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A Revisit of the Energy-Economy-Environment Nexus with Multi-Regression

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***Abstract*—Economic development leaves its residues on the environment, then it is believed as the cause of environmental damage. Recognizing the real cause of environmental damage during the development process is crucial, as it could prevent the government from using dirty energy sources in developing the economy. This study believes that the real cause of environmental degradation is energy consumption. Considering the importance of the energy-economy-environmental nexus where energy is hypothesized as the driver of the two–the economy and the environment, this study conducts a multi-regression analysis where the economy and environmental degradation are the dependent variables affected by energy consumption as the independent variable. Thus, the study aims to investigate whether energy consumption is the real driver of the economy and environmental degradation by comparing energy consumption impacts on both. The sample was all countries (world and economies group) from 1990-2013. The economy's elements expected to contribute to CO_2 emissions (FDI, Trade, Urban population) are also under investigation. The results show that the energy coefficients are always positive and have the largest value in almost all models, indicating that energy drives the economy and environmental quality (represented by CO_2 emissions). Following the second hypothesis, the impacts of Urban population, FDI, and Trade on CO_2 emissions depend on the development level of the three variables. This study is expected to make the policymakers aware that the energy type they choose could improve the economy and environmental quality or put both as a trade-off.**

***Keywords*— Energy consumption; energy and the economy; energy and the environment; multi-regression; energy-economy-environment nexus.**

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I. INTRODUCTION

Economic development has a high price to pay: the environmental impacts [1]–[6]. The impacts do not stop on the environment; it eventually affects the quality of life. Degraded quality of human health [7] and decreased life expectancy [8], [9] are among the by-products of industrialization as a stage that must be passed in the development process. At the global level, climate change caused by carbon emissions is increasingly threatening life on earth. The ozone hole and the melting pole impact high CO_2 emissions due to the rapid economic activities for development [10], [11]. The development leaves residuals that harm the environment, so it seems that there is a trade-off between economic development and environmental health [1]–[3], [12], [13]. However, according to the EKC hypothesis, the trade-off only occurs at the early stage of development, where the economy grows at the expense of environmental damages.

The hypothesis is based on the notion proposed by Simon Kuznets in 1955 to explain the inverted U-patterned relationship between economic growth and income inequality. Kuznets found that the increase of inequality accompanies an increase of per capita income until the peak is reached, and the relationship turns negative, following an inverted U curve [14]. The curve was then applied in investigating the relationship between income and environmental impact. In 1991, Grossman & Krueger found that economic growth due to trade liberalization was followed by environmental degradation [15]. The study was then explored further and found that GDP increase is associated with environmental deterioration in lower economies. However, the study also found the turning point in which the increase in GDP is no longer associated with environmental degradation [16].

The economy requires energy to grow and develop. Energy is the fuel and the prerequisite of economic activities [17], [18]. However, consuming energy to pursue economic growth always leaves the residuals of development (pollution to water, air, and land) to the environment. The environment must bear the cost of development [1]–[3]. The cost is known as external cost or the externalities [19], [20]. Internalizing the externalities is suggested to ease the environmental impacts of economic activity [2], [21]. However, internalizing the externality means increasing the price, affecting the consumer's welfare [22]–[24]. It will increase the product's price, making it unaffordable, especially for most consumers in developing countries [20]. Thus, it is usually avoided and not preferred. Since no one is willing to bear it, it will be borne by the environment and the local people [21], [25].

The economy, energy, and environment are inextricably connected and always exist in the development process. Economic development adversely impacts the environment represented by CO_2 emissions [4]–[6]. Previous studies found causality from energy consumption to environmental degradation or CO_2 emissions [4], [26]. Both the economy and energy worsened the environmental quality. Others investigated the simultaneous impacts of energy and the economy on the environment [4], [27]. The results are various. Some studies found the absence of EKC and do not support the hypothesis [28]–[30]. They believe that environmental damages cannot be improved automatically by relying on economic growth alone [1], [3].

However, other studies found that the adverse impacts of the economy and energy on the environment would end once the threshold of economic level is passed. It means that after reaching a certain economic level, the subsequent economic growth and energy consumption will improve environmental quality [31], [32]. CO_2 emissions decrease as income increases [5], [31]–[33] due to a shift in the economic structure from energy, and carbon-intensive industries to services, information, and technology-intensive industries [34], [35]. It occurs in developing and developed countries, but the former has a slower shift than the latter [36]. Thus, the EKC hypothesis is often used to explain the environmental damages during development. Since any country is believed to experience the hypothesis, it also becomes an 'excuse' for environmental damages during economic development.

The EKC hypothesis is logically acceptable as each country experiences stages of development with different priorities to meet. At the early stage, a country prioritizes more the basic, primary needs such as food security [37]. As the economy grows, the priorities expand to fulfill secondary or tertiary needs. Rostow categorizes economic development into five stages: the traditional society, the preconditions for take-off, the take-off, the drive to maturity, and the age of high mass consumption. A labor-intensive and agricultural-based economy specifies the economy of a traditional society with a limited production function. The *precondition to take off* is the transformation process, where modern manufacturing starts to develop with low productivity. The *take-off* stage is the turning point marked by intensive growth where industries proliferate the supporting industries and new industrial centers. At the *drive to maturity* stage, the economy no longer produces everything but whatever it chooses and wants to produce. Finally, the *age of high mass consumption* is marked by the capitalist system and consumerism, where resources are directed at producing durable goods and services to satisfy consumers' demands [38].

The existence of the EKC hypothesis may indicate the neglect of environmental health during the development process. Many governments only focus on pursuing growth without considering environmental health. For some countries, budget constraints hinder the government from freely deciding which type of energy sources to use [19], [39] or how strict environmental regulations to apply. As a result, the environment is suffering during development. They believe that environmental quality will improve as the income level reach its threshold. This study argues mainly due to the misunderstanding about the real cause of environmental deterioration. Once they are aware of the real cause, they can avoid or at least minimize it. Thus, this study investigates the real cause of environmental damage during development. Previous studies found the effect of energy consumption on economic growth [18], where a delay in energy provision decreases GDP [17]. Others found causality from energy consumption to environmental degradation [4], [26]. It shows that without energy, there is no economic development and no damaging environment. Hence, this study argues that energy consumption is the real cause of environmental damage.

Unfortunately, many studies consider that economic development, together with energy consumption, is the cause of environmental damage. They have missed exploring the culprit of environmental deterioration during development. In many regression studies, the model is conducted to see the impacts of energy and the economy (simultaneously) on the environment. The economy and energy consumption are put as the cause (as the independent variables) in examining environmental damages [4], [27], [36], [40]–[42]. Though, they should find the real cause of environmental damages during the development. Thus, the impacts of energy on the economy and the environment should be distinguished to identify (ensure) that energy's contribution to the economy outweighs its negative impacts on the environment.

Recognizing the real cause of environmental damage along the development process is crucial. It could prevent the government from using (or at least minimizing) dirty energy sources [43] that pollute and harm the environment. Unfortunately, it is the gap many studies have missed evaluating. Thus, this study is trying to understand the real cause of environmental degradation during economic development.

This study sees that there is a misleading view that economic development is the cause of environmental damage, and this study believes that the real cause of environmental damage is energy consumption, especially non-renewable energy. Thus, the EKC hypothesis should not be 'an excuse' for environmental damage during development. Furthermore, the basis of implementing sustainability principles is from the early stage of economic development.

Energy consumption affects both economic growth [17], [18] and environmental degradation or CO_2 emissions [4], [26]. Thus, consuming energy, on the one side, is a must for developing the economy, but on the other side, it creates a risk of damaging the environment. Considering the importance of the energy-economy-environmental nexus, where energy is hypothesized as the driver of the economy and the environment, this study conducts a multi-regression analysis. The study investigates whether energy consumption is the driver of the economy and environmental degradation by comparing its impacts (positive and negative) on the economy and the environment for the last two decades. The economy's elements that expect to contribute to CO_2 emissions (FDI, Trade, Urban population) are also under investigation. Thus, the hypotheses of this study are as follows:

- **Hypothesis 1**: Energy consumption is the real driver of the economy and environmental degradation, then it will always have positive, largest regression coefficients compared to the other explanatory variables' coefficients
- **Hypothesis 2**: The impact of the urban population, FDI, and Trade on CO_2 emissions depends on the development level of the three variables. Countries with low and high development levels would have control variables that negatively affect CO_2 emissions and vice versa
- **Hypothesis 3**: As the urban population, FDI, and Trade are elements of development, these variables are expected to have a positive relationship to the economy

This study is expected to make the policymakers and governments aware that the energy type they choose to utilize could improve both the economy and the environment or, conversely, put them both as a trade-off. This study's urgency is to change policymakers' mindset that 'growth first, sustainable later' is misleading. By realizing that energy consumption is the real driver of the economy and the environmental damages, they are expected to pursue growth targets and become wiser in choosing (clean) energy sources to develop the economy.

II. MATERIALS AND METHOD

This study uses a multi-regression method to observe the energy-economy-environment nexus (Fig. 1). The data are taken from the international relations database [44] extracted from the World Bank [45] and the Correlates of War (CoW) database [46]. For the initial observation, the time scope is from 1960 to 2016, while for the models are from 1990 to 2013, considering the data availability of the selected variables. The regression models are run using R software developed by the R Foundation. Observation is conducted for the world and the five economies: High-income non-OECD (HI), High-income-OECD (HI-OECD), Upper-middle-income- (UMI), Lower-middle-income- (LMI), and Low-income- (LI) countries.

This study investigates how much the contribution of energy consumption to the economy exceeds its negative impacts on the environment. Thus, there are two types of models with two dependent variables. The first model explains the contribution of energy consumption to the economy, while the other explains the impact of energy consumption on the environment. By varying the dependent variables on the same explanatory variables, this study compares the impacts of energy consumption on the economy and the environment.

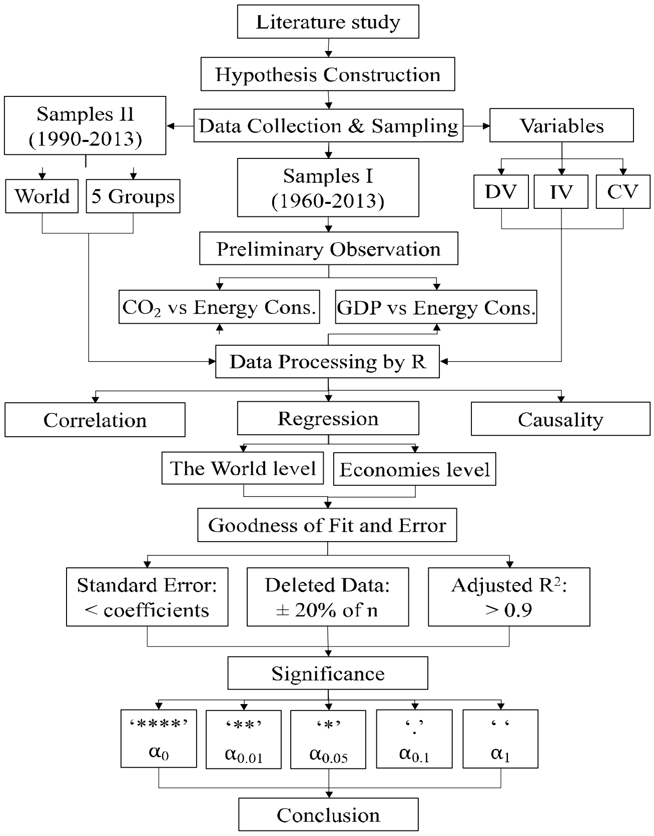

Fig. 1 The flow chart of the research stages

A. Dependent Variables (DV)

The dependent variables in this study are GDP and CO_2 emissions. GDP represents economic development, while CO_2 emissions represent environmental degradation. CO_2 emissions may not perfectly represent the actual damages, but it has been widely used to represent environmental damage due to economic development [4], [27], [31], [47]. Thus, using two dependent variables is to examine the impact of the same explanatory variables on two dependent variables: CO_2 emissions and GDP. GDP in this study is GDP constant 2010 US$, while CO_2 emissions are in kilotons (kt). Both GDP and CO_2 emissions are extracted from the WDI database [45].

CO_2 emission is the cause of climate change. It is produced by all organisms, from human activities like breathing and eating to mass, large-scale activities like electrifying households and manufacturing. Empirical findings show that CO_2 emissions are driven by energy consumption [4]–[6]. Specifically, non-renewable energy consumption increases CO_2 emissions [40], while renewable energy reduces it [26], [41], [48]–[51]. Thus, renewable energy is strongly recommended in pursuing growth while mitigating CO_2 emissions and environmental damages [42], [52].

Previous studies found different energy consumption patterns of economic development and CO_2 emissions in more developed and developing countries [4], [36]. A 1% increase in GDP in developed countries reduces CO_2 emissions by 1.037% [36]. These countries have been implementing sustainability principles by optimizing renewable energy sources [42] and implementing environmental policies such as taxes and environmental-friendly technology [52]. In developing countries, on the contrary, energy consumption and economic growth increase CO_2 emissions [5], [27], [33].

Therefore, consuming renewable energy is an opportunity of reducing CO_2 emissions without sacrificing the economy [48].

GDP (economic growth) is the standard indicator to measure economic performance, and its growth becomes the target any government must achieve to measure successful development. However, at least for two reasons, many doubt its role as an economic development target. First, GDP misses many illegal economic transactions, such as drug dealing and gambling, or legal but informal economic activities like babysitting. Thus, GDP is regarded as failing to measure the economic well-being of all people within a country [53]. Secondly, the development may leave the well-being of the environment and the poor behind, resulting in rising inequality and environmental degradation. Hence, growth receives many criticisms as it fails to conduct inclusive and sustainable development [54].

B. Independent Variable (IV)

The independent variable in this study is energy consumption since energy, according to empirical findings, is the main driver of economic growth [17], [18] and the driver of CO_2 emissions [6]. Energy in this study is primary, commercial energy sources used in industries from four energy sources (coal, petroleum, electricity, and natural gas). Other energy sources such as wood-burning, animal waste, and peat are not regarded as industrial energy sources, so they are not considered in this study. The unit is in thousands of coal-ton equivalents, and the data are taken from CoW [46].

This study argues that the economy or development process is not the culprit of worsened environmental quality, and instead, it is the energy type consumed to develop the economy. Thus, this study tries to reveal it by hypothesizing that energy consumption would always have positive and the largest coefficients compared to the other explanatory variables in GDP and CO_2 emissions models.

C. Control Variables (CV)

FDI, trade, and urban population are the variables controlled in this study, believed to affect the economy and the environment (CO_2 emissions). As one of the GDP elements, FDI contributes to GDP, but FDI is also believed as the pollutant carrier for the host countries [6]. In developed countries, a 1% increase in financial development increases CO_2 emissions by 0.499%, while in developing countries by 1.204% [36]. Financial development is believed to be the primary driver of high CO_2 emissions in the Central and Eastern European Countries [33]. However, FDI is also an opportunity for investing in a more environmental-friendly technology in consuming clean, renewable energy sources. Thus, the impact of FDI is regarded as essential to be investigated. FDI in this study is the net inflows or Balance of Payment (BoP) in the current US$, taken from WDI.

The second control variable is trading, as the indicator of dependency on the international or global world. Trade is a GDP element that contributes to the economy and deteriorates the environment [15]. In developed countries, trade positively affects the environment, reduces climate change, and improves environmental quality [41]. On the other hand, trade increases GHG emissions in developing countries [26] in the short and long term [35]. Trade is in the percentage of GDP and is taken from WDI [45].

The third CV is the Urban population. Its impact is regarded to be essential to investigate. On one side, the urban population may worsen environmental conditions: air pollution, waste, etc. On the other side, a large proportion of the urban population may also meet the economies of scale principle, leading to more efficient, less-energy-intensive development (rapid mass transportation, etc.). That over 80 percent of world GDP is generated in cities implies the essential role of urbanization. Moreover, more than half of the population lives in urban areas, and the number will increase by 1.5 times in 2045 [55]. Urbanization is one of the causes of GHG emissions [26] in Asia [27], [29], and the EU [42]. However, urbanization could also reduce CO_2 emissions [33]. Urban population is the percentage of the total population and is taken from WDI [45].

III. Results and Discussion

This section is divided into three main parts: the preliminary observation, the analysis at the world level, and the analysis at the group of economies level.

A. Preliminary Observation

Preliminary observation is applied to all countries in the database to observe the association between DVs and the IV visually. Fig. 2 shows that CO_2 emissions and GDP have positive relationships with energy consumption, which means that the increase follows the increase in energy consumption in GDP and CO_2 emissions.

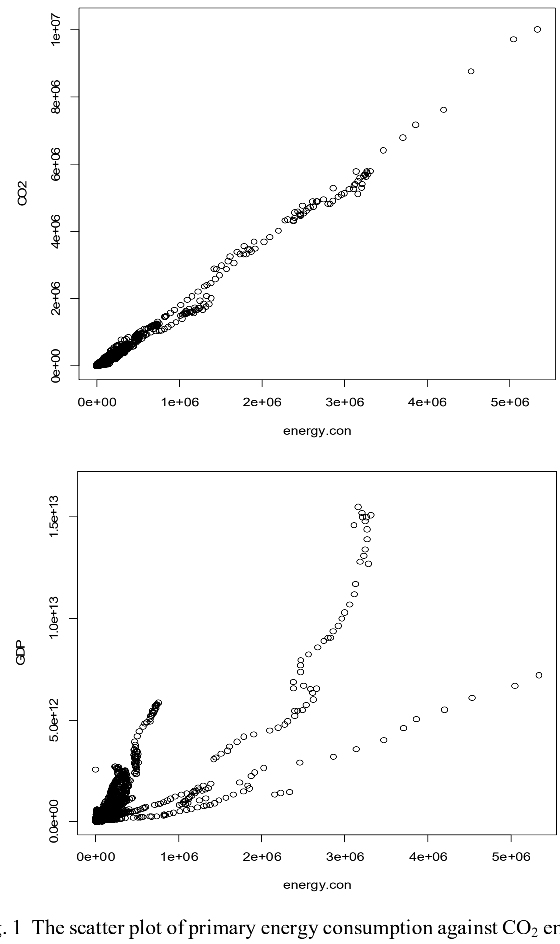

Fig. 1 The scatter plot of primary energy consumption against CO_2 emissions (above) and GDP (below) from 1960-2016 [45], [46], processed by R

This study also observes the correlations, *r* (Table I), and causality (Table II) between IV and DVs. Table I shows high correlations (r > 0.5) between primary energy consumption (Energy cons) with its DVs, implying a strong relationship between IV and DVs. On the other hand, the correlations among explanatory variables are low (r < 0.5), so multicollinearity problems are likely to avoid. Only FDI and Energy cons have a high correlation (r = 0.57696). The Granger causality test (Table III) shows that there are bidirectional (two-way) causalities between CO2 emissions and Energy cons, CO2 emissions and FDI, GDP and FDI, and Energy cons and FDI.

On the other hand, unidirectional (one-way) causalities are seen from Energy cons to GDP, FDI to the urban population, and Trade to FDI. In this study, no causality was found between GDP and CO_2 emissions also supports the idea of separating GDP and CO_2 emissions as the DV in two different models. In addition, causalities of energy consumption with GDP and CO_2 emissions support the idea of using Energy cons as the IV for GDP and CO_2 emissions (Table III).

B. World-level Analysis

The world-level analysis is conducted to observe the impacts of energy consumption on the environment or CO_2 emissions (Model 1a) and the economy or GDP (Model 1b). Both are statistically significant at the 0.001 level or 0.1 percent (***). Table IV shows that a 1 unit increase in energy consumption increases CO_2 by 1.873 units but increases about 1.4 million units of GDP, indicating that the benefits of energy consumption exceed its negative impacts on the environment. However, the results may not be precisely representative since environmental damage is not only CO_2 emissions. Due to unavailability, others (pollutants, waste, etc.) are not observed.

In Model 1a, urban population, trade, and FDI negatively affect CO_2 emissions, while in Model 1b, two out of three variables positively impact GDP. In Model 1a, the increase of urban population, Trade, FDI by 1 unit decreases CO_2 emissions by -679.4, -80.98, and -0.00000005169 units. The increase in urban population that reduces CO_2 emissions may be related to the economies of scale effect. While the urban population is large, the development of energy-efficient mass-rapid transport, for example, reduces CO_2 emissions. The negative relationship between Trade and CO_2 emissions may be due to the domination of less energy-intensive trade. For FDI, the negative sign of the FDI coefficient shows that the utilization of FDI is more dedicated to development activities that mitigate CO_2 emissions, although in a tiny number.

In Model 1b, urban population and FDI are statistically significant in increasing GDP. The increase of urban population and FDI by 1 unit is expected to increase GDP by 3.55 billion and 3.72 units. It shows that, globally, development-induced urbanization has positively contributed to the increase in GDP. However, this positive relationship does not indicate the success of countries in conducting sustainable development. In many cases, the positive growth of GDP may leave environmental health behind. FDI also positively contributes to the increase of GDP, although the impact is not as significant as the impact of the urban population on GDP.

The results in Table IV prove the first hypothesis partially, which is only in Model 1a (CO_2 emissions), energy consumption has the largest coefficient. In contrast, in Model 1b, the Urban population has the largest coefficient. It may imply two things. First, urban areas are the largest energy-consuming area. Secondly, most urban areas have been implementing less energy-intensive development. Thus, the impact of the Urban population on GDP is greater than the impact of primary energy consumption on GDP.

Model 1a proves hypothesis 2, where Urban population, trade, and FDI negatively affect CO_2 emissions. The previous explanation implies that the world has a high development level of the three, and the three have been utilized in the development, which has been mitigating CO_2 emissions. Model 1b also proves hypothesis 3, where Urban population, FDI, and trade positively impact the economy, but trade's impact is not statistically significant.

TABLE I
THE PEARSON CORRELATION (*r*) MATRIX BETWEEN VARIABLES

Variables	CO_2 (DV)	GDP (DV)	Energy Cons	Urban Pop	Trade	FDI
CO_2 (DV)	1	-	-	-	-	-
GDP (DV)	-	1	-	-	-	-
Energy Cons	0.996086	0.8276925	1	-	-	-
Urban Pop	0.1092051	0.208298	0.1293922	1	-	-
Trade	-0.1554444	-0.1759018	-0.1674507	0.2074542	1	-
FDI	0.5783213	0.6045684	0.57696	0.2125489	0.02468722	1

TABLE II
THE *p*-VALUE MATRIX OF THE GRANGER CAUSALITY TEST WITH ORDER 3*

Variables	CO_2	GDP	Energy Cons	Urban Pop	Trade	FDI
CO_2	-	0.1441	<2.2e-16***	0.8192	0.6864	2.156e-07***
GDP	0.1954	-	0.5897	0.8231	0.7621	2.57e-07***
Energy Cons	<2.2e-16***	0.0231*	-	0.619	0.7018	1.965e-07***
Urban Pop	0.6117	0.68	0.7011	-	0.8933	0.3982
Trade	0.3595	0.5368	0.19	0.1568	-	0.09092•
FDI	<2.2e-16***	<2.2e-16***	<2.2e-16***	0.001348**	0.4957	-

) To read the direction of the causality: vertical (column) to horizontal (row); Significance Codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

TABLE III

THE SUMMARY OF CAUSALITY BETWEEN VARIABLES IN THE STUDY

Variables	Causality
CO_2 – GDP	-
CO_2 – Energy Cons	$\rightleftarrows$
CO_2 – Urban Pop	-
CO_2 – Trade	-
CO_2 – FDI	$\rightleftarrows$
GDP – Energy Cons	Energy Cons $\rightarrow$ GDP
GDP – Urban Pop	-
GDP – Trade	-
GDP – FDI	$\rightleftarrows$
Energy Cons – Urban Pop	-
Energy Cons – Trade	-
Energy Cons – FDI	$\rightleftarrows$
Urban Pop – Trade	-
Urban Pop – FDI	FDI $\rightarrow$ Urban Pop
Trade – FDI	Trade $\rightarrow$ FDI

TABLE IV

THE REGRESSION ANALYSIS AT THE WORLD LEVEL (MODEL 1), FROM 1990 TO 2013, WITH CO_2 (MODEL 1a) AND GDP (MODEL 1b) AS THE DVs

Variables	Model 1a	Model 1b
DV	CO_2	GDP
Primary energy consumption	1.873e+00*** (4.407e-03)	1.445e+06*** (2.938e+04)
Urban population	-6.794e+02*** (1.460e+02)	3.550e+09*** (9.952e+08)
Trade	-8.098e+01*** (2.043e+01)	3.380e+07 (1.371e+08)
FDI	-5.169e-08* (2.202e-08)	3.722e+00*** (1.471e-01)
Constant	2.573e+04** (8.168e+03)	-7.676e+10 (5.471e+10)
Country fixed effect	Yes	Yes
Countries	174	172
n (sample size)	4,499	4,499
Deleted missingness	1,002	1,050
df	3,318	3,272
Adjusted R^2	0.9985	0.9816

Standard error in parentheses

*Significance Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

C. Economies-level Analysis

Previous studies investigating the relationship between CO_2 emissions and energy consumption found different patterns among the economies group [4], [5], [36], [42]. In this study, the global CO_2 emissions level from 1960 to 2013 is shown in Fig. 3. Generally, CO_2 emissions are increasing, but each economic group shows different emission patterns. In accumulative, HI-OECD seems to be the most significant contributor to CO_2 emissions. However, UMI's current CO2 emission level has surpassed the HI-OECD's, making it the topmost contributor to CO_2 emissions globally. The other three economic groups have relatively lower CO2 emissions than the first two groups. These findings indicate that the observation in each income-level group of economies is regarded to be essential to conduct.

The multi-regression models of each group are shown in Table V and Table VI. In HI non-OECD, 1 unit of energy consumption would increase 1.5 units of CO_2 emissions (Model 2a) and almost 1.5 million units of GDP (Model 2b). In Model 2a, only energy consumption is statistically significant to CO_2 emissions. In Model 2b, energy consumption and FDI are the variables statistically significant to the economy. The impacts of FDI are about 1.7 times the increase of a GDP unit. However, the regression model of HI non-OECD may not precisely represent the population since the deleted data due to the missingness are about 40 percent of the sample. Other than sample-lacking due to missing values [56], outlier [57] could also affect and even change the regression results.

In HI-OECD (Model 3), consuming a unit of energy is expected to increase CO_2 by about 1.6 (Model 3a) and GDP by about 6.7 million units (Model 3b). Besides energy consumption, FDI is the only variable contributing significantly to the increase in GDP (Model 3b). For OECD, the urban population is the largest contributor to the decrease of CO_2, followed by trade, respectively, by 3,621 and 377.7 units. FDI, in contrast, positively contributes to the increase of CO_2, despite a tiny number (Model 3a).

For UMI, the urban population is the largest contributor to its economy. The urban population increase by 1 unit would increase GDP by about 3 billion units (Model 4b). It follows the fact that more than 80 percent of GDP is created in cities [55]. The second-largest contributor to the economy is energy consumption. If the UMI consumes 1 unit of energy, its GDP is expected to increase by 1.1 million units. Compared to the impacts on CO_2 emissions, a unit of energy consumption only increases CO_2 emissions by 1.9 times. However, in UMI, urbanization seems to have paid attention to sustainable development since the increase in urban population reduces CO_2 emissions by around 1.2 thousand times (Model 4a). Unexpectedly, FDI is not the main contributor to UMI's economy as it only increases GDP by seven times in each unit of FDI increase (Model 4b).

In LMI, consuming a unit of primary energy would increase CO_2 emissions (Model 5a) and GDP (Model 5b) by 1.3 and 1.23 million units, respectively. As we found in UMI, the urban population is the largest GDP contributor to these economies. A unit increase in LMI urban population would increase its GDP to around 2 billion (Model 5b). Unfortunately, UMI's urban development still neglects the environment's health, as an increase in urban population by 1 unit would increase CO_2 emissions by 779 units (Model 5a). These countries still need FDI by around 5.816 to increase their GDP by 1 unit. However, most do not depend on trade yet, as the increase in trade would reduce GDP (Model 5b). International trade may not be the main GDP contributor for most (not all) of these countries. They may still depend on agriculture or natural resources traded domestically. Fortunately, trade could reduce LMI's CO_2 emissions by around 41.27 units in each unit of trade increase. Environmentally friendly commodities seem to dominate the trade commodities of most LMI countries. Also, their trade may not develop yet, to significantly increase CO_2 emissions. Therefore, following hypothesis two, where those with the system of any control variables do not develop yet, its control variable would negatively affect CO_2 emissions. Unfortunately, the investment inflow to LMI countries could increase their CO_2 emissions by a minor amount (Model 5a).

For LI, the benefit of energy consumption also outweighs its negative impacts on the environment (Model 6). In LI countries, a unit of energy consumption would increase GDP (Model 6b) and CO_2 emissions (Model 6a), respectively, by around 2 million and 1.2 units. These countries also still depend on FDI by about 1.7 units to increase a unit of their GDP (Model 6b). The good news is that urban population and trade could reduce CO_2 emissions in LI countries. Every unit increase in urban population and trade is expected to decrease CO_2 emissions by 49 and 6 times their initial value, respectively (Model 6a).

This observation shows that OECD's energy consumption is the greatest GDP contributor (Model 3a). UMI is the group where energy consumption contributes to the greatest CO_2 emissions (Model 4a). For LMI, the urban population is the largest contributor to CO_2 emissions (Model 5a), but for HI-OECD, it is the largest contributor to reducing CO_2 emissions (Model 3a). The urban population is UMI's largest GDP contributor (Model 4b). Unexpectedly, trade does not significantly contribute to the economy of all groups except for LMI. In contrast, all countries require FDI to developing the economy, with various contributions. UMI (Model 4b) is the most dependent group on FDI, followed by LMI (Model 5b).

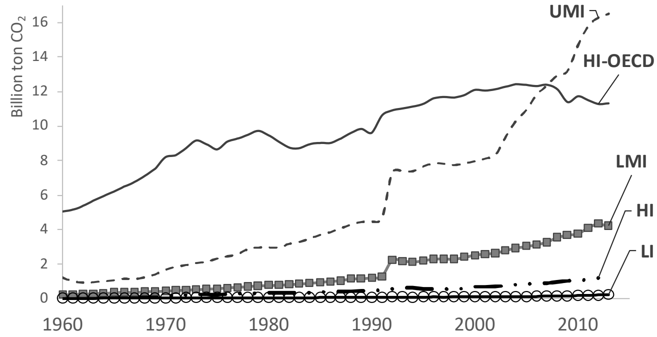

Fig. 3 The CO_2 emission level of five economic groups from 1960-2013 [45], processed by the author

TABLE V

THE REGRESSION ANALYSIS IN THE FIVE GROUPS OF ECONOMIES, FROM 1990 TO 2013, WITH CO_2 EMISSIONS AS THE DV

Variables	Model 2a (HI)	Model 3a (HI-OECD)	Model 4a (UMI)	Model 5a (LMI)	Model 6a (LI)
Primary energy consumption	1.539e+00*** (4.300e-02)	1.642e+00*** (3.518e-02)	1.907e+00*** (1.041e-02)	1.324e+00*** (1.303e-02)	1.191e+00*** (4.181e-02)
Urban Population	6.732e+02 (6.615e+02)	-3.621e+03*** (6.624e+02)	-1.190e+03*** (2.739e+02)	7.790e+02*** (1.372e+02)	-4.931e+01• (2.711e+01)
Trade	-2.453e+01 (1.704e+01)	-3.777e+02*** (8.428e+01)	-4.157e+01 (5.428e+01)	-4.127e+01• (2.287e+01)	-6.187e+00• (3.630e+00)
FDI	-1.750e-08 (9.859e-08)	5.627e-08• (2.970e-08)	3.508e-10 (1.440e-07)	1.902e-06*** (2.375e-07)	-2.215e-07 (2.454e-07)
Constant	-5.122e+04 (5.382e+04)	3.707e+05*** (5.587e+04)	5.648e+04*** (1.344e+04)	-1.843e+04*** (5.373e+03)	5.558e+03 (8.806e+02)
Country fixed effect	Yes	Yes	Yes	Yes	Yes
countries	14	30	45	47	33
n (sample size)	504	744	1,112	1,272	816
Deleted missingness	203	103	188	299	159
df	282	606	874	921	619
Adjusted R^2	0.9856	0.9991	0.999	0.9959	0.9282

*Standard error in parentheses; Significance Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

TABLE VI

THE REGRESSION ANALYSIS IN THE FIVE GROUPS OF ECONOMIES, FROM 1990 TO 2013, WITH GDP AS THE DV

Variables	Model 2b (HI)	Model 3b (HI-OECD)	Model 4b (UMI)	Model 5b (LMI)	Model 6b (LI)
Primary energy consumption	1.491e+06*** (6.614e+04)	6.740e+06*** (3.149e+05)	1.101e+06*** (2.060e+04)	1.230e+06*** (2.013e+04)	2.053e+06*** (7.114e+04)
Urban Population	8.851e+08 (9.893e+08)	9.257e+09 (6.697e+09)	3.016e+09*** (5.582e+08)	1.995e+09*** (2.125e+08)	5.969e+07 (4.820e+07)
Trade	2.487e+06 (2.496e+07)	-3.959e+08 (8.603e+08)	-6.465e+07 (1.095e+08)	-8.143e+07* (3.537e+07)	-3.955e+06 (6.166e+06)
FDI	1.682e+00*** (1.446e-01)	2.267e+00*** (3.024e-01)	6.897e+00*** (2.851e-01)	5.816e+00*** (3.669e-01)	1.701e+00*** (4.173e-01)
Constant	-6.630e+10 (8.052e+10)	-1.136e+12* (5.680e+11)	-1.269e+11*** (2.706e+10)	-2.193e+10** (8.318e+09)	8.281e+09*** (1.533e+09)
Country fixed effect	Yes	Yes	Yes	Yes	Yes
countries	14	30	45	46	32
n (sample size)	504	744	1,112	1,272	816
Deleted missingness	210	102	207	316	165
df	275	607	855	905	614
Adjusted R^2	0.9782	0.985	0.9927	0.9889	0.9553

*Standard error in parentheses; Significance Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

The results (Table V and Table VI) prove the first hypothesis where primary energy consumption coefficients are positive in all models with the largest values, except for Model 5a, Model 4b, and Model 5b, where the Urban population has the largest coefficients. Table V proves hypothesis 2, where the three variables' low and high development levels have negative coefficients of CV. HI-OECD and LI are the groups with high and low development of Urban population and trade, so both have negative coefficients of Urban population and trade. A high development level implies less-energy intensive activities for Urban population and trade, allowing CO_2 mitigation. Vice versa, low development implies that Urban population and trade have not developed yet, so they do not significantly increase CO_2 emissions. However, FDI in both groups has positive coefficients, implying that FDI has not been supported by the CO_2 mitigation system (regulations). In UMI and LMI, the coefficients' signs are mixed, implying that both are in between the low and high development levels of the Urban population, trade, and FDI. Overall, it proves hypothesis 2. Table VI proves hypothesis 3, where the Urban population and FDI have positive coefficients, which means they positively contribute to GDP. Only Trade in LMI, which (is statistically significant) has a negative coefficient, implying that these countries may not rely much on trade to develop their economy.

IV. CONCLUSION

This study compares the contribution of energy consumption to the economy and CO_2 emissions by conducting a multi-regression method. Following the first hypothesis, this study reveals that energy consumption is the driver of the economy. The second hypothesis is also proven where HI-OECD and LI with high and low development levels have Urban populations and trade that negatively contribute to CO_2 emissions. Finally, the third hypothesis is proven for the Urban population and FDI, which positively contribute to GDP. Trade is only statistically significant in LMI with a negative coefficient which implies its negative contributions to the GDP of these countries.

CO_2 emissions may not perfectly reflect the environmental degradation caused by economic development, and further study should use variables that reflect the actual environmental degradation (although not perfectly reflected). The method used in this study may not (yet) be able to prove fully that energy consumption is the primary cause of environmental damage. However, this study has raised the issue that policymakers have not fully realized, as indicated by the EKC hypothesis justifying the idea of 'growth first, sustainable later.' Thus, further studies should find a suitable method to prove that energy consumption, not the economy, is the real driver of environmental damage.

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