Economics Bulletin

Volume 37, Issue 3

Oil prices, renewable energy, CO2 emissions and economic growth in OECD countries

Taha Zaghdoudi
Faculty of Law, Economics and Management of Jendouba, Tunisia

Abstract

This paper examines the casual relationship between oil prices , renewable energy, carbon dioxide emissions and economic growth for the OECD countries over the period 1990-2015. By performing panel cointegration models, we found strong evidence of a negative and significant long-run relationship between oil prices, renewable energy and CO2 emissions. Findings indicate also that there is a quadratic long run relationship between CO2 emissions and economic growth, confirming the existence of an Environmental Kuznets Curve (EKC) for OECD countries. The Granger-causality results indicate bidirectional causality between CO2 emissions and oil prices in both short and long-run. This paper supports the view that an increase of oil prices decreases CO2 emissions in OECD countries.

Citation: Taha Zaghdoudi, (2017) "Oil prices, renewable energy, CO2 emissions and economic growth in OECD countries", *Economics Bulletin*, Volume 37, Issue 3, pages 1844-1850
Contact: Taha Zaghdoudi - zedtaha@gmail.com.
Submitted: July 27, 2017. **Published:** August 31, 2017.

1 Introduction

In recent years the increase of greenhouse gases emissions from continuous economic progress is a persistent and serious challenge to the world. Carbon dioxide emissions (CO2) which come from fossil fuels consumption is regarded to be the main source of the global warming. Therefore, since the Kyoto Protocol in 1997 and recently the COP21-22 in 2015-2016 most of the OECD countries have set voluntary targets for the reduction of pollution from nonrenewable energy consumption and attract wide attention to toward developing alternative energy sources. Hence, since 2002 investment in renewable energy in OECD countries has represented more than 1 trillion US dollars and renewable energy supply grew on average by 2.7% per year between 1971 and 2014 as compared to 1.0% per year for total primary energy supply(Factbook (2015)).

Nevertheless, oil prices have plummeted by 60% since June 2014. In Januray 2015 crude oil prices reached its lowest level since 2009 at just under 50 $. This is largely due to the emergence of the Canadian oil sands and United States (US) shale oil, which can be exploited by hydraulic fracturing and horizontal drilling technologies, an additional 4.2 million barrels per day arrived in the crude oil market, which have considerably increased the world's energy supply. However, shale oil will shorten oil price cycles and decreases their amplitude. Compared to conventional oil, this mode of production results in fewer sunk costs and a much shorter period between the start of investment and production. Furthermore, the changing strategy of Organization of the Petroleum Exporting Countries(OPEC), the projected increase in Iran's exports, the contraction of world demand (especially emerging markets), the secular decline in oil consumption in the US and the emergence of oil substitutes, affect oil prices. These phenomena, which are likely to persist, such as the development of shale oil, suggest a long-term low price scenario. This my reduces interest on renewable energy usage, increases fossil fuel consumption and CO2 emissions.

While, several empirical studies have been conducted on the relationship between CO2 emissions, oil prices and economic growth, relatively little attention has been given to the nexus between CO2 emissions, renewable energy, oil prices and economic growth. For instance, Antonakakis et al. (2017) used a panel vector autoregressive method to examine the dynamic interrelationship in the output-energy-environment nexus for 106 countries classified by different income groups over the period 1971-2011. Their results indicate a bidirectional causality between total economic growth and energy consumption. Moreover, their findings show that the continued process of growth aggravates the greenhouse gas emissions phenomenon. Alam et al. (2016) studied the impacts of income, energy consumption and population growth on CO2 emissions in India, Indonesia, China and Brazil over the period 1970-2012 by using an ARDL bounds test approach. They found that CO2 emission have increased with increases income and energy consumption in all four countries. Besides, by testing the environmental Kuznets curve (EKC) hypothesis they demonstrate that CO2 emissions will decrease over the time when income increases. Jebli et al. (2016) investigated the causal relationships between per capita CO2 emissions, gross domestic product (GDP), renewable and non-renewable energy consumption, and international trade for a panel of 25 OECD countries over the period 19802010. Their main results show that increasing non-renewable energy increases CO2 emissions and increasing trade or renewable energy reduces CO2 emissions. By using panel OLS, difference GMM and Granger causality within LA-VAR framework, Ito et al. (2016) they examined the relationship between CO2 emissions, renewable and non-renewable energy consumption, and economic growth for a panel of 31 developed countries over the period 1996-2011. Their results indicate that renewable energy consumption contributes to the reductions in CO2 emissions.

Otherwise, Zhang and Cheng (2014) analyzed international oil price's impact on carbon emissions in China's transportation industry by using the partial least squares regression model. Results show that with the same GDP growth, the industry carbon emissions increase with the rise in international oil prices, and vice versa, the industry carbon emissions decrease. By using a quantile regression framework, Hammoudeh et al. (2014) investigate the impact of changes in crude oil prices, natural gas prices, coal prices, and electricity prices on the distribution of the CO2 emission allowance prices in the United States. Their findings indicate that higher oil prices are effective in reducing energy consumption and arresting its associated fossil pollution when the carbon market is tight. Balaguer et al. (2014) estimated an environmental Kuznets curve dynamic structure for Spain over the period 1874-2011. Their results indicate that the rise in real oil prices decrease CO2 emissions. Chai et al. (2016) studied the impact international oil price on energy conservation and emission reduction in China by using the Structural Vector Autoregression model (SVAR). Results show that, in the short term, the indirect influence of international oil price on energy consumption in China is relatively significant.

However, Henriques and Sadorsky (2008) investigated the empirical relationship between alternative energy stock prices, technology stock prices, oil prices, and interest rates. They estimated a four variable vector autoregression model and they found that technology stock prices and oil prices each individually Granger cause the stock prices of alternative energy companies. Besides, their results show that a shock to technology stock prices has a larger impact on alternative energy stock prices than does a shock to oil prices .Sadorsky (2009) estimated an empirical model of renewable energy consumption for the G7 countries. Results indicate a positive and statistically significant relationship between real GDP per capita, CO2 per capita and renewable energy consumption. However, Oil price increases have negative impact on renewable energy consumption.Kumar et al. (2012) used a weekly five-variable VAR to study the relationships between clean energy stock prices, the stock prices of technology companies, oil and carbon prices. They found a positive relationship between the three indices of clean energy stocks and oil prices, stock prices of high technology firms and interest rates. By applying Markov-switching vector autoregressive models, Managi and Okimoto (2013) analyzed the relationship among oil prices, clean energy stock price and technology stock price. Their findings indicate a positive relationship between oil prices and clean energy price after structural breaks.

To the best of our acknowledge, the causal relationship between oil prices, renewable energy, CO2 emissions and economic growth for the OECD countries has not been previously studied. Thus, to fill this gap, we propose to verify the Environmental Kuznets Curve (EKC) hypothesis for OECD countries in addition to evaluating the casual direction between all variables. Moreover, our paper differs from existing studies in that we use the crude oil import prices which are influenced not only by traditional movements of supply and demand, but also by other factors such as geopolitics.

The rest of the paper is structured as follows. Section 2 presents the data and the model specification. Section 3 shows the model estimation and results and section 4 concludes.

2 Data and model specification

In this study, we use a balanced annual data of 676 observation for 26 countries from OECD. The period of the study spans from 1990 to 2015. All variables are collected from the U.S. Energy Information Administration, the Penn World Table (Feenstra et al. (2015)), the OECD database (OECD (2017)) and World Bank Development Indicators (WDI) database. The 26 OECD countries used in the sample include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, South Korea, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States .

The variables used in this study are per capital CO2 emissions in metric tons of carbon dioxide per person is measured from the consumption and flaring of fossil fuels which is the dependent variable for our model. The explicative variables include Renewable energy consumption (net geothermal, solar, wind and biomass energy) measured in millions of kilo watt hours (MkWh), crude oil import prices measured in U.S dollars per barrel of oil and real GDP per capita measured in millions of constant 2010 U.S dollars.

To find the relationship between oil prices, renewable energy CO2 emissions and economic growth for the panel of OECD countries we estimate the following model which describes the Environmental Kuznets Curve (EKC):

$$lnCO2_{it} = \alpha_i + \beta_1 lny_{it} + \beta_2 ln^2 y_{it} + \beta_3 lnmop_{it} + \beta_4 lnre_{it} + \varepsilon_{it} \quad (1)$$

Where $lnCO2_t$ refers to the CO2 emissions, $lny_t, lny2_{it}$, $lnmop_t$ and $lnre_t$ donate the economic growth, oil prices and renewable energy. The $(\beta_1, ..., \beta_4)$ represent the output elasticities of economic growth, oil prices and renewable energy. α_i is the country fixed effects and ε_{it} is the error term.

The econometric approach is based on three steps. In the first one, the stationarity of each variable is examined by performing three unit roots tests, namely, Levin et al. (2002) , Im et al. (2003), and Maddala and Wu (1999), these three tests incorporate both cross-sectional independence (LLC, IPS and Maddala and Wu tests) and cross sectional dependence cases. In the second one, if the variables are found to contain a unit root, we checked the cointegrating relationships between the variables are determined. In the third one, we apply both the fully modified OLS (FMOLS) and dynamic OLS (DOLS) methods for cointegrated panel data to estimate our model.

3 Model estimation and results

3.1 Panel unit root tests

Results of panel unit root tests are reported in Table 1. From this table it can be noted that the null hypothesis of the unit root cannot be rejected at the 1% level of significance for all panel time series taken in level. However, by testing for the unit root in the first difference, all panel unit root tests reject the null hypothesis at the 1% level of significance.

Table 1: Panel unit root test in level

Variables	LLC		IPS		ADF-Fisher		PP-Fisher	
	statistic	prob	statistic	prob	statistic	prob	statistic	prob
lnco2	0.49429	0.6895	2.36309	0.9909	42.7846	0.8151	36.2815	0.9520
dlnco2	-17.8198	0.0000***	-17.7735	0.0000***	369.628	0.0000***	482.878	0.0000***
lnmop	-0.16726	0.4336	2.64816	0.9960	17.7674	1.0000	17.0130	1.0000
dlnmop	-10.3092	0.0000***	-11.2202	0.0000***	232.455	0.0000***	213.083	0.0000***
lny	-4.87713	0.0000***	1.15176	0.8753	45.4076	0.7290	62.7758	0.1455
dlny	-12.6481	0.0000***	-12.7378	0.0000***	254.118	0.0000***	267.858	0.0000***
lny2	-4.67814	0.0000	0.64051	0.7391	55.0330	0.3606	87.8213	0.0014
dly2	-12.9054	0.0000***	-13.0636	0.0000***	261.118	0.0000***	273.307	0.0000***
lnre	6.12638	1.0000	8.52684	1.0000	16.7383	1.0000	18.0776	1.0000
dlnre	-22.9057	0.0000***	-21.5245	0.0000***	457.227	0.0000***	474.084	0.0000***

Notes: ***, **, * indicate statistical significance at 1, 5 and 10 percent level of significance, respectively.

3.2 Panel cointegration test

The panel unit root tests confirm that all variables are integrated in order I(1), then we test for evidence of a long-run relationship. The Pedroni's panel cointegration test (Pedroni (2004)) is used to test the null hypothesis of the nonexistence of cointegration against the alternative of cointegration. The results reported in Table 2 provide strong evidence for panel cointegration among the variables.

Table 2: Pedroni panel cointegration test

	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	3.013089	0.0013**	1.080570	0.1399
Panel rho-Statistic	−0.750379	0.2265	−0.833733	0.2022
Panel PP-Statistic	−7.724730	0.0000 * **	−6.963741	0.0000 * **
Panel ADF-Statistic	−8.293983	0.0000 * **	−7.708108	0.0000 * **
	Statistic	Prob.		
Group rho-Statistic	1.174119	0.8798		
Group PP-Statistic	−7.445501	0.0000 * **		
Group ADF-Statistic	−8.610890	0.0000 * **		

Notes: ***, **, * indicate statistical significance at 1, 5 and 10 percent level of significance, respectively.

3.3 Panel FMOLS, DOLS estimates and causality tests

Given the evidence of panel cointegration among variables, we perform both, the Fully modified OLS (FMOLS) and the dynamic OLS (DOLS) techniques. The results of the FMOLS and DOLS estimations are reported in Table 3.

Table 3: Parameter estimation using FMOLS and DOLS, 2000-2015.

Variables	FMOLS		DOLS	
	Coefficient	Prob.	Coefficient	Prob.
lny	2.758338	0.0000 * **	3.058842	0.0022 * *
lny2	−0.253060	0.0000 * **	−0.281451	0.0128 * *
lnmop	−0.051174	0.0000 * **	−0.061757	0.0000 * **
lnre	−0.175736	0.0000 * **	−0.196793	0.0000 * **
R^2	0.971424		0.988281	
Adj.R^2	0.969821		0.977601	

Notes: ***, **, * indicate statistical significance at 1, 5 and 10 percent level of significance, respectively.

All the coefficients are significant at the 1% and 5% significance level and they can be interpreted as elasticity estimates. The results indicate that a 1% increase in economic growth increases CO2 emissions by 275%. This means that economic growth simulate carbon dioxide emissions in the long-run. The CO2 emissions increases in OECD countries as the production of goods and services grow which requires energy, historically fueled by fossil fuels. Results show also that there are inverse U-shaped relationships between CO2 emissions and real GDP per capita for the EKC model in the long-run.

Contrary to the effect of economic growth, oil prices decreases CO2 emissions in OECD countries. Findings show that an increase in 1% in oil prices decreases CO2 emissions by 5%. Its well known that oil is the second most polluting fuel just behind coal and in light of the fact that OECD countries are quite dependent on oil, any increases in oil prices may lead to a reduction in carbon dioxide emission. Besides oil prices, renewable energy is associated negatively and significantly at 1% with the dependent variable. Specifically, an increase of 1 percent of renewable energy decreases CO2 emissions by 17%. Indeed, most of OECD countries by supporting investments in more efficient and cleaner energies, they accelerated their renewable roll-out and have set voluntary targets for the reduction of CO2 emissions by 20% in 2020 Marchal et al. (2011).

To determinate the causal relationship between the variables, we estimate a panel vector error correction model and the Engle and Granger (1987) two-step procedure is used. In the first step we estimate the long-run model specified in (FMOLS). In the second step we get the first lag residuals from (FMOLS) witch is used as the error correction terms. We performed The Arellano and Bover (1995) and Blundell and Bond (1998) system GMM for each equation above :

$$\Delta lnco2_{it} = \theta_{1j} + \sum_{k}^{q} \theta_{11ik} \Delta lnco2_{it-k} + \sum_{k}^{q} \theta_{12ik} \Delta lny_{it-k} + \sum_{k}^{q} \theta_{13ik} \Delta lny2_{it-k} + \sum_{k}^{q} \theta_{14ik} \Delta lnmop_{it-k} + \sum_{k}^{q} \theta_{14ik} \Delta lnre_{it-k} + \lambda_{1i} \varepsilon_{it-1} + \mu_{1it} \tag{3}$$

$$\Delta lny_{it} = \theta_{1j} + \sum_{k}^{q} \theta_{11ik} \Delta lnco2_{it-k} + \sum_{k}^{q} \theta_{12ik} \Delta lny_{it-k} + \sum_{k}^{q} \theta_{13ik} \Delta lny2_{it-k} + \sum_{k}^{q} \theta_{14ik} \Delta lnmop_{it-k} + \sum_{k}^{q} \theta_{14ik} \Delta lnre_{it-k} + \lambda_{1i} \varepsilon_{it-1} + \mu_{1it} \tag{4}$$

$$\Delta lny2_{it} = \theta_{1j} + \sum_{k}^{q} \theta_{11ik} \Delta lnco2_{it-k} + \sum_{k}^{q} \theta_{12ik} \Delta lny_{it-k} + \sum_{k}^{q} \theta_{13ik} \Delta lny2_{it-k} + \sum_{k}^{q} \theta_{14ik} \Delta lnmop_{it-k} + \sum_{k}^{q} \theta_{14ik} \Delta lnre_{it-k} + \lambda_{1i} \varepsilon_{it-1} + \mu_{1it} \tag{5}$$

$$\Delta lnmop_{it} = \theta_{1j} + \sum_{k}^{q} \theta_{11ik} \Delta lnco2_{it-k} + \sum_{k}^{q} \theta_{12ik} \Delta lny_{it-k} + \sum_{k}^{q} \theta_{13ik} \Delta lny2_{it-k} + \sum_{k}^{q} \theta_{14ik} \Delta lmop_{it-k} + \sum_{k}^{q} \theta_{14ik} \Delta lnre_{it-k} + \lambda_{1i} \varepsilon_{it-1} + \mu_{1it} \tag{6}$$

$$\Delta lnre_{it} = \theta_{1j} + \sum_{k}^{q} \theta_{11ik} \Delta lnco2_{it-k} + \sum_{k}^{q} \theta_{12ik} \Delta lny_{it-k} + \sum_{k}^{q} \theta_{13ik} \Delta lny2_{it-k} + \sum_{k}^{q} \theta_{14ik} \Delta lmop_{it-k} + \sum_{k}^{q} \theta_{14ik} \Delta lnre_{it-k} + \lambda_{1i} \varepsilon_{it-1} + \mu_{1it} \tag{7}$$

Where Δ is the first-difference operator; θ are the short-run parameters; q is the lag length which is determined by the Schwarz Information Criterion (SIC); ε_{it-1} is the lagged error term obtained from the long-run estimation; λ represent the adjustment coefficient toward the long run equilibrium and μ the serially uncorrelated error term. According to equation 3-7, short-run causality is determined by examining the statistical significance of the lagged variables using the Wald F-statistic test. Long-run causality is determined by the statistical significance of the respective error correction terms using a t-test.

Short-run and long-run Granger-causality tests results are summarized in Table 4

Table 4: Panel Granger causality results

Dependent variable	Source of causation (Independent variables)					
	Short run				Long run	
	$\Delta lnco2$	Δlny	$\Delta lny2$	$\Delta lnmop$	$\Delta lnre$	ECT t-statistics
$\Delta lnco2$	-	-3.124099	.3548058	-.0366774 **	0239506	-.4987586 ***
Δlny	.0334423	-	.3769345 ***	-.0454542 ***	.0080065	-.0356273*
$\Delta lny2$	.3489901	-26.86002 ***	-	-.4201054 ***	.0627804	-.484179
$\Delta lnmop$	.4257035 ***	-12.94981 ***	1.61928 ***	-	.4565847***	-.4537701 ***
$\Delta lnre$	-.0544209	-.5710145	.0611352	-.0113473	-	.2868916

Notes: ***, **, * indicate statistical significance at 1, 5 and 10 percent level of significance, respectively.

With respect to equation (3), the short run causality shows that only oil prices has a negative and statistically significant impact on CO2 emissions. In terms of equation (4), it appears oil prices has a negative and statistically significant impact on economic growth. With regard to equation (6), CO2 emissions and renewable energy have a positive and statistically significant impact on oil prices. Otherwise, real GDP per capita has a negative and statistically significant impact on oil prices. Nevertheless, coefficients in equation (7) are not significant.Furthermore, the error correction terms of equation (3), (4) and (6) are statistically significant at the 1 and 10 percent level.In order to test both short-run and long-run relationships we apply the joint Wald F-test reported in Table 5 witch reject the null of zero coefficient and short-run and long-run causality have significant impact to CO2 emissions.

Table 5: Wald joint test

Variables		
LD.lco2	LD.lco2	-
LD.lny	LD.lny	-
LD.lny2	LD.ly2	-
LD.lnmop	LD.lnmop	-
LD.lnre	LD.lnre	-
L.ECT	-	L.ECT
chi2(6) = 58.62***	chi2(5) = 43.66***	chi2(1) = 7.71***

Notes: ***, **, * indicate statistical significance at 1, 5 and 10 percent level of significance, respectively.

In summary,the short-run and long-run Granger-causality tests reveal a negative relation between oil prices and CO2 emissions. We can conclude that an increase of oil prices decreases CO2 emissions in the short and the long run.

4 Conclusion

This paper explores the casual relationship between oil prices, renewable energy, CO2 emissions and economic growth for the OECD countries over the period 1990-2015. Results from FMOLS and DOLS estimates show that oil prices has a negative and significant long-run effect on CO2 emissions. Findings indicate also a negative and significant relationship between renewable energy and CO2 emissions in the long-run. Otherwise, results show that the positive sign with income and negative sign with the quadratic term of income confirms the existence of EKC for OECD countries. The results of Granger's causality test reveal the presence of both short-run and long-run bidirectional causality between oil prices and CO2 emissions.

The findings of this study assert that oil prices decreases CO2 emissions in the long-run. Thus, productions of goods and services in OECD countries still dependent on oil energy use. In 2015, across the OECD countries, oil was responsible for the largest share of CO2 emissions from fuel combustion (40%) of the total primary energy supply(IEA (2016)). Hence, low oil prices are effective in expanding fossil fuel energy consumption and heighten pollution. Moreover, results report that renewable energy reduces CO2 emissions in the long-term. Therefore, the expansion of renewable energy would also diminish the dependence on fossil fuels energy and decreases its associated pollution. However, an inverted-U shape relationship between CO2 emissions and income was found in short and long-run. Thus, our results support the EKC hypothesis for the OECD countries.

This paper have some relevant policy implications.To mitigate pollution, developed and developing countries have to decrease energy intensity, increase energy efficiency and renewable energy use. Governments need to promote renewable energy generation and support investments in more efficient and cleaner energies.

References

Alam, M. M., Murad, M. W., Noman, A. H. M. and Ozturk, I. (2016), 'Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing environmental kuznets curve hypothesis for brazil, china, india and indonesia', *Ecological Indicators* **70**, 466–479.

Antonakakis, N., Chatziantoniou, I. and Filis, G. (2017), 'Energy consumption, co 2 emissions, and economic growth: an ethical dilemma', *Renewable and Sustainable Energy Reviews* **68**, 808–824.

Arellano, M. and Bover, O. (1995), 'Another look at the instrumental variable estimation of error-components models', *Journal of econometrics* **68**(1), 29–51.

Balaguer, J., Cantavella-Jordá, M. et al. (2014), The effect of economic growth and oil price variations on co2 emissions: Evidence from spain (1874-2011), Technical report.

Blundell, R. and Bond, S. (1998), 'Initial conditions and moment restrictions in dynamic panel data models', *Journal of econometrics* **87**(1), 115–143.

Chai, J., Zhou, Y., Liang, T., Xing, L. and Lai, K. K. (2016), 'Impact of international oil price on energy conservation and emission reduction in china', *Sustainability* **8**(6), 508.

Engle, R. F. and Granger, C. W. (1987), 'Co-integration and error correction: representation, estimation, and testing', *Econometrica: journal of the Econometric Society* pp. 251–276.

Factbook, O. (2015), 'Economic, environmental and social statistics, foreign direct investment'.

Feenstra, R. C., Inklaar, R. and Timmer, M. P. (2015), 'The next generation of the penn world table', *The American Economic Review* **105**(10), 3150–3182.

Hammoudeh, S., Nguyen, D. K. and Sousa, R. M. (2014), 'Energy prices and co 2 emission allowance prices: a quantile regression approach', *Energy Policy* **70**, 201–206.

Henriques, I. and Sadorsky, P. (2008), 'Oil prices and the stock prices of alternative energy companies', *Energy Economics* **30**(3), 998–1010.

IEA (2016), *Key world energy statistics*, International Energy Agency.

Im, K. S., Pesaran, M. H. and Shin, Y. (2003), 'Testing for unit roots in heterogeneous panels', *Journal of econometrics* **115**(1), 53–74.

Ito, K. et al. (2016), 'Co2 emissions, renewable and non-renewable energy consumption, and economic growth: evidence from panel data for developed countries', *Economics Bulletin* **36**(1), 553–559.

Jebli, M. B., Youssef, S. B. and Ozturk, I. (2016), 'Testing environmental kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in oecd countries', *Ecological Indicators* **60**, 824–831.

Kumar, S., Managi, S. and Matsuda, A. (2012), 'Stock prices of clean energy firms, oil and carbon markets: A vector autoregressive analysis', *Energy Economics* **34**(1), 215–226.

Levin, A., Lin, C.-F. and Chu, C.-S. J. (2002), 'Unit root tests in panel data: asymptotic and finite-sample properties', *Journal of econometrics* **108**(1), 1–24.

Maddala, G. S. and Wu, S. (1999), 'A comparative study of unit root tests with panel data and a new simple test', *Oxford Bulletin of Economics and statistics* **61**(S1), 631–652.

Managi, S. and Okimoto, T. (2013), 'Does the price of oil interact with clean energy prices in the stock market?', *Japan and the World Economy* **27**, 1–9.

Marchal, V., Dellink, R., Van Vuuren, D., Clapp, C., Chateau, J., Magné, B. and van Vliet, J. (2011), 'Oecd environmental outlook to 2050', *Organization for Economic Co-operation and Development* .

OECD (2017), 'Crude oil import prices', *OECD data* .

Pedroni, P. (2004), 'Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the ppp hypothesis', *Econometric theory* **20**(03), 597–625.

Sadorsky, P. (2009), 'Renewable energy consumption, co 2 emissions and oil prices in the g7 countries', *Energy Economics* **31**(3), 456–462.

Zhang, G. and Cheng, S. (2014), 'International oil price's impacts on carbon emission in china's transportation industry', *Journal of Industrial Engineering and Management* **7**(4), 749.