Attractiveness of Clean Energy Stocks in Europe: The importance of shocks in oil and gas prices

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Abstract

Europe is extremely reliant on imported oil and gas. Using monthly data from January 2008 to December 2021, this article pinpoints supply and demand shocks in the oil and gas markets and investigates their effects on clean energy stock returns in Europe using a structural VAR model. Our findings show that while a negative shock in global oil supply does not significantly affect clean energy stocks, a negative shock in the gas supply positively affects clean energy stocks. Moreover, both oil-specific and gas-specific demand shocks have a positive impact on the stock returns of European clean energy companies. Finally, the favorable impact of economic demand shocks on clean energy returns lasts more in the oil price model than in the gas price model. The earlier findings imply that clean energy can substitute oil and gas. As a result, we ought to observe a dramatic increase in clean energy returns as prices of fossil sources rise, as it is the case nowadays due to the conflict in Ukraine.

Keywords: Oil, gas, clean energy, EU, Europe, VAR, value-at-risk

JEL Classification: C2, D12, Q4

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1. Introduction

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The European Union (EU) is heavily reliant on imported oil and gas. In 2021, oil and petroleum products made up 34,1% of the EU's energy mix, followed by natural gas at 23,3%, renewable energy at 17,2%, nuclear energy at 12,7%, and solid fossil fuels at 11,1% (Eurostat, 2023a). Considering that the EU imported 55,6% of the energy used, only 44,4% of its energy needs were satisfied by domestic production and stock changes. Moreover, 92% of the EU's consumption of oil and petroleum products, as well as 83,3% of its consumption of natural gas, is imported (Eurostat, 2023b). 59,4% of the EU's final energy consumption comes from fossil sources (gas, oil, and solid fossil fuels) and the share of renewables and biofuels in the final energy consumption is 11,7% (Eurostat, 2023c). The EU is more susceptible to changes in oil and gas prices due to its high level of foreign dependency on fossil fuels and high rate of fossil fuel use in overall energy consumption. Accordingly, in the context of rising oil and gas prices, the question of whether this context will push for more investment in clean energy gains importance as an alternative way for Europe to ensure the security of supply while contributing to climate change mitigation.

Herein we investigate how the EU's clean energy stock returns respond to oil and gas price shocks. In the related literature, there are studies examining the effects of oil price shocks on different dynamics such as macroeconomic aggregates and agriculture. The relationship between oil price shocks and macroeconomic aggregates has been examined for the first time by Hamilton in 1983 for the US market. Studies focusing on the effects of oil price shocks on macroeconomic aggregates such as production or employment rates have proliferated since then (see, Kilian, 2009; Kilian and Vigfusson, 2011; Herrera et al., 2019; Wen et al. 2021, amongst others). Other related studies have focused on the impact of oil price shocks in the industrial sector (Scholtens and Yurtsever, 2012; Herrera, 2018), or in monetary policy (Natal, 2012; Kim et al., 2017). In fact, the relationship between oil price shocks and financial markets has been a hot topic in recent years (Kilian and Park, 2009; Degiannakis et al., 2014; Ready, 2016; Krokida et al., 2020; Demirer et al., 2020; Kielmann et al., 2021) as well as the impact of oil price shocks on agricultural commodity pricing (Wang et al., 2014; Umar et al., 2021).

There are a number of studies examining the effects of oil price shocks on clean energy stock returns using structural VAR (SVAR) (Henriques and Sadorsky, 2008; Zhao, 2020; Maghyereh and Abdoh, 2021[3]; Zhou and Geng, 2021). Others study this same interaction with different models such as Markov-switching vector autoregressive models and multivariate GARCH models (Managi and Okimoto, 2013; Inchauspe et al., 2015; Pham, 2019; Zhang et

[3] Maghyereh and Abdoh (2021) and Zhou and Geng (2021) apply different models in addition to SVAR.

al., 2020). To our knowledge, most studies focus on the relationship between oil price shocks and clean energy stock returns at the global level (see Table 1). There is one exception, the paper of Zhou and Geng (2021). Using China's new energy index (CNNE), the European renewable energy index (ERIX), and the WilderHill clean energy index (ECO) for the USA, Zhou and Geng (2021) compare the response of clean energy stock indices to three structural oil price shocks: Supply shock, demand shock, and risk shock. Unlike our paper, they use the World Integrated Oil and Gas Producer Index to represent the global oil industry, the 1-month returns on the second nearest maturity NYMEX Crude—Light Sweet Oil contract to indicate the changes in crude oil prices, and the VIX index to identify the risk shock. Zhou and Geng (2021) find that the oil demand and risk shocks have significant explanatory power on the returns of all new energy markets, while the oil supply shock has a minor effect. Aside from the methodological difference with Zhou and Geng (2021), herein we focus for the first time on the EU region and, moreover, we specifically consider gas markets. Instead, studies at the European level have focused on the dynamics of oil price shocks at the industrial level (Scholtens and Yurtsever, 2012), and the relationship between oil price shocks and the stock market (Degiannakis et al. 2014; Krokida et al. 2020).

Author(s)	Model(s)	Region
Henriques and Sadorsky, 2008	SVAR	Global
Managi and Okimoto, 2013	Markov-switching vector autoregressive models	Global
Inchauspe et al., 2015	A state-space multi-factor asset pricing model	Global
Pham, 2019	Multivariate GARCH models	Global
Zhao, 2020	SVAR	Global
Zhang et al., 2020	Wavelet-based quantile-on-quantile and Granger causality-in-quantiles methods	Global
Maghyereh and Abdoh, 2021	SVAR and novel quantile cross-spectral dependence approach	Global
Zhou and Geng, 2021	SVAR and the decomposition methods, the rolling window method	China, Europe, United States

Table 1: Literature on the interaction between oil price shocks and clean energy stock returns

There is a vast literature that investigates the relationship between natural gas and crude oil prices (Pindyck, 2004; Brown and Yücel, 2008; Zamani, 2016; Jadidzadeh and Serletis, 2017). Besides, numerous studies have been conducted to understand the behavior of the natural gas market, particularly what drives natural gas prices (Nick and Thoenes, 2014; Hou and Nguyen, 2018; Ji et al., 2018; Hailemariam and Smyth, 2019; Rubaszek et al., 2021). However, only a few studies have examined the interaction between natural gas and the stock returns of clean energy companies (Hou and Nguyen, 2018; Xia et al., 2019; Ghabri et al., 2021; Wang et al., 2022, amongst others). Without focusing on the stock returns of clean energy, Hou and

Nguyen (2018) discover gas price shocks for the US and study the US gas market's reaction to structural shocks in different regimes. With the exception of Hou and Nguyen (2018), these studies do not concentrate, as we do here, on the connection between gas price shocks and stock returns of clean energy companies, and none of them focuses on the European market.

Our study contributes to the existing literature in three ways. First, while the literature generally focuses on crude oil price shocks, we extend this literature by describing the impact of shocks in the price of another fossil fuel: natural gas. In this regard, following the three structural shocks in the oil market described in the literature, we use the same method to identify gas price shocks. Then, knowing that the gas market is mostly regional, even after the introduction of the North-American shale gas, we provide a complete representation of these shocks in Europe. Second, current literature mostly focuses on the relationship between oil price shocks and clean energy stock returns at the global level (as shown in Table 1). We extend the existing literature by focusing on the relationship between oil price shocks and clean energy stock returns at the European level. Third, especially due to the recent developments in the natural gas markets, herein we look at the effects of the changes in gas prices in terms of investment in clean energy technologies. The European Commission's endorsement of gas as a transition fuel due to its capacity to serve as backup for intermittent renewables, has raised the question of whether gas is viewed by investors as complementary to clean energy in European financial markets. Europe’s high dependence on Russian gas and the increased risk of gas shortages due to the conflict in Ukraine further emphasized the importance of understanding the impact of changes in gas prices. Herein we contribute to the literature by identifying the gas price shocks at the European level and then examine the effects of three different gas price shocks (gas supply shock, demand shock, and gas-specific demand shock) on clean energy stock returns.

The main findings are as follows. First, a negative gas supply shock positively affects clean energy stocks, which means that clean energy is a substitute to gas for European investors. Instead, a negative shock in global oil supply does not have a significant effect on clean energy stocks throughout the period studied. This means that rising oil prices in the global market do not encourage investors to switch to clean energy at the European level. Second, the positive effect of the economic demand shock on the stock returns of clean energy lasts longer in the model with oil price shocks than in the model with gas price shocks. Third, both the oil-specific demand shock and the gas-specific demand shock positively affect the stock returns of clean energy companies. The previous results suggest that, as expected, there is a substitution effect between oil,gas and clean energy stocks. This last result shows that, in terms of investment, gas cannot really be considered as a complement to intermittent technologies as the recent considerations of the EU Commission could suggest.

The remainder of the paper is organized as follows. Section 2 summarizes the previous literature on the subject. Section 3 describes the data. Section 4 describes the empirical methodology. Section 5 presents and discusses the empirical results. Section 6 concludes.

2. Literature Review

We divide the available literature into two sub-sections: sub-section 1 focuses on the relationship between changes in oil prices and clean energy stock returns, and sub-section 2 focuses on the relationship between changes in gas prices and clean energy stock returns.

2.1. Changes in oil prices and clean energy stock returns

Many studies have examined the connection between the oil and the clean energy stock markets, particularly at the global level, but their findings have not produced a consensus. The results can be put forward as follows. First, an increase in oil prices enhances clean energy stock returns (Kumar et al., 2012; Managi and Okimoto, 2013). Second, an increase in oil prices have a minimal impact on clean energy stock returns (Henriques and Sadorsky, 2008; Inchauspe et al., 2015). Third, an increase in oil prices owing to oil-specific demand shock increases clean energy stock returns (Maghyereh and Abdoh, 2021), decreases clean energy stock returns (Zhao, 2020), or has an asymmetric effect (Zhang et al., 2020). Fourth, in studies focusing on the effects of risk shocks rather than oil-specific demand shocks (eg Zhou and Geng, 2021), risk shocks have a major impact on the returns of clean energy stocks in China, Europe, and the US (see Table 2 for detail).

Author, Year, Journal	**Methodology**	**Data**	**Periods**	**Region**	**Results**
Henriques and Sadorsky, 2008, *Energy Economics*	SVAR	ECO, the Arca Tech 100 index (PSE), WTI, 3-month US Treasury bill	3.01.2001-30.05.2007 (weekly)	Global	An increase in oil prices has little statistically significant effect on clean energy stock returns
Kumar et al., 2012, *Energy Economics*	VAR	NEX, ECO, S&P global clean energy index, PSE, WTI, Brent, carbon allowance price future contracts, 3-month US Treasury bill	22.04.2005-26.11.2008 (weekly)	Global	An increase in oil prices increases clean energy stock returns

Managi and Okimoto, 2013, *Japan and the World Energy*	Markov-switching vector autoregressive models	ECO, PSE, WTI, Brent, 3-month US Treasury bill	3.01.2001-24.02.2010 (weekly)	Global	An increase in oil prices increases clean energy stock returns
Inchauspe et al., 2015, *Energy Economics*	A state-space multi-factor asset pricing model	NEX, WTI, PSE, MSCI World index	2001:08-2014:02 (monthly)	Global	In comparison to the MSCI World index and the PSE, the influence of oil prices on clean energy stock returns is quite minimal.
Pham, 2019, *Energy Economics*	Multivariate GARCH models	NASDAQ OMX Green Economy Index Family (comprising 11 indexes for sub-sectors), NYMEX continuous oil future contracts nearest to maturity, WTI, Brent	13.10.2010-21.08.2018 (daily)	Global	The link between oil prices and clean energy stocks varies significantly between subsectors of clean energy stocks. For instance, the biofuel industry has the strongest correlation to changes in oil prices.
Zhao, 2020, *Journal of Economic Structure*	SVAR	ECO, stock returns of the oil and gas industry from Fama-French, S&P 500 index, global crude oil production, global real economic activity index (Kilian index), RAC, economic policy uncertainty index	2001:01-2018:12 (monthly)	Global	An increase in oil prices due to oil supply and aggregate demand shock increases clean energy stock returns. An increase in oil prices due to oil-specific demand shock decreases clean energy stock returns
Zhang et al., 2020, *Energy*	Wavelet-based quantile-on-quantile, Granger causality-in-quantiles methods	European Renewable Energy Index (ERIX), ECO, FTSE ET50, global crude oil production, Kilian index, RAC	2006:01-2018:12 (monthly)	Global	At higher quantiles, an increase in oil prices due to oil supply and aggregate demand shock increases clean energy stock returns, whereas impact of oil-specific demand shock on clean energy stock returns is asymmetric.
Maghyereh and Abdoh, 2021, *Energy*	SVAR, novel quantile cross-spectral dependence approach	global crude oil production, Kilian index, RAC, S&P global clean energy index, S&P 500 integrated oil & gas stock index	2004:01-2019:06 (monthly)	Global	In general, there is a stronger correlation between clean energy and oil-specific demand shocks than there is between aggregate demand shocks and clean energy. An increase in oil prices due to oil-specific demand shock increases clean energy stock returns
Zhou and Geng, 2021, *Frontiers in Environmental Science*	SVAR, the decomposition methods, the rolling	China's new energy index, ERIX, ECO, the World integrated oil and gas producer index,	10.06.2009-30.10.2018 (daily)	China, Europe, US	Oil supply shock has a little impact on the returns of all new energy stock markets, whereas oil demand shock and risk

	window method	NYMEX crude-light sweet oil contract, VIX		shock have significant impact.

Table 2: A summary of previous studies on changes in oil prices and clean energy stock returns

2.2. Changes in gas prices and clean energy stock returns

The existing studies have looked at the effects of changes in gas prices on clean energy stock returns in general, but, to the best of our knowledge, there are basically three types of results regarding the relationship between gas prices and clean energy stock returns. First, changes in gas prices have a small impact on the stock returns of clean energy companies (Reboredo and Ugolini, 2018; Liu and Hamori, 2020; Umar et al., 2022). Second, changes in gas prices have no impact on the stock returns of clean energy companies (Xia et al., 2019; Ghabri et al., 2021). Third, changes in gas prices have a positive impact on the stock returns of clean energy companies (Fu et al., 2022).

Existing literature doesn't focus on the relationship between gas price shocks and stock returns of clean energy companies as we do herein. Instead, there are few studies identifying gas price shocks. For example, Ghabri et al. (2021) investigate how oil and natural gas price shocks affect clean energy stock markets, especially due to post-pandemic oil price shocks by applying a time-varying VAR model. They do not, however, recognize oil and gas price shocks the way we do herein. That is to say, they use the WTI as a benchmark for crude oil to reflect shocks in the price of oil and the NYMEX as a benchmark for natural gas to represent shocks in the price of gas. They find that the oil price shock has a greater impact on ECO returns than on ERIX returns and that clean energy stock prices have increased in response to the dramatic drop in oil prices. Moreover, renewable energy is unresponsive to the natural gas shocks after the oil price shocks. Without focusing on the stock returns of clean energy, Hou and Nguyen (2018), who concentrated on the US natural gas market and examined how the market responded to structural shocks in different regimes, identify gas price shocks for the US as supply (represented by gas production), demand (represented by US industrial production index), and specific demand (represented by gas price). Using a Markov switching VAR, they find that the price of gas is mainly driven by specific demand shocks.

Wang et al. (2022), on the other hand, estimate the volatility of clean energy stock returns and natural gas prices and use five uncertainty indices and seven global economic conditions. They detect that global economic conditions have more power than uncertainty indices to predict the volatility of natural gas and clean energy exchange-traded funds (ETFs) (see Table 3 for detail).

Author, Year, Journal	Method	Data	Periods	Region	Result(s)
Hou and Nguyen, 2018, *Energy Economics*	A Markov switching VAR	The wellhead price and natural gas import prices, US natural gas gross withdrawals, US industrial production index, RAC	1980:01-2016:12 (monthly)	US	The impact of gas demand and price shocks on gas production is negligible. The price of gas is mainly driven by specific demand shocks.
Reboredo and Ugolini, 2018, *Energy Economics*	Multivariate vine copula	Brent, WTI, UK gas futures, natural gas futures (NYMEX), the ARA (Argus/McCloskey), the Nymex Clearport Central Appalachian Coal Futures, the Phelix index, the NYMEX PJM Electricity futures, ERIX, ECO, S&P 500, STOXX 50	02.01.2009-01.09.2016 (daily)	US, Europe	The two main factors influencing changes in the price of new energy stock are electricity prices in the EU and oil prices in the USA. Gas prices have a small impact on the stock returns of clean energy companies.
Xia et al., 2019, *Journal of cleaner energy*	Connectedness network	ERIX, the Brent futures prices, UK natural gas futures prices, Phelix electricity index, coal future prices, EUA carbon futures settle prices	01.04.2008-10.06.2019 (daily)	Europe	Strong substitution relation between electricity, oil, and coal and renewable energy. The biggest contributor to the variations in ERIX is Brent, followed by coal and electricity.
Liu and Hamori, 2020, *Energies*	Connectedness network	WTI, Henry Hub gas futures, UK NBP gas futures, US government bond, UK government bond, S&P 500, STOXX 50, CBOE VIX, EURO VIX, ECO, ERIX, Brent	02.12.2003-02.12.2019 (daily)	US, Europe	The total return spillovers from fossil energy markets and financial variables to the ECO index in the US are marginally greater than those to the ERIX index in Europe. Both crude oil and natural gas returns have a modest amount of spillover effects on renewable energy stocks, with crude oil having a bigger impact than natural gas.
Ghabri et al., 2021, *Applied Economics*	TVP-VAR	-WTI -NYMEX -ECO -ERIX	10.03.2020-15.06.2020 (daily)	Global	ECO returns are more affected by oil price shock than ERIX returns.

					After the crude oil shocks, renewable energies did not respond to the natural gas shocks.
Wang et al., 2022, *Energy Economics*	Shrinkage method, volatility forecasting	Natural gas futures, Invesco WilderHill Clean Energy ETF, Invesco Global Clean Energy ETF, iShares Global Clean Energy ETF, VanEck Vectors Low Carbon Energy ETF, US equity market volatility, Global economic policy uncertainty, Geopolitical risk index, Monetary policy uncertainty, US economic policy uncertainty, World industrial production, Global steel production, Kilian index, Real Commodity Price Factor, Global Economic Conditions Index, Global Weakness Index, Global intensity index	2003:04-2020:03 (monthly)	Global	Global economic conditions have more power than uncertainty indices to predict the volatility of natural gas and clean energy exchange-traded funds (ETFs).
Fu et al., 2022, *Resources Policy*	QARDL	S&P global clean energy index, global financial stress index, WTI, gold prices, global natural gas prices	01.01.2008-30.04.2021 (daily)	Global	Changes in natural gas prices have a beneficial effect on clean energy stocks only in the long term, while they have no effect in the short run.
Umar et al., 2022, *Energy*	Frequency-domain approach	S&P global clean energy index, Bloomberg WTI Crude Oil subindex, Bloomberg Natural Gas Subindex, Bloomberg GasOil subindex, Bloomberg FuelOil subindex	01.01.2004-31.12.2020	Global	The prices of oil and clean energy stocks are highly correlated. There are limited relationships between clean energy stocks and the natural gas and gas oil markets.

Table 3: A summary of previous studies on changes in gas prices and the stock returns of clean energy companies

3. Data description

We use monthly data over the period January 2008 to December 2021, including the Eurozone debt crisis, the pandemic period, and the OPEC+ agreement. The data is collected mainly from DataStream and the Bloomberg terminal. The period has been determined according to the availability of data.

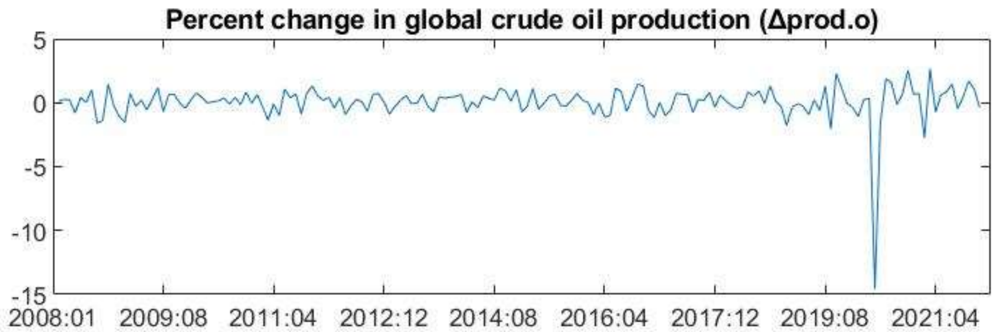
Regarding the model that considers oil-price shocks, our data consist of global crude oil production, Brent spot prices, the EU industrial production index (IPI), and the European renewable energy index (ERIX). In order to detect the oil supply shock, we will use the percent change in the global crude oil production by taking the log difference of world crude oil production in thousand barrels per day, instead of just the oil production in Europe. Since the EU relies on net imports for 92% of consumed crude oil and petroleum products, oil production in the EU alone will not have a significant impact. To obtain the real oil price, the nominal price of Brent is deflated by the harmonized index of consumer prices (HICP). The real oil prices are expressed in log levels. To capture the EU's economic activity, we use the EU monthly industrial production index, take the first difference of the natural logarithm, and convert the index into a growth rate. We use EU IPI because we are looking at the local market. Regarding the stock returns of clean energy companies, we use ERIX to represent renewable energy development. ERIX is Europe's most representative renewable energy market index, comprising the ten largest and most liquid stocks in biofuels, geothermal, marine, solar, water, and wind (Societe Generale, 2022). The ERIX index is used in log levels.

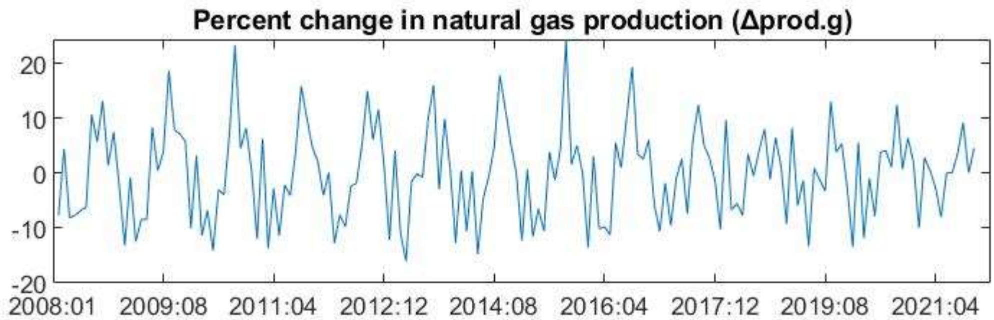
Regarding the model that considers gas-price shocks, our data consist of natural gas production, Dutch TTF (Title Transfer Facility) gas prices, the EU industrial production index, and ERIX. To define gas supply shock, we use natural gas production in terajoules.[4] There are basically two sources of gas supply in the EU which are production and gas storage capacity (Stern and Rogers, 2014) since the EU is a net importer of gas. Since imports are determined by the equilibrium of demand from the EU and supply from exporting countries, to consider an exogenous supply shock we consider total production (and not just imports) from the countries that serve the EU region. The total supply for Europe is then constructed summing its own production plus imports from its suppliers: Russia, Norway, and Algeria, and only to a lesser extent Qatar. Natural gas production enters the model as the percent change by taking the first difference of the natural logarithm. Then, the nominal price of TTF is deflated by the harmonized index of consumer prices (HICP) to obtain the real price of gas[5] and expressed in log levels. We consider the Dutch TTF gas price because it is the leading European benchmark price.[6] Finally, we express the EU monthly industrial production index as the percentual change and ERIX is in log levels as indicated in the model above.

Fig. 1 shows the historical development of all the data used over the sampling period for both the oil and gas models. The percent change in global crude oil production remained relatively stable until Covid-19. However, we observe that the percentage change in natural gas

[4] Since gas production data for Russia is obtained in million cubic meters, it is converted to terajoules.
[5] To obtain the real price of gas, we used HICP rather than US CPI that we use for obtaining the real price of oil because, unlike oil markets, natural gas markets are not yet global. Natural gas prices are mainly determined by regional supply and demand.
[6] Algeria and Qatar are not included in the empirical analysis due to data unavailability on monthly gas production.

production fluctuated a lot. Weather events are an important factor in the demand for gas. One reason is that a difference between a cold and warm winter in Europe can easily increase gas demand by 20-30 bcm (Honoré, 2020). Covid-19 caused a slowdown in industrial production and mobility due to containment measures, as we can also observe. The real prices of oil and gas react to various developments in the markets. For example, both prices start to decrease after 2008, 2014, and 2019 in conjunction with the 2008 financial crisis, an increase in shale gas and oil production, and the global pandemic, respectively. After Covid-19, the rate of increase in gas price is higher than the rate of increase in oil price. This is partially the case because after the pandemic, storage was not sufficiently full and, when the economic activity regained dynamism, gas prices increased more than proportionally. ERIX experienced a rapid decline after the 2008 financial crisis. One of the most important reasons for this is the temporary stimulus packages implemented to promote clean energy before the crisis. However, some governments decided to cut subsidies, and so cuts in subsidies due to unregulated government support made the clean energy sector more fragile in the years following the financial crisis. For example, Germany cut solar subsidies in 2010, while Italy limited subsidies for solar power that same year due to the crisis (Victor and Yanosek, 2011). Moreover, the Czech Republic and Spain reduced tariffs on solar energy in 2010 (Tirado and Bloom, 2013). It was only in 2012 that ERIX started to increase (see Figure 1).





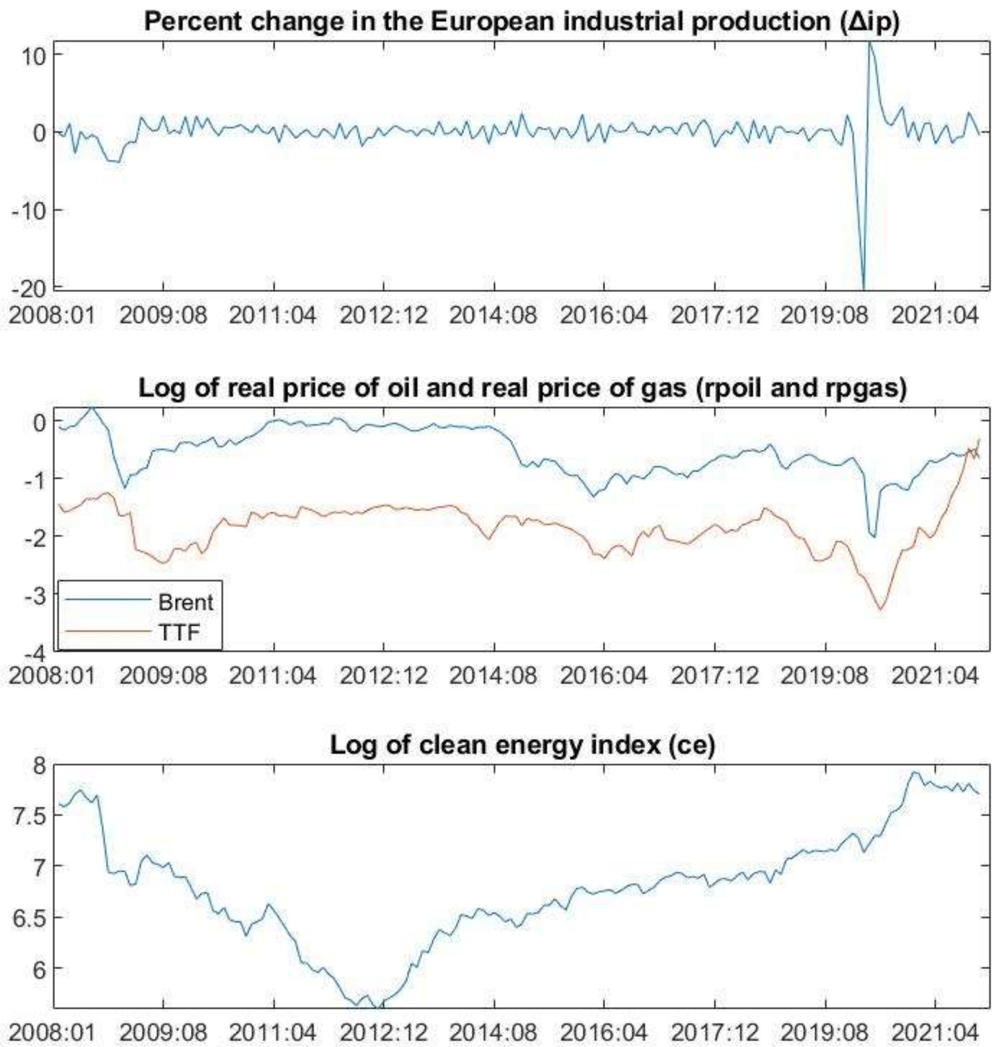


Fig.1. Historical evolution of the series, 2008:1-2021:12

4. Empirical Strategy

This study investigates how shocks in the oil and gas markets affect the stock returns of clean energy companies in Europe. Assuming that the natural gas market is regional and segmented, and that the price of oil is determined on global markets, we begin by analyzing the effects of oil price shocks. Hence, it is crucial to show how ERIX, which stands for renewable energy development in Europe, reacts to shocks in the global oil market before showing how it reacts to shocks in the regional gas market.

4.1. The relation between oil price shocks and European clean energy stocks

Following the global crude oil model proposed by Kilian (2009), we add a fourth dimension and estimate a SVAR model using monthly data of the variables described in the previous section. Precisely we estimate the SVAR for the vector of time series $z_t = (\Delta prod.o_t, \Delta ip_t, rpoil_t, ce_t)$, where $\Delta prod.o_t$ is the percent change in global crude oil production, Δip_t is the percent change in EU industrial production index, $rpoil_t$ is the real price of oil, and ce_t is the clean energy index. In order to capture changes in crude oil demand, we utilize the EU industrial production index rather than Kilian's (2009) index because we are interested in researching the European market.

The reduced-form VAR model is

(1) $$A_0 z_t = \alpha + \sum_{i=1}^{p} A_i z_{t-i} + \varepsilon_t$$

where ε_t denotes the vector of serially and mutually uncorrelated structural innovations, $\varepsilon_t = (\varepsilon_t^{\Delta prod.o} \varepsilon_t^{\Delta ip}{}_t, \varepsilon_t^{rpoil}, \varepsilon_t^{ce})'$. A_0 and A_i indicate the contemporaneous and lagged coefficient matrices, respectively. Assuming that e_t is the reduced-form error of the corresponding VAR innovations decomposing according to the expression $e_t = A_0^{-1}\varepsilon_t$, where A_0^{-1} has a recursive structure. p is the lag order of the VAR system and following Kilian (2009), we assume p=24 in Eq. (1).

We explain fluctuations in the real oil prices in terms of three structural shocks: shocks to the global crude oil production ("oil supply shock" denoted by ε_{1t}), shocks to the demand driven by EU economic activity, ("demand shock" denoted by ε_{2t}), and shocks from changes in precautionary demand for oil ("oil-specific demand shock" denoted by ε_{3t}).

The structural model is of the form

(2) $$e_t \equiv \begin{pmatrix} e_{1t}^{\Delta prod.o,t} \\ e_{2t}^{\Delta ip,t} \\ e_{3t}^{rpoil,t} \\ e_{4t}^{ce,t} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{pmatrix} \varepsilon_{1t}^{oil\ supply\ shock} \\ \varepsilon_{2t}^{economic\ demand\ shock} \\ \varepsilon_{3t}^{oil-specific\ demand\ shock} \\ \varepsilon_{4t}^{clean\ energy\ stock\ shocks} \end{pmatrix}$$

Our model (2) consists of two blocks, the first of which contains the first three equations and describes the global market for crude oil, and the second of which has just the last equation and describes the market for clean energy. This is the case since our primary purpose is to explore the effects of structural shocks in the crude oil market on clean energy stock prices in

Europe. Using the Cholesky decomposition method,[7] the order of the variables is important because it affects the results (Wang et al., 2014). Therefore, the Cholesky identification strategy (Eq. (2)) implicitly presupposes that economic activity, real price of oil and clean energy stock returns don't have a contemporaneous effect on supply of oil, but with a delay of at least one month. This is indeed the case, and has been verified in recent times where rising prices did not result in oil supply increases: only exogenous events, like decisions on OPEC production quotas, can affect oil production since it implies huge investments that take time to become operative. Moreover, supply of oil does not contemporaneously react to economic activity, to the real price of oil and to changes in clean energy returns. This is what the restrictions $a_{12}=a_{13}=a_{14}=0$ imply. Also, the Cholesky decomposition assumes that economic activity is only affected by supply shock and economic demand shocks, whereas oil-specific demand shock and clean energy stock shocks don't have a contemporaneous effect on economic activity, according to $a_{23}=a_{24}=0$. In the same line, this methodology assumes that real price of oil changes instantaneously in response to oil supply shock, economic demand shock and oil-specific demand shock, but that real price of oil doesn't contemporaneously react to clean energy stock shocks ($a_{34}=0$). Finally, clean energy stock returns are affected by oil supply shock, economic demand shock, and oil-specific demand shock contemporaneously. The previous assumptions do not seem very restrictive given the theoretical foundations of our model as well as the realizations observed in Figure 2.

4.1.1. Structural VAR estimates in Europe for global oil-price shocks

Fig. 2 shows the time path of the structural shocks in the global oil market. After the Arab Uprising and the European debt crisis in 2011, there are disruptions in the oil supply. On the other hand, from 2014, a rise in oil supply is shown along with an increase in shale oil and gas production (Liu and Li, 2018). After the pandemic, all shocks decreased except for the clean energy stock shock, which remained unchanged. By the rising investment in clean energy, this may indicate the start of the decoupling between fossil fuel energy sources and economic activity.

[7] Cholesky decomposition is utilized in the model to derive impulse response functions and variance decompositions.

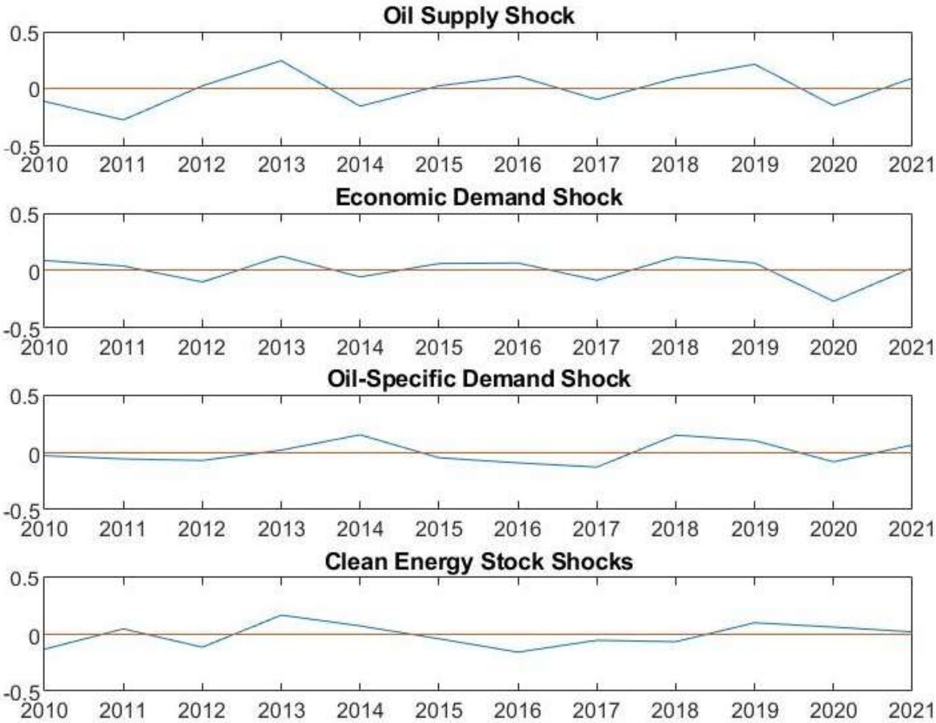


Fig.2. Historical evolution of the structural shocks in the global oil market

Fig. 3 represents the responses of global oil production, economic activity, the real price of oil, and clean energy stock returns to the three structural shocks in the global oil market. We observe that the oil supply shock has no stable effect on oil production.[8] Similarly, the impact of an oil supply shock on real activity is not significant throughout the whole period. Moreover, a negative shock in global oil supply has a statistically insignificant effect on clean energy stock returns in the first six months, followed by a statistically significant negative effect on clean energy stock returns. This means that rising oil prices in the global market do not encourage investors to switch to clean energy in the European market. Instead, oil-specific demand shocks inside the European region positively affect the clean energy stock returns after the 12-months horizon[9]. This supports the hypothesis of substitutability between oil and clean energy in the region. The explanation of this result lies in the fact that oil-specific demand shocks capture the factors that affect oil prices because of the relationship between precautionary demand and the availability of future crude oil supply (Melek et al., 2015). In more detail, oil-specific demands

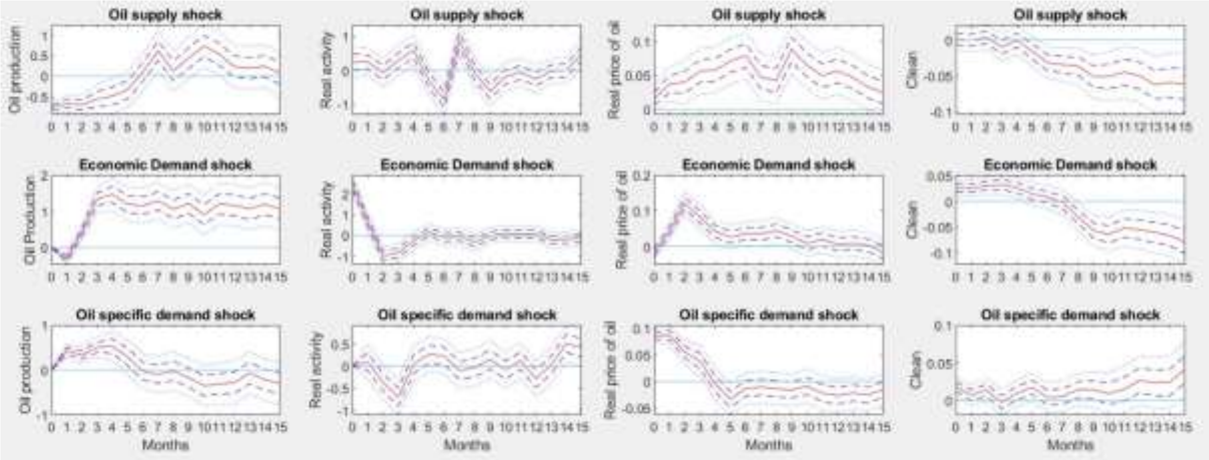
[8] In the first 5 months, there is an increase in oil production from -0.5 to 0. Then, in the sixth month, the standard error bands cross the zero axis, which means that oil supply shock has no significant effect on oil production. In the seventh month, a negative oil supply shock reduces oil production, then in the eighth month, the standard error bands cross the zero axis again. After that, oil production increases for 2 months, then falls again. At 12 months, it again has a statistically insignificant effect.

[9] Early on, clean energy stock returns' response to the oil-specific demand shock was statistically insignificant. The reason for this is that, despite the rise in oil prices after 2009, the oil-specific demand shock could not be absorbed since ERIX prices continued to fall.

are a reflection of the demand for just oil, driving the substitution effect (Maghyereh and Abdoh, 2021).

Oil-specific demand shock initially has a strong positive impact on oil prices, but during the first 5-months horizons, that impact shifts to a downwards trend. One possible explanation is the decline in oil demand in the EU since 2000 (Eurostat, 2023d) as a result of many developments, such as the development of environmentally friendly vehicles, advancements in vehicle efficiency, the blending of biofuels, and the worldwide economic crisis (Cai et al., 2022). Second explanation is that following the global financial crisis of 2008, both the price of oil and the rate of consumer price inflation as measured by HCIP, as well as the price of ERIX, all plummeted. There were significant developments that contributed to the decline in the oil price during the time when the oil-specific demand shock had a declining impact on the price of oil and even when the effect turned negative: Global pandemic in 2019, shale gas and oil production boom in 2014, and 2008 global economic crisis. Both oil prices and inflation rise following these periods. According to Henriques and Sadorsky (2008), increased oil prices are frequently connected with inflationary pressures. Moreover, according to Kilian (2009), positive precautionary demand shocks increase consumer prices. Recently, rising oil prices with the Russia-Ukraine War contributed more than three percent to consumer price inflation in most countries in Europe, and even more than five percentage points in some countries such as Belgium, Netherlands, Romania (Ari et al., 2022).

We find that an unexpected increase in economic demand in Europe results in an immediate increase in the real price of oil and gas (see Fig. 3 and Fig. 5), which is similar to the findings of Jadidzadeh and Serletis (2017) at the global level. We also find that the positive effect of the increase in economic activity on the stock returns of clean energy lasts for eight months and turns into a negative effect afterward. The positive effect can be explained by the fact that when there is a positive aggregate demand shock, oil demand will increase, and this will cause an increase in oil prices. The effects of rising oil prices on oil-importing countries will positively affect renewable energy investment in the EU (Karacan et al., 2021). After the second month, an economic demand shock results in a decline in the real price of oil as well as a decline in the returns on clean energy stocks.



Note: One-standard error and two-standard error bands are represented by dashed and dotted lines, respectively.

Fig.3. Responses to one-standard-deviation structural shocks

4.2. Model for the relation between gas price shocks and clean energy in Europe

We estimate the SVAR model using monthly data for the vector of time series z_t = (Δprod.g_t, Δip_t, $rpgas_t$, ce_t), where Δprod.g_t is the percent change in gas production, Δip_t the percent change in EU industrial production index, $rpgas_t$ is the real price of gas, and ce_t denotes the stock returns of the clean energy companies.

The SVAR representation is the same as in Eq. (1) but considering gas shocks. This means that, in this case, ε_t denotes the vector of serially and mutually uncorrelated structural innovations, $\varepsilon_t = (\varepsilon_t^{\Delta prod.g)}, \varepsilon_t{}^{\Delta ip}{}_t, \varepsilon_t^{rpgas}, \varepsilon_t^{ce})'$. Similarly to the previous model for oil, here A_0 and A_i indicate the contemporaneous and lagged coefficient matrices, respectively and we assume that e_t is the reduced-form error of the corresponding VAR innovations decomposing according to the expression $e_t = A_0^{-1}\varepsilon_t$, where A_0^{-1} has a recursive structure.

Again, similarly to the oil price shock model, here we explain fluctuations in the real gas prices in terms of three structural shocks: shocks to the gas production (“gas supply shock” denoted by ε_{1t}), shocks to the demand driven by EU economic activity, (“demand shock” denoted by ε_{2t}), and shocks from changes in precautionary demand for gas (“gas-specific demand shock” denoted by ε_{3t}).

The structural model is therefore

$$(4) \qquad e_t \equiv \begin{pmatrix} e_{1t}^{\Delta prod.g,t)} \\ e_{2t}^{\Delta \mathrm{ip,t}} \\ e_{3t}^{rpgas,t} \\ e_{4t}^{ce,t} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{pmatrix} \varepsilon_{1t}^{gas\ supply\ shock} \\ \varepsilon_{2t}^{economic\ demand\ shock} \\ \varepsilon_{3t}^{gas-specific\ demand\ shock} \\ \varepsilon_{4t}^{clean\ energy\ stock\ shocks} \end{pmatrix}$$

Eq. (4) assumes that economic activity, real price of gas and clean energy stock returns don't have a simultaneous effect on supply of gas, but with a delay of at least one month. This is because only exogenous events can affect gas production, i.e. weather events affect gas production, as implied by the restrictions $a_{12}=a_{13}=a_{14}=0$. Also, it assumes that economic activity is only affected by supply shocks and economic demand shocks, whereas gas-specific demand shock and clean energy stock shocks don't have a contemporaneous effect on economic activity, i.e. $a_{23}=a_{24}=0$. Accordingly, real price of gas changes instantaneously in response to gas supply shock, economic demand shock and gas-specific demand shock, but that real price of gas doesn't contemporaneously react to clean energy stock shocks ($a_{34}=0$). Finally, clean energy stock returns are affected by gas supply shock, economic demand shock, and gas-specific demand shock contemporaneously. The previous assumptions seem plausible given that, as it is the case for oil markets, gas supply is usually decided before short-run fluctuations in the market and it is mostly affected by economic activity and not the reverse.

4.2.1. Structural VAR estimates for gas-price shocks in Europe

Fig.4 shows the time path of the structural shocks in the local gas market. Following the Arab Uprising and the Eurozone debt crisis in 2011, the supply of gas is falling, just as oil supply. Clean energy stock returns have declined since that time. This can be explained by the fact that whereas oil is a global commodity, the gas market has a significant local component. Moreover, when compared to the model with oil price shocks, clean energy stock returns clearly increased in 2013 in the model with gas price shocks, suggesting that gas price shocks indicate an increase in the attractiveness of clean energy. The price of oil and gas has decreased as shale gas and oil production increased in 2014. After the pandemic, a decrease is observed in all shocks.

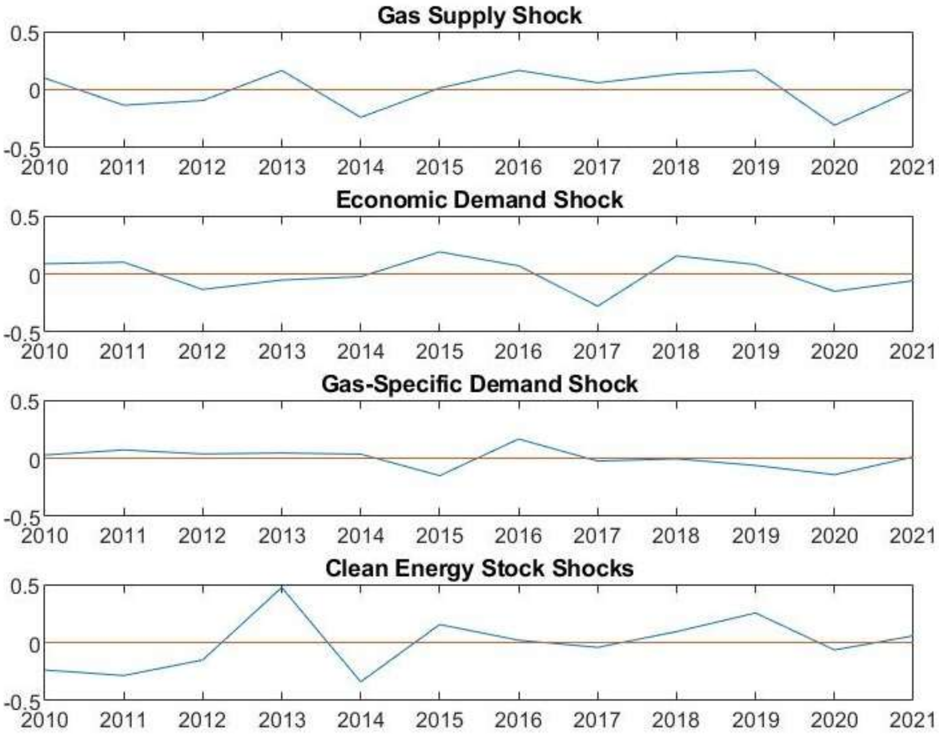


Fig.4. Historical evolution of the structural shocks

Fig.6 shows the responses of natural gas production, economic activity, the real price of gas, and clean energy stock returns to the three structural shocks in the regional gas market. The real price of gas initially decreases in response to an unexpected fall in gas production before rising. Economic demand shock affects the real price of gas at a time horizon between one and five months with a statistically significant positive impact. The real price of gas is positively impacted by the gas-specific demand shock, but this impact fades over time. One possible explanation is the decline in gas demand in Europe in the period between 2008-2015[10]. In Europe, the gas pricing formula underwent a change as of 2008. Hubs replaced oil-linked gas pricing as the predominant method of establishing gas prices between 2008 and 2014 in north west Europe and central Europe. The main factors influencing European hub pricing are gas supply and demand. Besides, the supply of LNG and Russian price/volume policy are two of the key factors that affect hub prices (Stern and Rogers, 2014). Several global events that could have an impact on gas prices happened during this time: 2009 Russia-Ukraine gas disputes, 2011 Libya civil war and the withheld Russian gas (Nick and Thoenes, 2014). Knowing that the natural gas market is regional and segmented, due to the EU's heavy reliance on foreign gas, problems in the countries it imports have an impact on regional gas prices. For instance, the gas dispute that began between Russia and Ukraine in 2009 and persisted in

[10] Gas demand in the EU has decreased from 418,7 bcm in 2008 to 346,7 bcm in 2015 (BP, 2021).

various forms until 2014 has had an impact on the EU. Gas prices in the EU fell at this time despite the possibility of a gas supply interruption as a result of the gas dispute. This is due to three key factors. First, Russia's gas does not only transit via Ukraine on its route to Europe. Second, Europe's gas demand decreased because to the mild winter. Third, on a global scale, it was projected that natural gas liquefaction capacity would significantly grow (Desbois, 2015). Fig. 5 shows the cumulative effect of gas price shocks on the real price of gas in the EU. Keeping with Hou and Nguyen (2018), gas-specific demand shocks are mainly responsible for the sharp increases and decreases in the real price of gas. On the other hand, Brown and Yücel (2008), Nick and Thoenes (2014) and Jadidzadeh and Serletis (2017) emphasize that gas prices are mainly driven by other shocks in the real price of gas, such as weather, seasonality, storage, and other fuel prices, rather than the three structural shocks on the gas market.

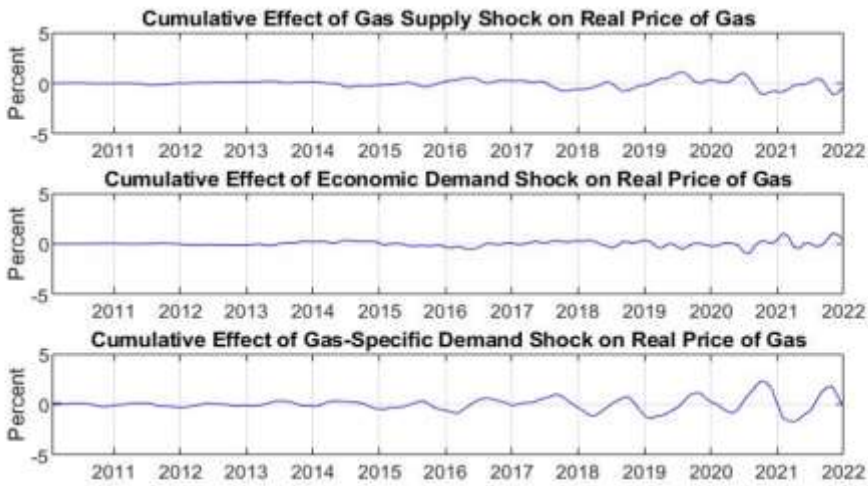
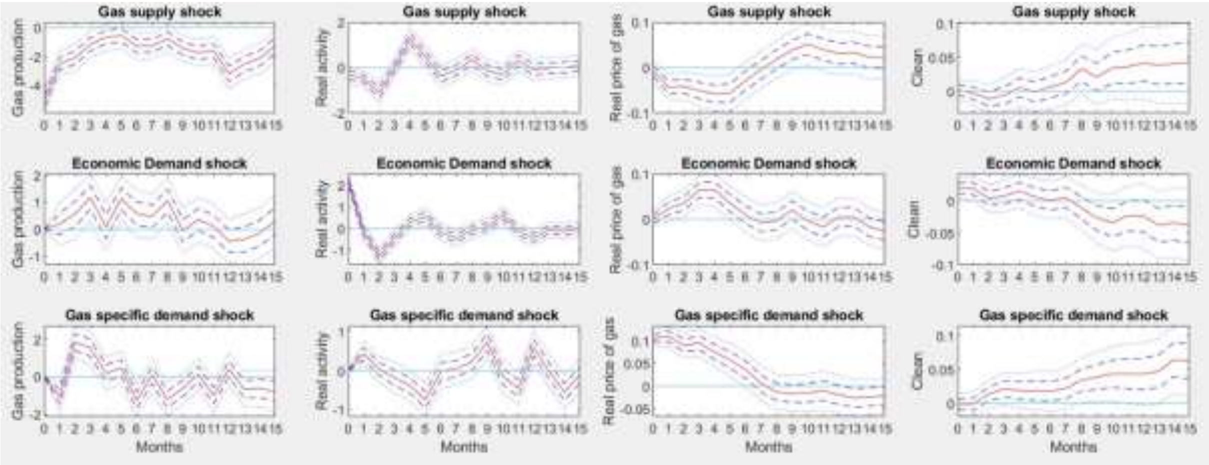


Fig. 5. Cumulative effects of gas price shocks on the real price of gas

The positive effect of the economic demand shock on the stock returns of clean energy lasts for seven months but this positive effect is statistically insignificant after the first month and turns into a negative after the eighth month (and statistically significant based on a one-standard error band). An unexpected decrease in gas production has a positive and statistically significant effect on clean energy stock returns according to one standard error band after the tenth month. This is probably explained by the fact that rising gas prices encourage investors to switch to clean energy. This substitution effect can also be observed in the positive effect of a gas-specific demand shock on clean energy stock returns. If the current demand for gas decreases, this may indicate that gas producers are switching to renewable energy.

In Europe, gas is used for both heating and electricity generation. Also, in some countries, such as France, gas is used as a transition fuel meaning that its usage is coupled with renewables. Instead, in countries like Germany, gas is used to generate electricity as a baseload. Therefore, Europe, which is dependent on gas imports for both heating and electricity generation, is greatly affected by the changes in natural gas prices. One of the best ways to get out of this situation is seen as the transition to renewable energy. The record high gas prices, especially after Covid-19, brought this transition to the fore. However, the transition to renewable energy did not go as expected. One of the reasons for this is that gas is used for heating. Even if gas prices rise drastically, the switch to renewable heat, such as heat pumps, is not easily encouraged to replace gas used for heating. Most homeowners need to change their heating source, but this is very difficult, so sudden changes in prices are not enough to encourage the transition to renewable heat (Keating, 2022). On the other hand, the share of fossil sources in electricity generation in the EU has decreased from 39% in 2019 to 37% in 2021. In the EU, the proportion of fossil fuels used to generate electricity has dropped from 39% in 2019 to 37% in 2021. The largest portion of this fall is due to the decline in coal, as Europe's concentration prior to Covid-19 was on coal and not natural gas. In other words, coal was being replaced by renewable energy prior to Covid-19. However, the situation altered after Covid-19, and the gas crisis resulting from the Russia-Ukraine war served as a major wake-up call for all investors. Although gas prices soared to extremely high levels in Europe as a result of the global pandemic, the prices of renewable energy fell to extremely low levels. But instead of spurring a significant expansion in renewable energy, this led to the replacement of gas by renewable energy. Over the previous two years, the amount of renewable electricity has increased by an average of 44 terawatt-hours annually, with half of this new wind and solar power replacing gas plants (Keating, 2022; Moore, 2022). Ghabri et al. (2021) reveal that the announcement of Covid-19 affected the ERIX index more than the ECO index because Covid-19 created more uncertainty in Europe than in the US, especially in the early days of its spread. They also find that gas prices and the ERIX index are moving in the same direction. In the impulse response function above, a demand shock decreases both the real price of gas and clean energy stock returns after the third month.



Note: One-standard error and two-standard error bands are represented by dashed and dotted lines, respectively.

Fig.6. Responses to one-standard-deviation structural shocks

5. Concluding Remarks

This study tackles the question of how different oil and gas price shocks affect the stock prices of clean energy companies in Europe by using a structural VAR. To the best of our knowledge, this is the first study of the relationship between oil price shocks and clean energy stock returns at the European level. In addition, previous studies on the natural gas market do not separately identify gas price shocks at the European level.

Our main findings are as follows. First, a negative gas supply shock positively affects clean energy stocks, which means that clean energy is a substitute to gas for European investors, contrary to what we could expect given the labeling of gas as green by the European Commission in July 2022. Instead, a negative shock in the global oil supply does not have a statistically significant impact throughout the period studied. This means that rising oil prices in the global market do not encourage investors to switch to clean energy in the European market. This may be showing a lack of credibility in the European agenda on green transportation. Second, we reasonably find that both the oil-specific demand shock and the gas-specific demand shock positively affect the stock returns of clean energy companies, meaning that there is a king-of-scale effect in demand that extends to all energy sources. Finally, we find that the positive effect of the economic demand shock on the stock returns of clean energy lasts longer in the model with oil price shocks than in the model with gas price shocks.

The previous results show there is a substitution effect operating in Europe, where a shock that decreases competitivity of fossil sources positively affects clean energy stocks. Zhao

(2020) and Maghyereh and Abdoh (2021) find that oil-specific demand shocks are much more important than oil supply and aggregate demand shocks in explaining the variability in clean energy stock returns. This is because a negative supply shock is a temporary reduction in production caused by the interruption of supply in the short term. This may be due to a shock such as an unexpected military intervention in an oil-exporting country. We do not expect this kind of event to produce an immediate substitution in oil-importing countries. Indeed, Wang et al. (2014) emphasize that crude oil production consists of long-term investments that are capital-intensive.

The previous results are important to draw the lines for future energy policy. Firstly, they show that, even if the European Commission endorsed gas as a green course thinking to its complementarity with intermittent renewables, investors do not consider gas this way, and shocks in the market generate substitution towards clean energy. Secondly, in the actual context of rising fossil fuel prices due to the Ukrainian conflict, we are likely to observe a strong substitution of those sources with clean energy, good news for European energy sovereignty as well as for the transition to a net-zero economy.

References

Ari, A., Arregui, N., Black, S., Celasun, O., et al. 2022. Surging energy prices in Europe in the aftermath of the war: How to support the vulnerable and speed up the transition away from fossil fuels. IMF Working Papers, WP/22/152.

BP, 2021. Statistical review of world energy, BP Publishing.

Brown, S.P.A., Yücel, M.K. 2008. What drives natural gas prices? Energy J. 29 (2), 45-60. http://doi.org/10.5547/ISSN0195-6574-EJ-Vol29-No2-3.

Cai, Y., Zhang, D., Chang, T., Lee, C.C. 2022. Macroeconomic outcomes of OPEC and non-OPEC oil supply shocks in the euro area. Energy Econ., 105975.

Degiannakis, S., Filis, G., Kizys, R. 2014. The effects of oil price shocks on stock market volatility: Evidence from European data. Energy J. 35 (1), 35-56. http://doi.org/10.5547/01956574.35.1.3.

Demirer, R., Ferrer, R., Shahzad, S.J.H. 2020. Oil price shocks, global financial markets, and their connectedness. Energy Econ. 88, 104771. https://doi.org/10.1016/j.eneco.2020.104771.

Desbois, B. 2015. Has the Ukraine crisis affected gas prices in Western Europe?, E&C Consultants. Available at: https://www.eecc.eu/blog/2015/02/18/has-the-ukraine-crisis-affected-gas-prices-in-western-europe

Eurostat, 2023a. Gross available energy by product. Available at: https://ec.europa.eu/eurostat/databrowser/view/ten00121/default/table?lang=en

Eurostat, 2023b. Energy import dependency by product. Available at: https://ec.europa.eu/eurostat/databrowser/view/sdg_07_50/default/table?lang=en

Eurostat, 2023c. Final energy consumption by product. Available at: https://ec.europa.eu/eurostat/databrowser/view/ten00123/default/table?lang=en

Eurostat, 2023d. Oil and petroleum products – a statistical overview. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Oil_and_petroleum_products_-_a_statistical_overview#Production_of_crude_oil

Fu, Z., Chen, Z., Sharif, A., Razi, U. 2022. The role of financial stress, oil, gold and natural gas prices on clean energy stocks: Global evidence from extreme quantile approach. Res. Pol. 78, 102860.

Ghabri, Y., Ayadi, A., Guesmi, K. 2021. Fossil energy and clean energy stock markets under COVID-19 pandemic. Appl. Econ. 53 (43), 4962-4974. https://doi.org/10.1080/00036846.2021.1912284.

Hailemariam, A., Smyth, R. 2019. What drives volatility in natural gas prices? Energy Econ. 80, 731-742. https://doi.org/10.1016/j.eneco.2019.02.011.

Henriques, I., Sadorsky, P. 2008. Oil prices and the stock prices of alternative energy companies. Energy Econ. 30 (3), 998–1010. https://doi.org/10.1016/j.eneco.2007.11.001.

Herrera, A.M. 2018. Oil price shocks, inventories, and macroeconomic dynamics. Macroeconomic Dynamics, 22(3), 620-639.

Herrera, A.M., Karaki, M.B., Rangaraju, S.K. 2019. Oil price shocks and US economic activity. Energy Pol. 129, 89–99. https://doi.org/10.1016/j.enpol.2019.02.011

Honoré, A. 2020. Natural gas demand in Europe: The impacts of COVID-19 and other influences in 2020. Oxford Institute for Energy Studies.

Hou, C., Nguyen, B.H. 2018. Understanding the US natural gas market: A Markov switching VAR approach. Energy Econ. 75, 42-53. https://doi.org/10.1016/j.eneco.2018.08.004.

Inchauspe, J., Ripple, R.D., Trück, S. 2015. The dynamics of returns on renewable energy companies: A state-space approach. Energy Econ. 48, 325–335. https://doi.org/10.1016/j.eneco.2014.11.013.

Jadidzadeh, A., Serletis, A. 2017. How does the U.S. natural gas market react to demand and supply shocks in the crude oil market? Energy Econ. 63, 66-74. https://doi.org/10.1016/j.eneco.2017.01.007.

Ji, Q., Zhang, H.Y., Geng, J.B. 2018. What drives natural gas prices in the United States? A directed acyclic graph approach. Energy Econ. 69, 79-88. https://doi.org/10.1016/j.eneco.2017.11.002.

Karacan, R., Mukhtarov, S., Barış, İ., İşleyen, A., Yardımcı, M. E. 2021. The impact of oil price on transition toward renewable energy consumption? Evidence from Russia. Energies 14 (10), 2947. https://doi.org/10.3390/en14102947.

Keating, D. 2022. Will rising gas prices hasten the switch to renewables? Available at: https://www.energymonitor.ai/sectors/power/will-rising-gas-prices-hasten-the-switch-to-renewables.

Kielmann, J., Manner, H., Min, A. 2021. Stock market returns and oil price shocks: a CoVaR analysis based on dynamic vine copula models. Emp. Econ. 62, 1543-1574. https://doi.org/10.1007/s00181-021-02073-9.

Kilian, L. 2009. Not all oil price shocks are alike: disentangling demand and supply shocks in the crude oil market. Am. Econ. Rev. 99 (3), 1053-1069. http://doi.org/10.1257/aer.99.3.1053

Kilian, L., Vigfusson, R.J. 2011. Are the responses of the US economy asymmetric in energy price increases and decreases? Quantitative Econ. 2 (3), 419-453. https://doi.org/10.3982/qe99

Kilian, L., Park, C. 2009. The impact of oil price shocks on the US stock market. Int. Econ. Rev. 50(4), 1267–87. https://www.jstor.org/stable/25621509.

Kim, W.J., Hammoudeh, S., Hyun, J.S., Gupta, R. 2017. Oil price shocks and China's economy: Reactions of the monetary policy to oil price shocks. Energy Econ. 62, 61-69. http://doi.org/10.1016/j.eneco.2016.12.007.

Krokida, S.I., Lambertides, N., Savva, C.S., Tsouknidis, D.A. 2020. The effects of oil price shocks on the prices of EU emission trading system and European stock returns. European J. Finance 26 (1), 1-13. http://doi.org/10.1080/1351847X.2019.1637358.

Kumar, S., Managi, S., Matsuda, A. 2012. Stock prices of clean energy firms, oil and carbon markets: A vector autoregressive analysis. Energy Econ. 34, 215-226.

Liu, T., Hamori, S. 2020. Spillovers to renewable energy stocks in the US and Europe: Are they different? Energies, 13(3162). 1-28.

Liu, H., Li., J. 2018. The US shale gas revolution and its externality on crude oil prices: A counterfactual analysis, Sustainability, 10(697).

Maghyereh, A., Abdoh, H. 2021. The impact of extreme structural oil-price shocks on clean energy and oil stocks. Energy 225. https://doi.org/10.1016/j.energy.2021.120209.

Managi, S., Okimoto, T. 2013. Does the price of oil interact with clean energy prices in the stock market? Japan World Econ. 27, 1–9. https://doi.org/10.1016/j.japwor.2013.03.003.

Melek, N.Ç., Davig, T., Nie, J., Smith, A.L., Tüzemen, D. 2015. Evaluating a year of oil price volatility. Econ. Rev. Q III, 5–30.

Moore, C. 2022. European electricity review 2022. Ember.

Natal, J.M. 2012. Monetary policy response to oil price shocks. J. Money Credit Banking 44 (1), 53-101. https://www.jstor.org/stable/41336816.

Nick, S., Thoenes, S. 2014. What drives natural gas prices? A structural VAR approach. Energy Econ. 45, 517-527. https://doi.org/10.1016/j.eneco.2014.08.010.

Pham, L. 2019. Do all clean energy stocks respond homogeneously to oil price? Energy Econ. 81, 355–79. https://doi.org/10.1016/j.eneco.2019.04.010.

Pindyck, R.S. 2004. Volatility in natural gas and oil markets. J Energy Dev. 30 (1), 1-19. https://www.jstor.org/stable/24808787.

Ready, R.C. 2018. Oil prices and the stock market. Rev. Finance 22 (1), 155–76. http://doi.org/10.1093/rof/rfw071.

Reboredo, J.C., Ugolini, A. 2018. The impact of energy prices on clean energy stock prices. A multivariate quantile dependence approach. Energy Econ. 76, 136-152.

Rubaszek, M., Szafranek, K., Uddin, G.S. 2021. The dynamics and elasticities on the U.S. natural gas market. A Bayesian structural VAR analysis. Energy Econ. 103, 105526. https://doi.org/10.1016/j.eneco.2021.105526.

Scholtens, B., Yurtsever, C. 2012. Oil price shocks and European industries. Energy Econ. 34 (2), 1187-1195. https://doi.org/10.1016/j.eneco.2011.10.012.

Societe General, 2022. European renewable energy. Available at: https://sgi.sgmarkets.com/en/index-details/TICKER:ERIX/.

Stern, J., Rogers, H.V. 2014. The dynamics of a liberalized European gas market: Key determinants of hub prices, and roles and risks of major players. Oxford Institute for Energy Studies. Working Paper No. 286084.

Tirado, J., Bloom, J.R. 2013. Solar energy reforms in Spain and Czech Republic threaten international investors. Available at: https://www.lexology.com/library/detail.aspx?g=ab40069a-7f6a-4c84-9291-3bda41429af4.

Umar, Z., Gubareva, M., Naeem, M., Akhter, A. 2021. Return and volatility transmission between oil price shocks and agricultural commodities. PLoS ONE 16 (2). https://doi.org/10.1371/journal.pone.0246886.

Umar, M., Farid, Z., Naeem, M.A. 2022. Time-frequency connectedness among clean-energy stocks and fossil fuel markets: Comparison between financial, oil and pandemic crisis. Energy, 240, 122702.

Wang, Y., Wu, C., Yang, L. 2014. Oil price shocks and agricultural commodity prices. Energy Econ. 44, 22-35. https://doi.org/10.1016/j.eneco.2014.03.016.

Wang, J., Ma, F., Bouri, E., Zhong, J. 2022. Volatility of clean energy and natural gas, uncertainty indices, and global economic conditions. Energy Econ. 108, 105904. https://doi.org/10.1016/j.eneco.2022.105904.

Wen, F., Zhang, K., Gong, X. 2021. The effects of oil price shocks on inflation in the G7 countries. North Am. J. Econ. Finance 57. https://doi.org/10.1016/j.najef.2021.101391.

Xia, T., Ji, Q., Zhang, D., Han, J. 2019. Asymmetric and extreme influence of energy price changes on renewable energy stock performance. J. Clean. Prod. 241, 118338. https://doi.org/10.1016/j.jclepro.2019.118338.

Victor, D.G., Yanosek, K. 2011. The crisis in clean energy: stark realities of the renewables craze. Foreign Affairs 90 (4), 112–20. https://www.jstor.org/stable/23039611.

Zamani, N. 2016. How the crude oil market affects the natural gas market? Demand and supply shocks. Int. J. Energy Econ. Policy 6 (2), 217-221.

Zhang, H., Cai, G., Yang, D. 2020. The impact of oil price shocks on clean energy stocks: Fresh evidence from multi-scale perspective. Energy 196, 117099. https://doi.org/10.1016/j.energy.2020.117099.

Zhao, X. 2020. Do the stock returns of clean energy corporations respond to oil price shocks and policy uncertainty? J. Econ. Structures 9, 53. https://doi.org/10.1186/s40008-020-00229-x.

Zhou, L., Geng, J.B. 2021. Dynamic effect of structural oil price shocks on new energy stock markets. Front Environ. Sci. 9. https://doi.org/10.3389/fenvs.2021.636270.