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DO ENVIRONMENTAL AND ECONOMIC FACTORS MATTER FOR INNOVATION? EVIDENCE FROM OIL-IMPORTING AND OIL-EXPORTING COUNTRIES

Mervan SELÇUK[1], Şakir GÖRMÜŞ[2], Murat GÜVEN[3]

Abstract

The purpose of this paper is to investigate the effect of GDP, trade openness, renewable energy, energy use, FDI, carbon emission, and oil prices on innovation for selected 11 oil-importing and 11 oil-exporting countries and to compare the results from both country groups to see the differences and similarities. For this purpose, we employ Poisson regression and negative binomial fixed effect techniques from 1990 to 2018. The empirical findings illustrate that all variables are significant except for renewable energy in oil-exporting countries. Trade openness and carbon emission have a significant and negative association with innovation, GDP, energy use, foreign direct investment, and oil price have a significant and positive relationship with innovation in oil-exporting countries.

Keywords: *Renewable Energy, Carbon Emissions, Economic Growth, Innovation, Oil-Importing Countries, Oil-Exporting Countries*
JEL Classification: *C23, F18, N50, R11*

İNOVASYON İÇİN ÇEVRESEL VE EKONOMİK FAKTÖRLER ÖNEMLİ MİDİR? PETROL İTHAL EDEN VE PETROL İHRAÇ EDEN ÜLKELER ÖRNEĞİ

Öz

Bu çalışmanın amacı, seçilmiş 11 petrol ithal eden ve 11 petrol ihraç eden ülkeler için GDP, ticari açıklık, yenilenebilir enerji, enerji tüketimi, doğrudan yabancı yatırımı, karbon emisyonu ve petrol fiyatlarının inovasyon üzerindeki etkisi 1990 ve 2018 yılları arasında sabit etkili negatif binom regresyonu ve poisson regresyonu aracılığıyla araştırmaktır. Elde edilen sonuçlara göre petrol ihraç eden ülkelerde yenilenebilir enerji dışındaki tüm değişkenlerin anlamlı olduğu görülmektedir. Petrol ihraç eden ülkelerde ise ticari açıklık ve karbon emisyonunun inovasyonla olan ilişkisi anlamlı ve negatifken, GDP, enerji tüketimi, doğrudan yabancı yatırımı ve petrol fiyatı inovasyonla anlamlı ve pozitif bir ilişkiye sahiptir.

Anahtar Kelimeler: *Yenilenebilir Enerji, Karbon Emisyonları, Ekonomik Büyüme, İnovasyon, Petrol İthal Eden Ülkeler, Petrol İhraç Eden Ülkeler*
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[1]*Asst. Prof, Sakarya University, Faculty of Political Sciences, Department of Islamic Economics and Finance, mervanselcuk@sakarya.edu.tr, ORCID: 0000-0001-8384-373X*
[2]*Prof, Sakarya University, Faculty of Political Sciences, Department of Public Finance, sgormus@sakarya.edu.tr, ORCID: 0000-0002-1857-8682*
[3]*Asst. Prof, Sakarya University, Faculty of Arts and Sciences, Department of Statistics, muratguven@sakarya.edu.tr, ORCID: 0000-0001-5604-4369*

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1. Introduction

The development of technology has facilitated human life in many areas such as transportation, manufacturing, health, and education. Innovation has an outstanding contribution to the growth of economies by increasing production capacity and productivity. In this respect, it can be said that innovation is among the most important engines of economic growth. The concept of innovation can be defined in many ways, such as the. The number of patents, the development of intellectual property rights, the budget allocated for research and development, and the number of universities and research centers (de Rassenfosse & van Pottelsberghe de la Potterie, 2009).

Oil and natural gas resources are the national assets of countries that should use for their economic development. On the other hand, under certain circumstances, they cause some problems for economic development. In an oil-dependent country, the variability of the oil revenues will lead to a spill-over effect on the real exchange rate. When oil prices increase, that will cause a real appreciation and a decrease in non-oil exports. This situation is known as the main indication of the Dutch disease (Mehrara & Oskoui, 2007). It was named “Dutch” in the literature to the decrease in manufacturing and increase in unemployment in the Netherlands after the 1970s the North Sea oil and gas reserves discovery (Ismail, 2010). Also known as a resource curse, it is the phenomenon of countries with an abundance of natural resources that have less economic growth or development outcomes than countries with fewer natural resources (Namazi & Mohammadi, 2018). This means that these countries are coming up against different economic outcomes. However, some natural resource-rich countries have appreciated the abundance of resources and refrained from the resource curse. The US economy can be a good example that is a significant positive relationship between rapid economic growth and natural resources (Wang et al., 2021).

The resource curse has a negative effect on innovation performance as increasing local currency causes cheap imports and high production costs, both of which severely slow the development of innovation in the country (Corden & Neary, 1982). This also leads to permanent economic barriers and deters entrepreneurship as people easily earn income from natural resources advantages than engaging businesses such as manufacturing and innovation that comprise more risk (Sachs & Warner, 2001). Countries that do not have oil reserves must produce and export high-tech products which need innovation since there is high competition in the international market except for oil and arms. Because of high oil income, oil-exporting countries (OEX) do not depend highly on the export of high-tech products (Ovadia, 2014). Therefore, an increase in trade openness negatively affects to innovation in oil-exporting countries while positively affects to innovation in oil-importing countries (OIM). The abundance of natural resources may also inhibit diversified economic growth by crowding out innovation or entrepreneurship. On the other hand, new technological opportunities drive innovation in local industries (Pietrobelli et al., 2018).

Increasing the environmental degradation through the carbon emissions forces the government to take action about these problems. Environmental innovation (also known as green technology or ecological innovation) means diverse forms of technological activities that provide the development of environmental protection. Implementing these green technologies may hinder or significantly diminish the adverse effects of environmental degradation (Razzaq et al., 2021). Innovation not only has a positive impact on economic growth but also leads to cost minimization and mitigates energy consumption (Erdoğan et al., 2020) . International trade and trade openness has been regarded as other crucial factors that express CO_2 emissions (Liu et al., 2018). Although international trade benefits economic activities, it has severe side effects on the environment (Khan et al., 2020). The Porter hypothesis refers that more stringent and properly designed environmental measures can provide innovation and competitiveness, hence making regulation a significant effect on the direction of innovation (Porter & Linde, 1995).

The aim of this paper is to investigate the effect of GDP, trade openness, renewable energy, energy consumption, foreign direct investment, carbon emission, and oil prices on innovation for selected 11 oil-importing and 11 oil-exporting countries using panel count data techniques in the period of 1990-2018. In addition, the effect of the selected variables on innovation in OIM is compared with the effect in OEX. Here, we investigate the literature and the studies done so far in the second part. Data and methodology are given in the third part. The findings are presented in the fourth part. Discussion and conclusion are mentioned in the last parts of the study, respectively.

2. Literature Review

Innovation and trade openness have a crucial role for sustainable economic growth (Pradhan et al., 2016; Romer, 1986). Several papers argue that financial development and trade openness spur innovation (Belazreg & Mtar, 2020; Hsu et al., 2014; Rivera-Batiz & Romer, 1991). Previous studies use economic, social, and institutional factors as determinants of innovation for both a single country and a group of the country such as OECD, G7, ASIAN and Developed Countries (Chen & Lee, 2020; Guloglu et al., 2012; Kirikkaleli et al., 2018). One of the shortcomings of previous studies neglects to investigate the effect of environmental factors on innovation. The rapid growth of economies leads to many problems, especially environmental pollution, such as the increase of CO_2, greenhouse gases and climate change. To decrease environmental pollution, governments encourage innovation.

In addition to the classification between developed and developing economies, several papers have begun to differentiate countries into OIM OEX due to their different economic structures (de Jesus et al., 2020; Mokni, 2020; Wen et al., 2020). Therefore, it can be assumed that the effect of macro-economic and environmental variables on innovation may have different on both country groups.

The relationship between innovation and macro-economic variables as well as environmental variables is controversial. In the existing literature, several studies investigate the effect of macroeconomic variables on innovation. Ghimire and Paudel (2019) investigate the impact of R&D, FDI, and GDP on innovation using the GMM method for OECD countries in the period of 1996-2015. The innovation in this study is evaluated with the number of the patent application by resident and non-resident. The empirical result shows that FDI is significant and positively associated with patent applications by the resident but negatively associated with patent applications by the non-resident. In addition, GDP has a negative and significant association with the number of patent application only by non-resident.

Guloglu et al. (2012) investigate the association between technological development and some macroeconomic variables for G7 countries using Poisson regression and negative binomial models in the period of 1991-2009. They find that hi-tech exports and FDI accelerate technological improvement. On the other hand, there is no significant association between trade openness and innovation. Song et al. (2020) examine the relationship between eco-innovation and export-oriented economic development (trade openness), employing the GMM model for 30 provinces in China between 2009 and 2017. The findings show that trade openness has significant and negative effects on eco-innovation. Guillouzouic-Le Corff (2018) examine that how biofuels innovation has been affected by oil prices for 22 OECD countries using Poisson regression and GMM models in the period of 1985-2009. The empirical results demonstrate that increases in oil prices significantly boosted patent applications in biofuels.

Although most studies examine the impact of innovation on environmental variables (Ahmed et al., 2016; Awaworyi Churchill et al., 2019; Cheng et al., 2019; Fei et al., 2014; Gu & Wang, 2018; Riti et al., 2017; Su & Moaniba, 2017), as our best knowledge there is no study analysing the effect of environmental variables on innovation. As energy consumption and CO_2 increase, governments will make more investments on innovation to reduce environmental pollution and increase energy efficiency.

Su and Moaniba (2017) investigate the association between climate change innovation and sub-CO_2 emissions (solid, gas and liquid) employing various econometric methods (GMM, negative binomial random and fixed effect models) for 70 countries in the period of 1976-2014. The empirical findings show that climate change innovation is significant and positively (negatively) affected by CO_2 emissions from gas and solid fuel (carbon emission from liquid fuel). In addition, GDP has a positive and significant impact on climate change innovation.

Zhang et al. (2017) study the impact of environmentally friendly innovation on CO_2 for the provinces of China in between 2000 and 2013 by using the SGMM model. Empirical Findings demonstrate that different variation of innovation indicators reduce CO_2 emissions in Chinese provinces. Johnstone et al. (2010) investigate the effect of different sources of electricity consumption (wind, solar and geothermal) and electricity price on innovation employing the negative binomial fixed effects models for 25 countries in the period of 1978-2003. The results show that electricity consumption and electricity price do not affect innovation, whereas electricity price has a significant and positive impact on solar energy innovation.

Belazreg & Mtar (2020) investigate the causal relationship between trade openness, innovation, financial development, and economic growth in 27 OECD countries in the period of 2001-2016 employing a panel VAR model. The empirical findings show that there is no causal relationship between innovation and trade.

Nunes & Catalão-Lopes (2020) examine the effect of oil price on innovation in the period of 2000-2018 employing negative binomial regression for the 10 most innovative countries regarding alternative energy technologies. The empirical findings indicate that the effect of oil prices on patent applications for renewable energies is asymmetric. When prices are decreasing the reduction in innovation is more reported than the development when prices are increasing. The findings may demonstrate that there is a less commitment to discover sustainable alternatives sources to the use of fossil energies.

To the best knowledge of the authors, there is no study in the literature comparing any country groups to test whether the effect of explanatory variables on innovation in different country groups are similar or not. Different country groups may have different economic structures. Therefore, the sign and severity of explanatory variables on innovation can be different. Thus, the main contribution to the literature is threefold. First, in addition to macro-economic variables, we use environment variables such as carbon emissions, energy consumption and renewable energy to analyse the effect on innovation. Second, we analyse the effect of explanatory variables on innovation, whether it is similar or not in OEX and OIM. Third, we employ poisson regression and negative binomial fixed effect techniques to obtain robust results.

3. Data and Econometric Methods

3.1. Data

World Bank's 2020, World Development Indicators (WDI) are used to obtain the data except for oil prices. This dataset covers 11 OIM and 11 OEX in the period of 1990-2018. We use this period and countries according to the availability of the data. There is a close relationship between innovation, macro-economic, and environmental variables.

In our study, we select innovation as a dependent variable and define innovation as the number of resident patent applications. As independent variables, we use GDP, trade openness, FDI, and crude oil prices in the context of macro-economic variables. At the same time, energy use, renewable energy and CO_2 are used in the context of environmental variables. Table 1 illustrates all these variables and sources.

Table 1: **Variables and Sources**

Variable	Description	Source
Innovation	Number of resident patent applications	WDI
Openness	Trade openness (as the total of exports and imports divide GDP)	WDI
GDP	Per capita (constant 2010 US$)	WDI
Energy	Energy use (kg of oil equivalent per capita)	WDI
Renergy	Renewable energy (% of total final energy use)	WDI
FDI	Foreign direct investment (net inflows, US$)	WDI
CO_2	CO_2 emissions (metric tons per capita)	WDI
Oil	Crude oil prices (Brent – Europe)	U.S. Energy Information Administration

We determine OIM and OEX depending on the percentage of oil export and import in merchandise imports and exports as can be seen Table 2.

Table 2: **Innovation and Oil Trade in OIM and OEX**

Oil Importing Country			**Oil import % of merchandise**	**Oil Exporting Country**			**Oil export % of merchandise**
Country	**Rank**	**Score**	**Imports**	**Country**	**Rank**	**Score**	**Exports**
Netherlands	4	61.44	15	USA	3	61.73	14
Finland	6	59.83	14	Canada	17	53.88	25
South Korea	11	56.55	27	Norway	19	51.87	62
Japan	15	54.68	23	Australia	22	50.34	24
New Zealand	25	49.55	12	Malaysia	35	42.68	15
Spain	29	47.85	15	Russia	46	37.62	52
Italy	30	46.3	14	Saudi Arabia	68	32.93	77
Greece	41	38.9	29	Kazakhstan	79	31.03	70
Ukraine	47	37.4	23	Azerbaijan	84	30.21	92
India	52	36.58	35	Indonesia	85	29.72	23
South Africa	63	34.04	19	Egypt	92	27.47	26

Source: Dutta et al. (2019) and The World Bank (2021)

India and New Zealand have the highest and the lowest rate of the percentage of oil imports with %35 and %12, respectively. Azerbaijan and USA have the highest and the lowest rate of the percentage of oil export with %92 and %14, respectively. With respect to this classification, Australia, Azerbaijan, Canada, Egypt, Indonesia, Kazakhstan, Malaysia, Norway, Russia, Saudi, and United States are considered oil-exporting countries.

However, Greece, India, Italy, Japan, Finland, South Korea, New Zealand, South Africa, Spain, Ukraine, and Netherlands are oil-importing Countries. Table 2 shows that OIM and OEX innovation and oil trade scores. Table 3 indicates the descriptive statistics for OIM and OEX.

Table 3: **Descriptive Statistics of Oil-Exporting Countries**

	Innovation	**Openness**	**GDP**	**Energy**	**Renergy**	**FDI**	**CO_2**	**Oil**
Mean	20929.11	70.56	24393.43	4155.18	4.63	3.05E+10	10.41	48.69
Median	1150	64.97	10867.70	4540.91	.30	6.40E+09	10.89	38.28
Maximum	295327	220.41	92119.50	8455.55	1.38	5.10E+11	24.40	111.96
Minimum	16	19.79	1235	540.66	.01	-2.50E+10	0.82	12.72
Std. Dev.	59355.88	39.50	25326.96	2491.71	18.71	7.20E+10	6.15	32.42
Obser.	319	319	319	319	319	319	319	29
Countries	11	11	11	11	11	11	11	11

Table 3 (Contnued): **Descriptive Statistics of Oil-Importing Countries**

	Innovation	Openness	GDP	Energy	Renergy	FDI	CO_2	Oil
Mean	40693.65	62.10	25287.14	3383.72	14.92	1.98E+10	7.87	48.69
Median	2348	56.14	28091.40	3086.21	8.26	4.90E+09	8.17	38.28
Maximum	384201	157.82	55021	7134.85	58.65	7.30E+11	13.17	111.96
Minimum	138	15.510	575.50	350.08	0.44	-2.40E+11	0.71	12.72
Std. Dev.	95461.64	28.99	16080.13	1488.94	14.90	6.35E+10	2.71	32.42
Obser.	319	319	319	319	319	319	319	29
Countries	11	11	11	11	11	11	11	11

The mean value of innovation, GDP and renewable energy are greater in OIM than OEX. However, the mean value of trade openness, energy use, FDI and CO_2 are greater in OEX than OIM. In addition, the mean value of oil price is the same since it is cross-sectionally invariant variable.

3.2. Econometric Methods

In this study, the relationship between Innovation, Openness, GDP, Renergy, Energy, FDI, CO_2, and Oil for oil-exporting and oil-importing countries can be modeled within the panel framework (Baltagi, 2013) as follows:

$$\mathrm{Innovation}_{it} = \beta_{i0} + \beta_{i1}\mathrm{Openness}_{it} + \beta_{i2}\mathrm{GDP}_{it} + \beta_{i3}\mathrm{Energy}_{it} + \beta_{i3}\mathrm{FDI}_{it} + \beta_{i4}\mathrm{CO2}_{it} + \beta_{i5}\mathrm{Oil}_{it} + \beta_{i6}\mathrm{Renergy}_{it} + \varepsilon_{it} \quad (1)$$

Where t =1990, 1991 … 2018 and i= 1, 2, …11

In this model, the subscript i and the subscript t represent the individual (country) and time. β_{i0} and ε_{it} denote intercept and disturbance. Lastly, β_{1i}, β_{2i}, β_{3i}, β_{4i}, β_{5i} and β_{6i} are coefficients of the independent variables, respectively.

3.2.1. Cross-Section Dependence

We employ Pesaran et al. (2008)'s bias-adjusted LM test to investigate the absence of cross-section dependence among the Oil-Importing Countries and Oil-Exporting Countries. This bias-adjusted LM test, in panel data models with strictly exogenous regressors and normal errors, is the bias adjusted version of Breusch & Pagan (1980)'s LM test statistic of error cross-section dependence. In addition, even if Pesaran (2004)'s test (panels with short T and Large N) is inconsistent , This bias adjusted LM test is consistent.

The test statistics of the Pesaran et al. (2008)'s bias-adjusted LM is

$$\mathrm{LM}_{adj} = \sqrt{\frac{2}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\frac{(T-k)\hat{\rho}_{ij}^2 - \mu_{Tij}}{v_{Tij}} \rightarrow d^{N(0,1)} \quad (2)$$

Where $\hat{\rho}_{ij}^2$ denotes the sample estimate of pairwise correlation in the residuals, and k indicates the number of parameters in the model under consideration. T and N represent the number of periods and the number of cross-sections, respectively. Lastly, μ_{Tij} and v_{Tij} shows the mean and variance of the series, respectively.

3.2.2. Panel Unit Roots Tests

We employ both Pesaran (2007), Hadri and Kurozumi (2012) tests that allow for cross-section dependence to test the stationarity of the variables. The cross-sectionally augmented (hereafter

CIPS) test by Pesaran (2007) is based on simple averages of the individual cross-sectionally augmented ADF statistics (hereafter CADF) and defined by

$$\mathrm{CIPS} = \frac{\sum_{i=1}^{N} \mathrm{CADF_i}}{N} \tag{3}$$

The Hadri and Kurozumi (2012) test considers the cross-sectional dependence in the form of a common factor in the disturbance and is built as in the same way of Hadri(2000)'s study. They define as

$$Z_A^{SPC} = \frac{\sqrt{N}(\overline{ST_{SPC}} - \xi)}{\zeta} \text{ where } \overline{ST_{SPC}} = \frac{\sum_{i=1}^{n} ST_i^{SPC}}{N} \text{ and } ST_i^{SPC} = \frac{1}{\hat{\sigma}_{iSPC}^2 T^2} \sum_{t=1}^{T} (S_{it}^{W})^2 \tag{4}$$

$$Z_A^{LA} = \frac{\sqrt{N}(\overline{ST_{LA}} - \xi)}{\zeta} \text{ where } \overline{ST_{LA}} = \frac{\sum_{i=1}^{n} ST_i^{LA}}{N} \text{ and } ST_i^{LA} = \frac{1}{\hat{\sigma}_{iLA}^2 T^2} \sum_{t=1}^{T} (S_{it}^{W})^2 \tag{5}$$

with $S_{it}^{W} = \sum_{s=1}^{t} \hat{\varepsilon}_{iS}$ and $\hat{\sigma}_i^2$: long run variance estimator in the case of intercept, $\xi = 1/_6$ and $\zeta^2 = 1/_{45}$ in the case of intercept and trend, $\xi = 1/_{15}$ and $\zeta^2 = 11/_{6300}$.

Hadri and Kurozumi (2012) obtain Z_A^{SPC} test statistics and Z_A^{LA} test statistics in equation (4) and in equation (5). To test the stationarity of the cross-sectionally invariant variables, We also use Phillips and Perron (1988) unit root test.

3.2.3. Panel Cointegration Test

We employ Westerlund (2008)'s panel cointegration test allowing cross-section dependence. Westerlund (2008) test is based on Durbin Hausman principle and proposes panel statistics (hereafter DH_g), and group mean statistics (hereafter DH_p) given as

$$DH_g = \sum_{i=1}^{n} \hat{S}_i (\tilde{\phi} - \hat{\phi})^2 \sum_{t=2}^{T} \hat{e}_{it-1} \tag{6}$$

$$DH_p = \hat{S}_n (\tilde{\phi} - \hat{\phi})^2 \sum_{t=1}^{n} \sum_{t=2}^{T} \hat{e}^2{}_{it-1} \tag{7}$$

In equation (6), DH_g is built by summing then n individual terms before multiplying them together. However, DH_p is built by multiplying the various terms at first then summing in equation (7).

3.2.4. Poisson Regression and Negative Binomial Fixed Effect

As our dependent variable (Number of resident patent applications) is nonnegative, we use two-panel count data models. Firstly, we use the Poisson Regression model developed by Palmgren (1981) to investigate the relationship between these patent applications and independent variables.

As stated in (Cameron & Trivedi, 2013), even though the most common starting point in the analysis of count data is Poisson regression, the results of the Poisson regression model can be misleading due to the overdispersion.

For this purpose, we test the overdispersion using the likelihood ratio test (LR) as proposed by Cameron & Trivedi (2013). Secondly, depending on the results of LR test, for the case of overdispersion, we use the Negative Binomial Fixed Effect model, introduced by Hausman et al. (1984), to analyse the relationship between these variables.

4. Results

4.1. Panel Unit Roots Tests

We investigate the time-series properties of the variables before the estimation of the regression model. For this purpose, we firstly test the absence of cross-section dependence across OIM and OEX employing the bias-adjusted LM test developed by Pesaran et al. (2008). The findings of the bias-adjusted LM tests are illustrated in Table 4.

Table 4: **Panel Unit Root Test Results**

Oil-Importing Countries

Variables	**CIPS Int**	**CIPS Int + Tr**	**Z_A^{SPC} Int**	**Z_A^{LA} Int**	**Z_A^{SPC} Int + Tr**	**Z_A^{LA} Int + Tr**	**LM_AD Int**	**LM_AD Int + Tr**
				Level				
Innovation	-1.27	-1.81	21.9***	98***	-2.39	-3.31	98.10**	106.97**
Openness	-2.33	-2.56	-2.43	-2.85	-1.39	-2.37	99.87***	87.86**
GDP	-1.37	-1.93	14.3***	2.72***	0.38	-1.65	90.73***	86.7***
Energy	-2.8***	-2.43	-1.1	-1.88	-2.5	-2.68	99.91***	95.5***
Renergy	-2.12	-2.24	-0.5	-1.68	-2.16	-2.84	115.7***	122.9***
FDI	-2.35	-2.3	-0.71	1.92*	1.43	1.57	93.02***	90.05***
CO_2	-2.55	-2.9***	0.99	2.28**	1.46	1.53	100.2***	106.5***
				First Difference				
ΔInnovation	-3.3***	-3.6***	21.9***	98.19***	-2.54	-3.45	107.1***	90.7**
ΔOpenness	-2.8***	-2.8***	-1.8	-1.6	-0.68	0.96	85.79***	83.09***
ΔGDP	-2.7***	-2.5***	12.2***	5.91***	0.03	0.39	99.41***	82.1***
ΔEnergy	-3.1***	-3.5***	-0.81	-1.59	-2.85	-3.09	97***	93.1***
ΔRenergy	-3.3***	-3.4***	-0.41	-1.34	-0.99	-1.74	87.61***	82.6***
ΔFDI	-3.7***	-3.6***	-1.21	-0.46	0.71	0.83	91.83***	86.5***
ΔCO_2	-3.6***	-3.8***	0.72	1.72	6.24***	8.72***	86.1***	81.9***

Oil-Exporting Countries

Variables	**CIPS Int**	**CIPS Int + Tr**	**Z_A^{SPC} Int**	**Z_A^{LA} Int**	**Z_A^{SPC} Int + Tr**	**Z_A^{LA} Int + Tr**	**LM_AD Int**	**LM_AD Int + Tr**
				Level				
Innovation	-1.60	-1.86	-2.34	-0.08	-0.44	3.69	89.97*	98.51*
Openness	-2.28	-2.56	-1.29	-0.23	-1.39	-2.02	65.78*	62.9*
GDP	-1.92	-1.96	-0.64	-0.09	2.88	14.51	109.60*	87.42*
Energy	-3.49***	-2.72	-0.31	1.47	0.57	2.33	86.74*	83.15*
Renergy	-2.97***	-2.37	-2.23	-2.15	-2.22	-2.01	114.20*	74.41*
FDI	-2.09	-2.26	-2.09	-1.87	1.58	2.55	98.05*	95.17*
CO_2	-4.15***	-2.25	0.75	6.12***	5.69	2.76	128.23*	87.06*
				First Difference				
ΔInnovation	-3.75***	-4.02***	-2.38	-1.25	-0.44	3.69	94.50*	92.79*
ΔOpenness	-3.54***	-3.59***	-0.69	-0.56	-0.79	-2.15	90.24*	89.08*
ΔGDP	-2.78***	-2.92**	-0.51	0.17	4.21	5	97.44*	91.84*
ΔEnergy	-3.29***	-3.64***	-0.18	1.43	1.08	6.88	122.98*	117.72*
ΔRenergy	-4.12***	-4.20***	-2.4	-2.19	-2.50	-1.12	86.28*	79.52*
ΔFDI	-3.61***	-3.51***	-0.71	-0.80	5.04	4.61	85.90*	80.26*
ΔCO_2	-4.17***	-4.43***	1.05	1.68	5.6	2.41	104.45*	104.29*

Note: Int and Int + Tr demonstrate Intercept and Intercept + Trend, respectively.
*, **, *** Indicates 10%, 5% and 1% level of significance, respectively.

The LM_AD test statistics in Table 4 indicate that we reject the null hypothesis of no cross-section dependence for cases of intercept as well as intercept and trend. This provides strong evidence for cross-section dependence among OIM and OEX countries. Thus, we employ the CIPS tests by Pesaran (2007) along with Z_A^{SPC} and Z_A^{LA} tests proposed by Hadri and Kurozumi (2012) since these tests allow for cross-section dependence across the Oil-Importing Countries and Oil-

Exporting Countries.The results from Table 4 indicate that we do not reject the null hypothesis of a unit root in some variables in level while we reject the null hypothesis of a unit root in first difference in almost all variables. In addition, since the Oil variable is the cross-sectionally invariant, we use Philip-Perron unit root test by Phillips and Perron (1988).

In Table 5, the results from Philip-Perron unit root test show that we do not reject the null hypothesis of a unit root in level while we reject the null hypothesis of a unit root in the first difference for the Oil variable. To sum up, variables are integrated of different order due to the contradictory results of all tests.

Table 5: **Philip-Perron Unit Root Test**

Level	intercept	intercept + trend	First Difference	intercept	intercept + trend
Oil	-1.330669	-1.926997	Δ Oil	-4.437060*	-4.334175**

Note: *, **, *** Indicates 10%, 5% and 1% level of significance, respectively.

Before testing the cointegration between variables, we check the cross-section dependence across residuals.

4.2. Panel Cointegration Test

The results of cross-section dependence (LM_AD) across residuals are illustrated in Table 6. The LM_AD test statistics in Table 6 illustrate that we reject the null hypothesis of no cross-section dependence across residuals for the case of Oil Importing Countries (at 1% level of significance) and Oil Exporting Countries (at 10% level of significance).

These results provide strong evidence for cross-section dependence among residuals in Oil-Importing Countries and Oil-Exporting Countries. Hence, we can apply the panel cointegration model test by Westerlund (2008) for OEX and OIM. The test statistics of panel cointegration tests in Table 6 reject the null hypothesis of no-cointegration in both country groups. Thus, we use the level of the variables for the rest of the paper.

Table 6: **Panel cointegration test results**

Oil Importing Countries		
CSD for cointegration	LM_AD	3.292***
Westerlund (2008) cointegration test	DH_P	1.969**
	DH_g	-1.556
Oil Exporting Countries		
CSD for cointegration	LM_AD	1.636*
Westerlund (2008) cointegration test	DH_p	0.120
	DH_g	2.751***

Note: *, **, *** Indicates 10%, 5% and 1% level of significance, respectively.

4.3. Empirical Results from Poissthe Regression and Negative Binomial

The Estimation results of Poission regression and Negative Binomial fixed effect estimators for OIM and OEX are presented in Table 7 and Table 8, respectively. According to Poisson regression results, all the seven explanatory variables seem to be significantly related to innovation in both country groups. LR test results in Table 7 reject the null hypothesis of equality of mean and variance in both country groups. Thus, the data is overdispersed, and overdispersion leads to a problem in poisson regression models. We deal with the overdispersion problem using a negative binomial fixed effect regression model.

The estimation results from the negative binomial fixed effect regression model is represented in Table 8 for both country groups. In oil-exporting countries, all variables are significant except for renewable energy.

Table 7: **Poission Regression and LR Results**

	Oil Exporting Countries	**Oil Importing Countries**
Openness	.0055022***	-.0000969*
	[.0000715]	[.000059]
GDP	.0000525***	.0000126***
	[1.46e-07]	[1.48e-07]
Energy	.0000228***	.0003178***
	[2.98e-06]	[1.31e-06]
Renergy	.0373336***	-.0324561***
	[.0007231]	[.0002599]
FDI	1.20e-13***	-6.14e-13***
	[5.79e-15]	[2.10e-14]
CO_2	-.0042052***	.123898***
	[.0005237]	[.0007403]
Oil	.000481***	-.0012812***
	[.0000209]	[.000016]
LR	87190.225***	440077.88***

Note: *, **, *** Indicates 10%, 5% and 1% level of significance, respectively.

Trade openness and carbon emission have a significant and negative relationship with innovation, while GDP, energy consumption, FDI, and oil price have a significant and positive relationship with innovation in oil-exporting countries.

Table 8: **Negative Binomial Fixed Effect Results**

	Oil Exporting Countries	**Oil Importing Countries**
Openness	-.0038231**	.0016733
	[.0016015]	[.001586]
GDP	.0000111***	.000021***
	[3.80e-06]	[3.94e-06]
Energy	.0002695***	.000097*
	[.0000626]	[.0000555]
Renergy	-.0058645	-.0133838***
	[.0047357]	[.0042605]
FDI	1.55e-12***	-8.22e-14
	[3.37e-13]	[1.95e-13]
CO_2	-.0583817***	.0465654*
	[.02104]	[.0251208]
Oil	.0032372***	.0004775
	[.0008159]	[.0006924]
Constant	.9136951***	1.148523***
	[.2487308]	[.18291]

Note: *, **, *** Indicates 10%, 5% and 1% level of significance, respectively.

In oil-importing countries, GDP, energy consumption, renewable energy, and carbon emission have significant and positive relationships with innovation. In the meantime, innovation has a significant and negative relationship with renewable energy and trade openness.

5. Discussion

The existing literature shows that trade openness increases innovation (Bhattacharya & Bloch, 2004). In our results, even if we expect significant relation, there is a positive and insignificant association between trade openness and innovation in oil-importing countries. This result is in line with the results of Guloglu et al. (2012). However, there is a negative and significant association between trade openness and innovation in oil-exporting countries. Because of high oil income, oil-exporting countries do not depend highly on the export of high-tech products. Therefore, an increase in trade openness negatively affects to innovation in oil-exporting countries while positively affects to innovation in oil-importing countries.

As it is common in the literature, also in our result, the effect of GDP on innovation is significant and positive for both country groups. In both country groups, there are significant and positive relationships between energy consumption and innovation. As energy consumption increases, countries allocate more resources for innovation to provide energy efficiency. There is a negative and insignificant relationship between renewable energy and innovation in oil-exporting countries and a negative and significant association between these variables in oil-importing countries. This finding may be the importation of renewable energy by oil-importing countries instead of developing it.

The effect of FDI on innovation in oil-exporting countries is positive and significant. This result aligns with Ghimire & Paudel (2019) and Guloglu et al. (2012). On the other hand, there is no association between FDI and innovation in oil-importing countries. There is a significant and negative relationship between CO_2 and innovation in oil-exporting countries. Carbon emissions in oil-exporting countries are mainly from fossil fuels consumption (The World Bank, 2021). These results are in line with Su & Moaniba (2017)'s study showing a negative relationship between climate change innovation and carbon emission resulting from fossil fuel consumption. At the same time, there is a significant and positive association between CO_2 and innovation in oil-importing countries as expected.

The effect of oil price on innovation is significant and positive in oil-exporting countries, while it is insignificant in oil-importing countries. The result of oil-exporting countries is in line with Guillouzouic-Le Corff (2018)'s study. An increase in oil prices will increase GDP in oil-exporting countries. Therefore, oil-exporting countries will allocate more sources to innovation. In addition, it is expected that increase in oil price stimulate oil importing countries to use alternative energy sources such as solar and wind.

6. Conclusion

We empirically investigate how innovation has been affected by selected macro-economic and environmental variables in OIM and OEX. To the best knowledge of the authors, there is no study in the existing literature that compares OIM and OEX in terms of the effect of explanatory variables on innovation. Moreover, we use environmental variables such as carbon emissions, energy consumption, and renewable energy along with macro-economic variables.

Trade openness negatively affects innovation in oil-exporting countries, while there is no effect in oil-importing countries. GDP positively affects innovation in both country groups. FDI and oil price positively affect innovation in oil-exporting countries while there is no effect in oil-importing countries.

The effect of macro-economic and environmental variables on innovation may have different on both country groups because of different economic structures and environmental approaches related to natural energy resources. Therefore, investigating oil-exporting and oil-importing countries separately to understand the effect of environmental and macro-economic variables is more valuable. The results from this comparison provide a better understanding of the determinants of innovation and will be better guidance for policymakers.

When we compare the effect of environmental variables on innovation in both country groups, it can be seen several differences. The main difference between both country groups is that CO_2 positively affects innovation in oil-importing countries whereas negatively affects innovation in oil-exporting countries. In addition, renewable energy negatively affects innovation in oil-importing countries while there is no effect in oil-exporting countries. Lastly, energy consumption has positive effects on innovation in both country groups. For future studies, the relationship between these variables can be investigated for different country groups using different techniques.

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