts negatively on the stock prices of eco-friendly firms. Figure 4 depicts that crude oil prices and the OVX move in opposite directions. So, the OVX exhibits a more (consistent) negative correlation with equity prices of environmentally friendly firms. As a result, the implied volatility of crude oil provides more diversification benefits and thereby acts as a more effective hedging tool. Dutta et al. (2020) claim that lower crude oil prices reduce the attractiveness and economic viability of investment in clean energy projects, which leads to a pause in the development of clean energy and, thus to adverse impacts on the stock prices of clean energy firms. Hence, a drop in crude oil prices causes green asset prices to decline. In contrast, the implied volatility of crude oil tends to increase, implying an ability of the oil implied volatility index to hedge the downside risk of green asset classes.

The findings of this empirical study could receive special attention from current and future investors in the eco-friendly business. Given that growing concerns about climate change and energy security, market participants shifts towards ethical investments, our results could be of interest to investors aiming at decarbonizing their portfolios by including more environmental assets. Besides, as portfolio management is an important process for financial institutions or retail investors to mitigate potential threats, the findings could help the investors and policymakers to understand the risk associated with green assets.

Moreover, as environmental stocks appear to be a new asset class, investing in such assets could be risky. Therefore, proper assessment of risk associated with green investments plays a crucial role in portfolio management. Sound knowledge on how environmentally friendly investors can diversify their risks is thus required. To this end, the use of modern portfolio theory could help investors to hedge the downside risk of their investments. Hence, our findings have useful implications for ethical investors who aim to detect the risk associated with environmental assets.

It is also worth mentioning that investments in renewable energies have positive environmental and socio-economic impacts that potentially help to ensure a certain degree of sustainability. Thus, the findings of this empirical research have significant implications for investors who aim at swapping dirty assets (e.g., oil) for clean energy equities to make their portfolios as low-carbon as possible. Portfolios consisting of such assets that emit less carbon are simply less susceptible to the consequences of climate change.

5. Conclusions

This study explores whether green investments are connected to oil price shocks. While earlier papers explore the linkage of clean energy stock and oil prices, we have considered recently introduced environmental indexes, which consist of companies that use eco-friendly production

processes and develop green infrastructures. Using the Markov regime switching regression approach, it is not evidenced that oil prices have significant impacts on environmental assets. The results also indicate switching between high and low volatility regimes. One important finding of our empirical analysis is that green assets are more susceptible to oil market volatility rather than to oil price fluctuations. This is a novel finding given that prior literature focusing on the association of oil sectors and green assets mainly consider the information on oil prices rather than oil volatility. Hence, our study significantly extends previous works.

Our investigation seems to have notable implications for portfolio managers. Given that the main interest of investors lies in achieving healthy returns from their investments, an environmentally friendly investor's portfolio will still contain those assets which promise higher returns in addition to serving the environment and society. For such investors, our results indicate the benefits of diversification as there is no significant linkage between environmental assets and oil price changes. Besides, the negative association between crude oil volatility (OVX) and green assets would also encourage the investors to include these assets in their portfolios so that the risk is minimized during the turmoil periods. Therefore, this research offers new insights for efficient hedging strategies of market participants who intend to invest in green stocks.

Policymakers could also utilize our findings when formulating appropriate strategies for environmental assets. As the effect of oil prices on green investments appears to be insignificant, policy formulation for ethical investments should be independent. In sum, policymakers should consider the detachment of these assets to make effective hedging decisions.

Furthermore, the results suggest important implications for researchers and academicians as well. For example, researchers always look for appropriate econometric models and developing such processes often requires better understanding of how financial variables are interrelated. Hence, our

findings would be useful for them to precisely model the return and volatility dynamics of environmental assets. Additionally, as the findings indicate the existence of high and low volatility states for green stocks, employing regime dependence econometric models would be an apparent choice for academics working in the arena.

Future research could focus on the asymmetric association between oil and green assets. In addition, our study can be extended to observe the time-varying correlations between these assets.

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Table 1: Descriptive Statistics

Index ↓	Mean	Standard Deviation	Skewness	Kurtosis	Jarque-Bera Test
WTI	-0.0098	0.9052	-0.0117	6.33	1004.71*** (0.00)
Environment	0.0100	0.4081	-0.4514	7.40	1828.82*** (0.00)
Green building	0.0151	0.4010	-1.2576	17.12	18630.76*** (0.00)

Notes: *p*-values are given in parentheses. ***, ** and * indicate statistically significant results at 1%, 5% and 10% levels respectively.

Table 2: Results of unit root tests

Index ↓	ADF Tests		PP Tests	
	Level	1st Difference	Level	1st Difference
WTI	-1.07 (.73)	-49.12 (.00)***	-1.01 (.75)	-49.10 (.00)***
Environment	-1.41 (.58)	-40.31 (.00)***	-1.32 (.62)	-39.88 (.00)***

| Green building | -1.36 (.60) | -40.43 (.00)*** | -1.33 (.61) | -40.03 (.00)*** |

Notes: *p*-values are given in parentheses. ***, ** and * indicate statistically significant results at 1%, 5% and 10% levels respectively.

Table 3: Results of augmented Zivot-Andrews test accounting for structural breaks

Index	Levels	1st differences
WTI	-4.90 (0.02)**	-50.75 (0.00)***

Environment	-3.01(0.68)	-41.37 (0.00)***
Green building	-3.03 (0.66)	-41.84 (0.00)***

Notes: This Table exhibits the findings of the Zivot-Andrews test accounting for structural breaks. *p*-values are given in parentheses. ***, ** and * indicate statistically significant results at 1%, 5% and 10% levels respectively.

Table 4: Results of Markov regime switching model

		Panel A: Estimated coefficients				
Index	State	Constant	AR(1)	WTI shocks	Sigma	χ^2 test
Environment	S1	0.031***	0.105***	-0.003	0.278***	409.94***
		(0.00)	(0.00)	(.73)	(0.00)	
	S2	-0.044 (0.11)	0.104**	0.039	0.616***	
			(0.03)	(.15)	(0.00)	
Green Building	S1	0.025***	0.127***	0.011	0.288***	382.53***
		(0.00)	(0.00)	(.18)	(0.00)	
	S2	-0.069	0.073	0.059	0.807***	
		(0.18)	(0.30)	(.19)	(0.00)	

	Panel B: Transition probabilities and expected durations					
Index	P11	P12	P21	P22	DU1	DU1	RCM
---	---	---	---	---	---	---	---
Environment	0.9818	0.0182	0.0467	0.9533	54.98	21.45	22.63
Green Building	0.9206	0.0794	0.0116	0.9884	12.59	95.98	24.37

Notes: The results presented in this table are derived from a Markov regime switching (MRS) model of this form: $R_{i,t} = \alpha_{i,r_t} + \beta_{i,r_t} R_{t-1} + \gamma_{i,r_t} WTIRET_{t-1} + u_{i,t}$, where $R_{i,t}$ refers to the return for green assets at time t and $WTIRET_{t-1}$ indicates the return of WTI oil price index at time t-1. There are two panels in this Table: Panel A includes the estimates of MRS process and Panel B displays the transition probabilities and expected durations. In addition, RCM is the regime classification measure. The transition probabilities are reported as Pij. The expected duration of being in state i is reported as DUi, i.e., DU1 for state 1 and DU2 for state 2. The χ^2 test is performed to examine whether the state variances are equal. p-values are given in parentheses. ***, ** and * indicate statistically significant results at 1%, 5% and 10% levels respectively.

Table 5: Impact of crude oil volatility shocks on green assets

Panel A: Estimated coefficients

Index	State	Constant	AR(1)	OVX shocks	Sigma	χ^2 test
Environment	S1	-0.019	0.115***	-0.159***	0.471***	248.94***
		(0.26)	(0.00)	(.00)	(0.00)	
	S2	0.036***	0.083***	-0.034***	0.266***	
		(0.00)	(0.00)	(.00)	(0.00)	
Green Building	S1	-0.021	0.117***	-0.177***	0.601***	276.98***
		(0.43)	(0.00)	(.00)	(0.00)	
	S2	0.026***	0.148***	-0.028***	0.274***	
		(0.00)	(0.00)	(.00)	(0.00)	

Panel B: Transition probabilities and expected durations

Index	P11	P12	P21	P22	DU1	DU1	RCM
Environment	0.9500	0.0500	0.0334	0.9666	19.98	29.92	20.49
Green Building	0.9130	0.0870	0.0256	0.9744	11.49	39.02	22.27

Notes: The results presented in this table are derived from a Markov regime switching (MRS) model of this form: $R_{i,t} = \alpha_{i,r_t} + \beta_{i,r_t} R_{t-1} + \gamma_{i,r_t} \Delta OVX_{t-1} + u_{i,t}$, where $R_{i,t}$ refers to the return for green assets at time t and ΔOVX_{t-1} indicates the first-order difference of the crude oil volatility index (OVX) at time t-1. There are two panels in this Table: Panel A includes the estimates of MRS process and Panel B displays the transition probabilities and expected durations. In addition, RCM is the regime classification measure. The transition probabilities are reported as Pij. The expected duration of being in state i is reported as DUi, i.e., DU1 for state 1 and DU2 for state 2. The χ^2 test is performed to examine whether the state variances are equal. p-values are given in parentheses. ***, ** and * indicate statistically significant results at 1%, 5% and 10% levels respectively.
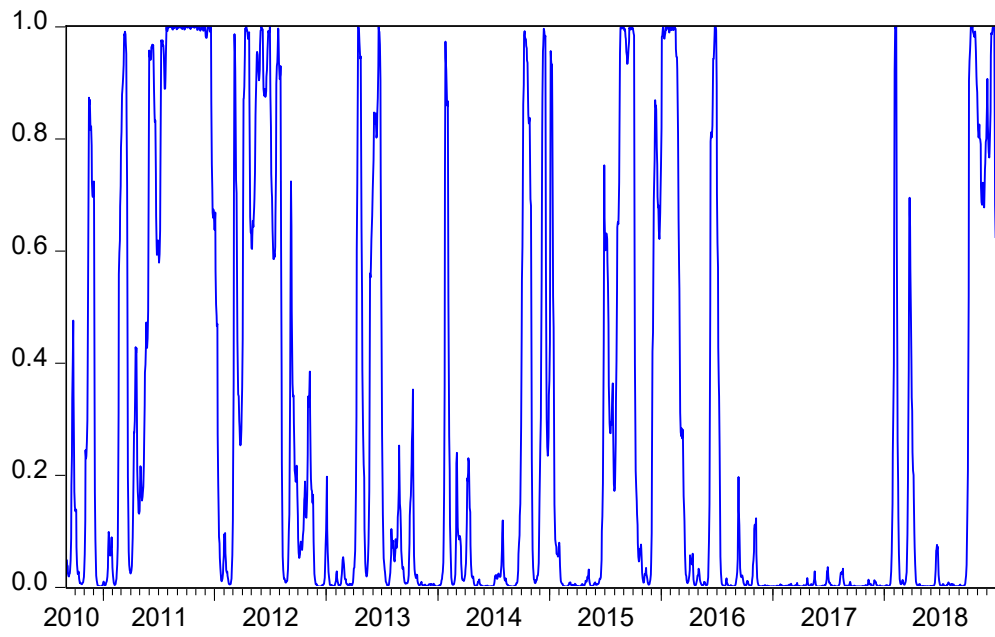
Table 6: Impact of WTI oil price shocks during stress periods

Panel A: Estimated coefficients

Index	State	Constant	AR(1)	WTI shocks	Sigma	χ^2 test
Environment	S1	-0.038	0.143**	0.039	0.566***	164.43***
		(0.28)	(0.04)	(.12)	(0.00)	
	S2	0.033***	0.072*	-0.020	0.259***	
		(0.00)	(0.09)	(.11)	(0.00)	
Green Building	S1	-0.096	0.152	0.031	1.502***	193.72***
		(0.20)	(0.13)	(.53)	(0.00)	
	S2	0.032***	0.099**	0.012	0.276***	
		(0.00)	(0.02)	(.25)	(0.00)	

Panel B: Transition probabilities and expected durations

Index	P11	P12	P21	P22	DU1	DU1	RCM
Environment	0.9665	0.0335	0.0158	0.9842	29.87	63.21	24.08
Green Building	0.8704	0.1296	0.0215	0.9785	7.71	46.48	25.71

Notes: The results presented in this table are derived from a Markov regime switching (MRS) model of this form: $R_{i,t} = \alpha_{i,r_t} + \beta_{i,r_t} R_{t-1} + \gamma_{i,r_t} WTIRET_{t-1} + u_{i,t}$, where $R_{i,t}$ refers to the return for green assets at time t and $WTIRET_{t-1}$ indicates the return of WTI oil price index at time t-1. This analysis is conducted to observe the impact of WTI oil price shocks during the periods (December 2014 to March 2016) when global oil market experiences a significant downturn. There are two panels in this Table: Panel A includes the

estimates of MRS process and Panel B displays the transition probabilities and expected durations. In addition, RCM is the regime classification measure. The transition probabilities are reported as Pij. The expected duration of being in state i is reported as DUi, i.e., DU1 for state 1 and DU2 for state 2. The χ^2 test is performed to examine whether the state variances are equal. *p*-values are given in parentheses. ***, ** and * indicate statistically significant results at 1%, 5% and 10% levels respectively.
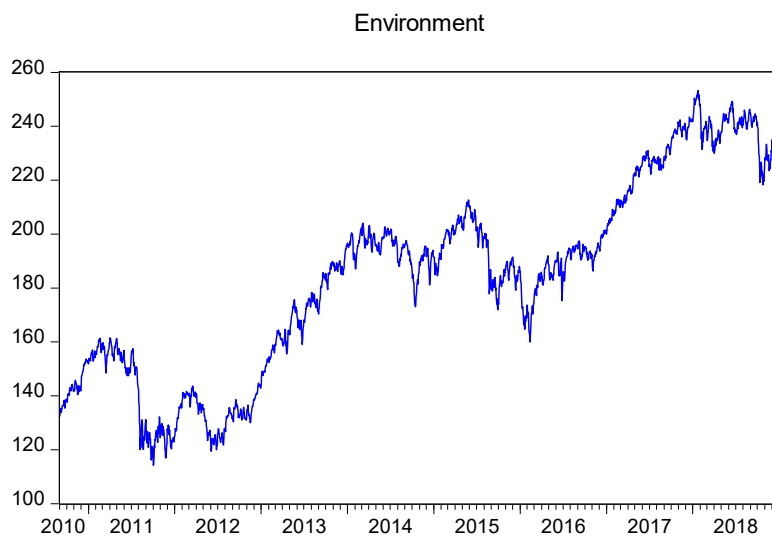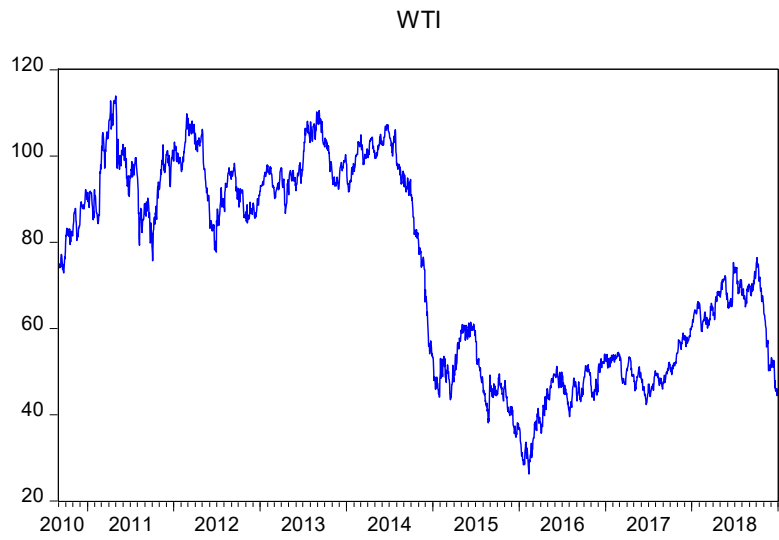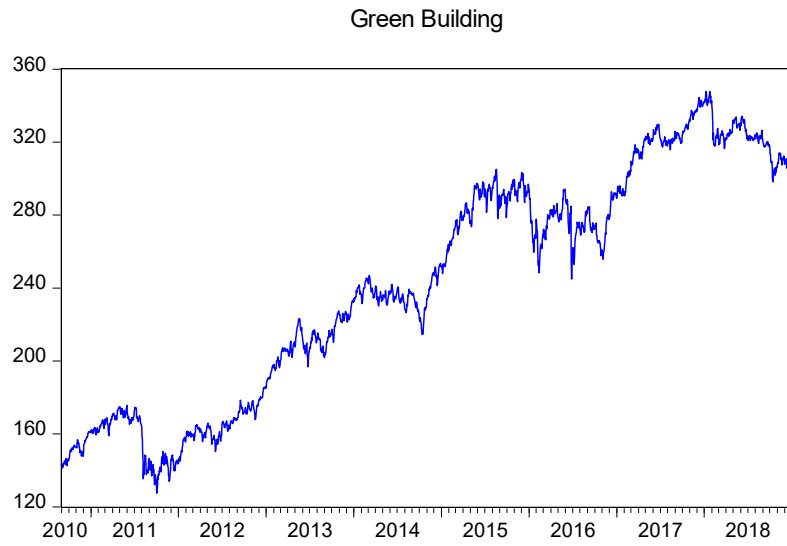
Environment

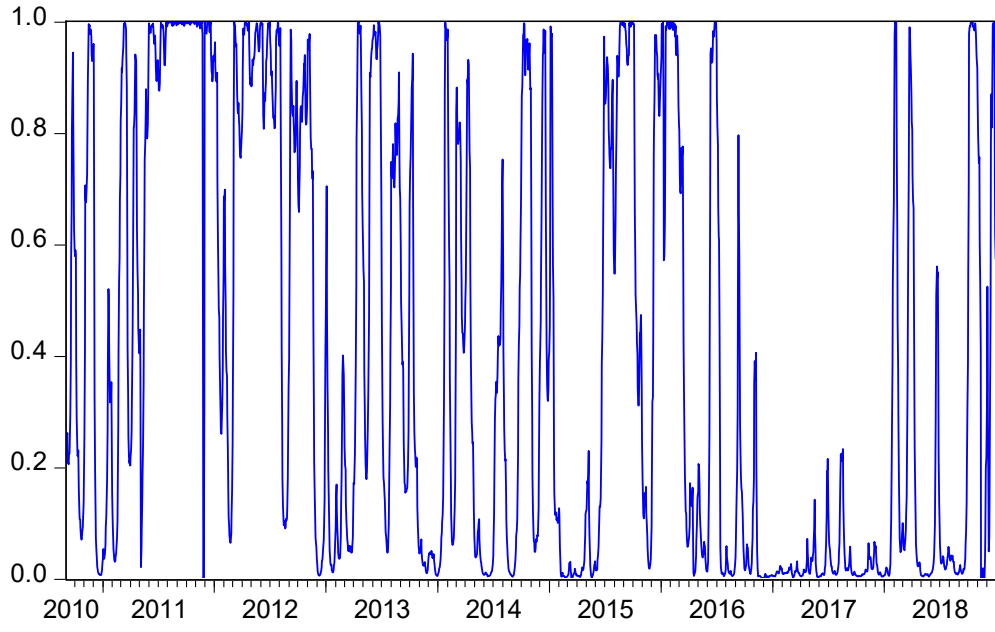**Figure 1: Price indexes of different assets studied**
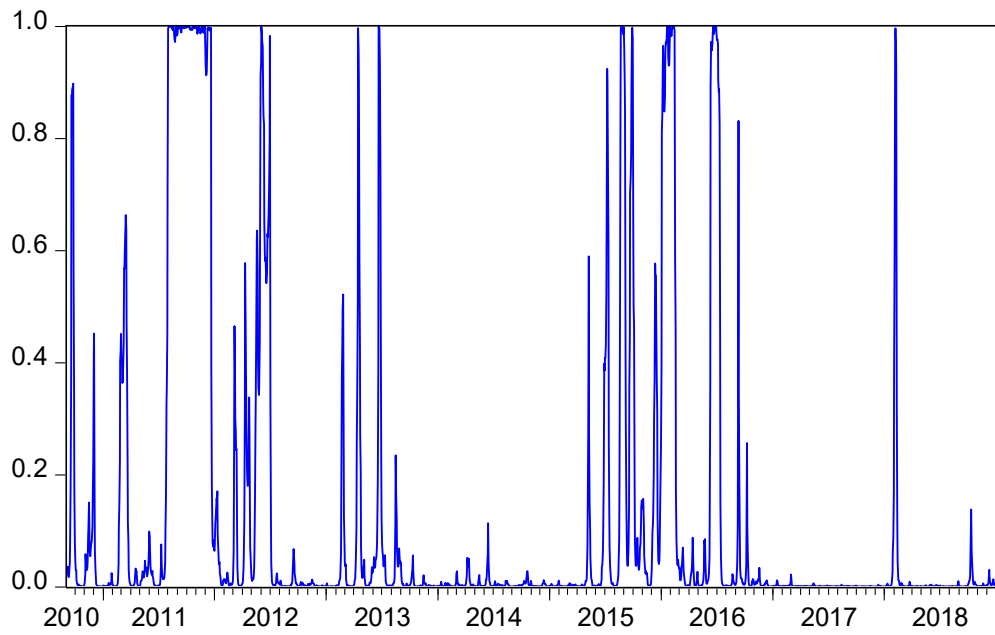
Figure 2: Smoothed probabilities of high volatility states for different environmental assets

OVX and Environment
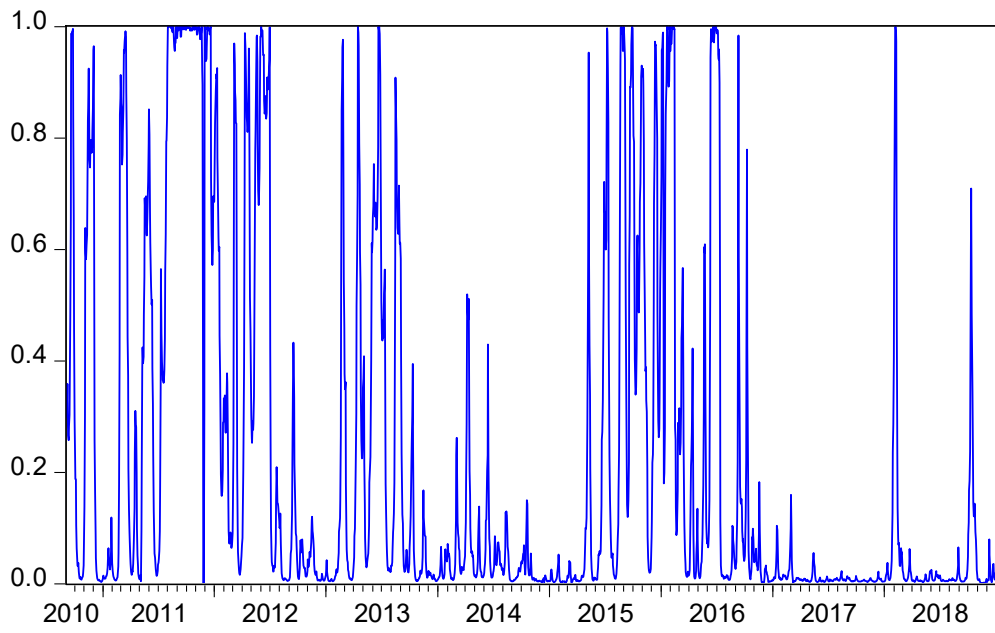
OVX and Green Building

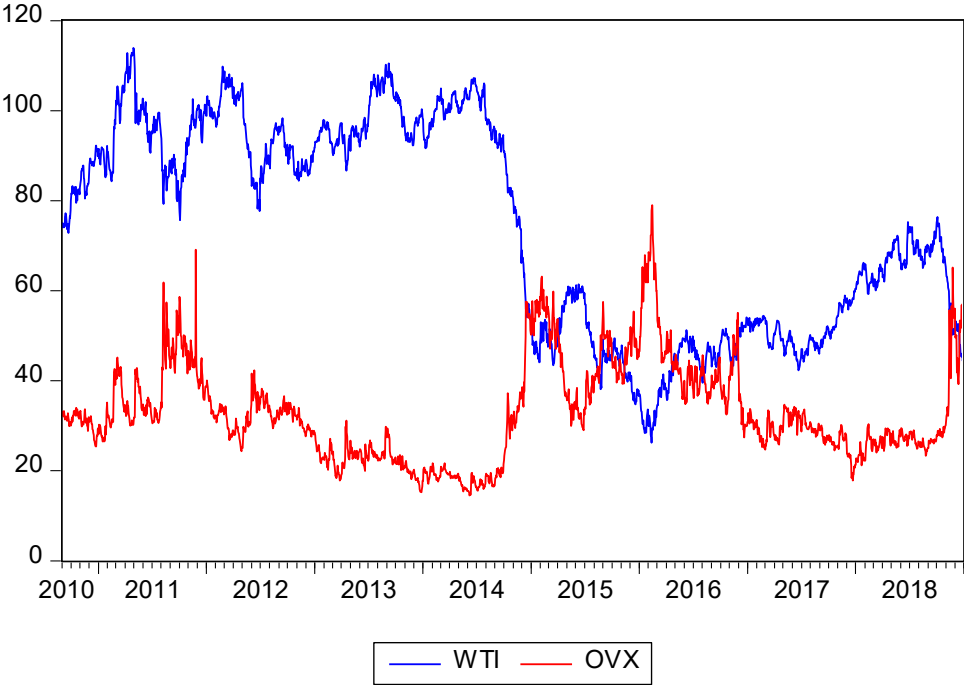**Figure 3: Smoothed probabilities of high volatility states for different environmental assets (the case of OVX)**

Figure 4: OVX and WTI indexes for the whole sample period