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Energy Subsidies and Environmental Quality: Evidence from Low- and Middle-Income Countries

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Abstract. Applying the least square dummy variable corrected (LSDVC) method, this study examines the impact of energy subsidies on the environmental quality of 70 low- and middle-income countries over the 2010–2019 period. The results indicate a positive impact of energy subsidies on environmental degradation. Also, the estimated results suggest a significant negative relationship between energy subsidies and environmental degradation in low-income countries after decomposing the countries into income categories (low income, lower middle income, and upper middle income). In addition, the results validate the existence of the Environmental Kuznets Curve hypothesis in the full panel. Similarly, while environmental pollution increases in the upper-middle-income and lower-middle-income countries as foreign direct investment (FDI) increases, the low-income countries show a positive effect of FDI on environmental quality, which indicates that pollution levels in these countries decrease as the net inflow of FDI increases. On the other hand, the result suggests that population density generally increases environmental pollution. These findings provide information and a clear understanding of the influence of energy subsidies on environmental quality and call on regulators and policymakers to carefully review energy subsidy policies.

1. Introduction

Energy subsidies are important determinants of energy consumption and environmental pollution. Environmental regulations that result in the elimination of subsidies allow for the implementation of technologies that target changes in manufacturing processes that improve energy efficiency and conservation, improvements or changes in input composition and manufacturing processes that would lead to innovation between firms, and improve productivity, and foster environmental technological progress [10, 15]. The conflict between energy security and sustainable development goals needs a satisfactory solution as changes in the patterns of production, consumption, and climate change require a critical assessment. Governments pay subsidies to augment the production and consumption of energy, which often leads to economic distortions. While the sheer of subsidies is a significant drain on the national budget, it also encourages overconsumption or wasteful consumption of subsidized products.

As developing middle-income countries, Turkey, China, Indonesia, and other emerging market economies are experiencing expanded demand for electric power and use of essential energy sources [3]. The implication is that a large portion of these nations have not accomplished stability regarding energy demand per capita. They equally face several obstacles while supporting the expected levels of growth in demand considering the huge investments required in infrastructure and generation capacity, in addition to the changes in the reforms of the energy market initiated over the years. However, these countries are also facing the challenge of guaranteeing a cost-competitive energy supply, thereby attaining energy security and reducing emissions [9, 37, 38].

More recently, the desire to achieve sustainable economic development has become a universal goal, and hence the establishment of UNFCCC [16, 21]. This convention has a legally binding commitment to control greenhouse gas (GHG) emissions amongst the member nations. In order to achieve this goal, governments at various levels have launched programmes and incentives to encourage the production and consumption of low-carbon or green products [24]. For instance, the introduction of the energy car subsidy policy in China is a strategy to provide subsidies for both manufacturers and consumers of these cars to encourage the production and consumption of low carbon cars [22, 42]. However, He et al. [23] argued that subsidies should only be at the level necessary to provide effective incentives. Obviously, subsidies are not required if pollution producers value environmental quality more than consumers. However, when subsidies are required, they must be within a level that governments are willing and able to effectively finance (without a massive drain on the national budget) and that target recipients consider acceptable compensation for implicit policy changes and internal sacrifices.

The current study investigated the environmental effects of existing energy subsidies in low- and middle-income countries using the least squares dummy variable corrected over the 2010-2019 period. It contributes to existing research in this field by integrating energy subsidies into the EKC model. This addition could reduce the misspecification and omitted variable bias observed in the traditional EKC model and also play a key role in improving environmental policies. The study further assesses the environmental benefits of reducing subsidies and examines the income heterogeneity of the countries by decomposing them into low income, the lower middle-income, and the upper middle-income countries. This study is unique as it segregates the countries into three income groups and provides a detailed assessment of the impact of subsidies on each income group. This would enable policymakers to identify more robust and specific policies according to the response of each income group to energy subsidies as well as the ability to mitigate environmental pollution. In addition, cross-country analysis of the subsidy-environment relationship is scanty. Hence, this study adds to the existing literature on energy subsidies and environmental degradation.

The literature on energy subsidies is enormous and growing persistently. Numerous empirical studies have been conducted in several countries and regions. The recent developments in empirical approaches, measurement procedures, and accessibility of reliable data have further enriched the literature. The relationship is based on the premise that lower prices for environmentally harmful energy will increase emissions, thereby compromising the current efforts to mitigate environmental challenges encountered globally. Previous empirical studies such as [2, 4, 5, 20, 29, 30], and several others are examples of studies that examined the subsidies-environment relationship.

Nevertheless, the extent to which the elimination of various subsidies can improve environmental quality depends on the nature of the subsidies in place, the baseline for emissions, and the sectoral response to such subsidies [12, 25, 31, 35, 39, 41]. On a methodological basis, the computable general equilibrium (CGE) approach has been widely adopted to examine the impact of subsidies on environmental degradation [4, 5, 20, 28, 29, 30]. In addition, several previous studies such as [27, 33] have applied different econometric methods including the Autoregression Distributive Lag (ARDL), Generalized Method of Moment (GMM), Vector Error Correlation Model (VECM), and Feasible Generalised Least Square (FGLS) to examine the subsidy-environment relationship.

The remaining part of the paper is organized as follows: Section 1.2 "empirical review of energy subsidies and environmental degradation" presents a review of existing literature related to energy subsidies and the environment. Section 2. "Material and method" explains the theoretical background, the nature of data, the empirical model, and the econometric method applied. Section 3 "empirical results" presents and interprets the empirical results, while Section 4 ''discussions" discusses the empirical results. Finally, section 5, "conclusion and policy implications," concludes the paper and provides recommendations.

2. Material and Method

2.1. Data sources and estimation method

This study selects a panel of seventy (70) low- and middle-income countries for the 2010–2019 period. The countries are segregated into three (3) categories; upper-middle-income, lower-middle-income, and low-income countries. This classification follows the most recent classification of countries by the World Bank. While upper-middle-income countries consist of thirty (30) countries, lower-middle-income countries consist of twenty-eight (28) countries, and low-income countries consist of twelve (12) (Appendix). Data on post-tax subsidies for final consumption was obtained from the IMF Database. The estimation which is often referred to as the externality approach, sums up environmental externalities into a framework based on a traditional methodology that incorporates global warming, supply costs, local air pollution, congestion, and accidents to determine the efficient price of energy and thereby establish the difference between the efficient price and the consumer price of energy. Hence, this study adopted a combination of environmental externality and the price gap approach.

Table 1. Summary of Variables.

Variable	Data Source	Measurement
Emissions	IEA, 2020	Total CO_2 emissions
Subsidy	IMF, 2020	Post tax energy subsidies (billion US$)
Economic Growth	WDI, 2020	GDP per capita (constant US$)
Foreign Direct Investment	WDI, 2020	Inflow (% GDP)
Population Density	WDI, 2020	People per square kilometer

2.2. Empirical model

The traditional subsidy-environmental pollution nexus is modelled as a function that includes environmental pollution as the dependent variable and energy subsidy as an explanatory variable. Following [27, 33], we specify our model as follows:

$$Emissions_{it} = \lambda_0 + \lambda_1 Subsidy_{it} + \lambda_2 GDPC_{it} + \lambda_3 GDPC_{it}^2 + \lambda_4 FDI_{it} + \lambda_5 PD_{it} + \varepsilon_{it} \quad (1)$$

Where Emissions generally represent environmental pollution, GDPC represents economic growth, while $GDPC^2$ is the squared term (squared of GDPC), FDI represents foreign direct investment, PD denotes population density, and λ_0 is the intercept, while $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5,$ are vectors of coefficients. While ε and the subscripts *i* and *t* are the country and period, respectively.

Generally, modelling dynamic panel data requires the addition of the lagged of the dependent variable as an explanatory variable. In addition, estimating a dynamic panel model with finite time-series often leads to poor asymptotic estimates and may as well lead to type one error [34]. However, Bun and Kiviet [11] proposed the LSDVC estimator to address this problem, and it is regarded as a more efficient estimator compared to other instrumental and least squares estimators such as GMMs and Anderson and Hsiao IV estimators since they are inefficient in a relatively small sample [32]. Following Abdulwakil et al. [1], we transformed the equation (1) into a first-order (AR1) stationary dynamic panel model;

$$Emissions_{it} = \beta_0 + \beta_1 Emissions_{it-1} + \beta_2 Subdsidy_{it} + \beta_3 GDPC_{it} + \beta_4 GDPC_{it}^2 + \beta_5 FDI_{it} + \beta_6 PD_{it} + \mu_{it} + \varepsilon_{it} \quad (2)$$

$Emissions_{it}$ is regressed on the lagged dependent variable ($Emissions_{it-1}$) and exogenous independent variables. The error term is decomposed into country-specific effects (η_i) and error term (ε_{it}) with variance (δ_ε^2). The variances of the LSDVC are reported to be smaller than other mean estimators given the bootstrapping procedure, unlike the asymptotically efficient GMM, especially in the event of a finite sample, where the LSDVC offers more accurate estimates [11, 17].

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3. Empirical results

This study evaluates the impact of energy subsidies on environmental quality in low- and middle-income countries for the period 2010–2019, using the LSDVC. Table 2 presents the impact of subsidies on environmental quality in low-and-middle-income countries for the 2010–2019 period. The full panel results indicate that subsidies, GDPC, FDI, and population density have positive coefficients, suggesting that they influence environmental degradation positively in low- and middle-income countries, while $GDPC^2$ has a negative coefficient, implying a negative impact on environmental degradation in low- and middle-income countries. Specifically, the results imply that a 10% growth in subsidies, GDPC, and population density can lead to growth in the level of environmental pollution by 0.8%, 0.1%, and 3%, respectively. Interestingly, the findings suggest that environmental pollution is less responsive to an increase in subsidies compared to income and population density.

The results for upper middle income countries reveal that subsidies, GDPC, $GDPC^2$, and FDI are positive, suggesting that they positively influence environmental degradation in upper middle-income countries. While population density has a negative coefficient, implying that the concentration of population in cities within the upper middle-income countries is instrumental in reducing environmental pollution. The positive effect of FDI validates the pollution haven hypothesis in the low and middle-income countries, while a positive coefficient of $GDPC^2$ indicates that environmental pollution in these countries increases as incomes increase. As for the lower middle-income countries, subsidies, GDPC, FDI, and population density have positive coefficients, suggesting an increasing effect on environmental degradation, while $GDPC^2$ is negative, implying that environmental degradation reaches its threshold and subsequently declines in the lower middle income countries as income multiplies. The results indicate that increasing subsidies, a rise in the real GDCP, and population density will result in increased environmental pollution in the lower middle-income countries.

On the contrary, subsidies, GDPC, and FDI have negative coefficients, implying that energy subsidies, growth in real income, and the increase in the net inflow of FDI improve environmental quality in the low income countries. While, population density has a positive coefficient, suggesting that increase in population density contributes positively to environmental degradation in low-income countries. The negative effect of FDI validates the pollution halo hypothesis in low-income countries, while an insignificant real $GDPC^2$ indicates the absence of the EKC in low-middle-income countries.

Table 2: Summary Results for Low and Middle Income Countries 2010–2019.

	Full Panel	Upper Middle Income	Lower Middle Income	Low Income
L.emissions	0.693^{***}	0.751^{***}	1.482^{***}	0.994^{***}
	(0.000)	(0.000)	(0.000)	(0.000)
Subsidies	0.084^{*}	0.176^{**}	0.055^{**}	-0.109^{**}
	(0.051)	(0.034)	(0.026)	(0.040)
Per Capita GDP	1.943^{**}	0.222^{*}	0.870^{*}	-2.241^{**}
	(0.029)	(0.093)	(0.071)	(0.012)
Per Capita GDP^2	-0.786^{*}	0.491^{**}	-0.175^{*}	1.276
	(0.069)	(0.040)	(0.084)	(0.795)
FDI	0.010^{*}	0.076^{**}	0.025^{*}	-0.076^{**}
	(0.089)	(0.025)	(0.073)	(0.046)
Population Density	0.338^{*}	-0.721^{**}	2.284^{***}	1.746^{***}
	(0.066)	(0.049)	(0.003)	(0.000)
No. of Countries	70	30	28	12

Notes: ***, ** and * indicate significance at 1%, 5% and 10%, respectively and values in parenthesis represent p-values.

4. Discussions

In this section, we analyse and discuss the environmental impact of energy subsidies and other factors influencing environmental pollution. The results indicate that environmental pollution is significantly influenced by energy subsidies in these countries. While subsidies deplete environmental quality in middle-income countries regardless of their categories, the subsidies' effect is negative in low-income countries. This implies that only low-income countries have benefitted from energy subsidies in terms of environmental quality.

Our results suggest that there would be over-consumption and/or wasteful consumption of energy, particularly in middle-income countries, should the amount spent on energy subsidies increase, which will lead to environmental pollution through increased emissions from various sectors of the economy. This finding is in tandem with empirical studies, for example, [14, 23, 28] investigated the environmental impact of energy subsidies. In addition, inappropriate subsidies will discourage innovation and adoption of more energy-efficient technologies as producers are compensated. On the other hand, inappropriate subsidies would erode the marginal benefit of bioenergy production, thereby limiting the role of bioenergy in the mitigation of climate change [26]. This influences the trade-off between energy and environmental policies that consider the effect of energy consumption and environmental pollution. Subsidies generally lead to a decline in energy efficiency and environmental quality, while cutting of energy subsidies in the form of an increase of fuel excise taxes help to control over-consumption, create green jobs and/or green energy, and thereby reduce emissions [4, 6].

On the contrary, findings also indicate that energy subsidies significantly contribute to environmental quality in low income countries. This implies that low income countries predominantly rely on energy subsidies to augment energy consumption as well as a shift away from dirtier energy sources. For example, kerosene and cooking gas subsidies would result in a shift away from the use of fuelwood and reduce rural reliance on forests. This will in turn decrease the rate of deforestation and loss of forest area as a carbon sink and, thereby, result in environmental quality. This finding is consistent with previous studies such as [39] and [45] that stress the influence and role of cooking gas subsidies in deforestation, fuelwood consumption, and environmental pollution in the USA and the European Union respectively.

In addition, empirical results reveal the presence of the EKC hypothesis in the full panel of low and middle-income countries, suggesting that environmental pollution first increases as income increases and then falls after reaching a threshold following a rapid increase in income resulting in environmental pollution abatement. This lends empirical support to [8] and [44], which confirm the existence of the EKC hypothesis in Sub-Saharan Africa. However, we found mixed results after categorizing the countries into their specific income groups. The results do not provide empirical support for the existence of the EKC hypothesis in the upper middle income and low-income countries, indicating that the ensuing pollution in these countries is yet to reach a turning point, especially in the low-income countries where communities heavily rely on subsidies for the consumption of clean energy [7, 36]. In this case, these countries are expected to continue growing with little concern about environmental quality and then gradually adjust and improve the environment as the economy continues to grow.

Interestingly, the result indicates the validity of the pollution haven hypothesis, suggesting that emissions increase as FDI increases. This implies the exportation of pollution from high-income countries to less developed countries as a result of less stringent environmental policies. This finding lends empirical support to [43]. However, we found a varying outcome when the countries are segregated into upper middle income, lower middle income and countries. While the upper- and lower middle income countries show support for the existence of the pollution haven hypothesis, the lower middle-income countries validated the pollution halo hypothesis given the negative effect of FDI on emissions, indicating that pollution levels in these countries decrease as the net inflow of FDI increases. This situation is also obtainable when FDI comes with more energy-efficient technologies that create positive spill-overs for existing domestic industries [18].

Finally, our findings suggest that population density increases environmental pollution, indicating that a higher concentration of the population in cities will lead to higher emissions through increased consumption of energy-intensive products and transportation, thereby increasing emissions, especially in low-income countries [8]. However, results revealed that population density or urbanization reduces the environmental population in upper-middle-income countries after decomposing the countries into more comprehensive income groups. This indicates that a higher concentration of population in cities within the upper-middle-income countries may result in a fall in the average cost of natural monopoly industries like liquefied petroleum gas, coal gas, electricity, and public transportation, resulting in more consumption of public transport, clean energy, thereby reducing emissions and consequently improving air quality [13]. This implies that higher population density is not entirely the cause of environmental pollution [19].

5. Conclusion and Policy Implications

The current economic and environmental problems that emerging market economies face offer an opportunity to rethink existing environmental and economic policies. As countries vary according to their level of income, development, and economic peculiarities, this study contributes to the subsidy-environment relationship by emphasizing the significance of considering these peculiar characteristics when conducting panel studies.

More specifically, this study examines the effect of energy subsidies on environmental quality/degradation for low and middle income countries for the 2010-2019 period. The study applies the bias-corrected least square dummy variables for empirical analysis. The results confirm that there is a positive relationship between energy subsidies and environmental degradation. However, estimates suggest a significant negative relationship between energy subsidies and environmental degradation in low income countries. In addition, results confirm a significant relationship between environmental degradation and economic growth, FDI, and population density. Specifically, the result validates the existence of the EKC hypothesis in the full panel, but does not support the existence of the EKC hypothesis in the low income and upper middle income countries. Similarly, while environmental pollution increases in the upper middle income and lower middle income countries as FDI increases, the low-income countries show a positive effect of foreign direct investment on environmental quality, indicating that pollution levels in these countries decrease as the net inflow of FDI increases. On the other hand, our result suggests that population density generally increases environmental pollution. However, this claim is not valid for upper middle income countries.

Some important information can be obtained from this study. First, it is generally recommended that low and middle countries consider environmental sustainability when allocating resources to subsidy payment and designing environmental policies. Precisely, inappropriate subsidy levels higher emissions. Therefore, policymakers should consider optimizing the amount of subsidy. Since these countries are at different income levels, it is important to have a country-specific optimal subsidy level that does not harm the environment, especially in the middle income countries. Second, these countries can continue their efforts to minimize environmental damage while they stimulate economic growth. This could be achieved through a shift to environmentally friendly production methods, renewable energy sources, such as bioenergy, thermal, solar, and the need to incorporate energy-efficient technologies to reduce waste and thereby mitigate environmental pollution. Third, increasing fuel taxes, especially in upper middle-income countries, will be effective in reducing fuel consumption and thus CO_2 emissions. The authorities are subsequently expected to consider reinvesting revenue from subsidy-cut and/or gasoline taxes in cleaner alternative energy sources such as biofuel production. This will result in a decrease in general levels of emissions.

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