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Exploring the Public-private partnerships, Environmental Kuznet's curve, and Environmental Degradation nexus: An Empirical Analysis of Asia

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Abstract— The present study aims to empirically assess the effect of public-private partnerships, financial development, renewable energy consumption, and population on environmental degradation, as captured by ecological footprint, on a dataset of select Asian countries for the period 2012-2022. The study has also attempted to test the Environmental Kuznets Curve (EKC) hypothesis by analyzing the short-term and long-term impact of gross domestic product (GDP) per capita on environmental degradation. In this context, the study has relied on static and dynamic panel models, i.e., fixed effects, random effects, and system generalized method of moments. The results indicate that public-private partnerships, financial development, and population are positively related to ecological footprint. In contrast, an increase in renewable energy consumption reduces the level of ecological footprints. Further, the results show the presence of an N-shape of the EKC. The results underline the importance of promoting initiatives aimed at increasing the use of renewable energy across countries to reduce the damage caused to the environment.

Keywords— Public-private partnerships, environmental degradation, financial development, environmental sustainability, renewable energy, Environmental Kuznets Curve (EKC)

Introduction

Driven by the trajectory of accelerated economic growth, the contemporary global milieu is inescapably witnessing a persistent escalation in the imperative for energy consumption, a trend that has culminated in elevated carbon emissions and the consequential degradation of the environment. It is particularly discernible in economies undergoing the stages of development, wherein a conspicuous focus on the manufacturing sector, driven by an export-oriented paradigm of gross domestic product (GDP) growth, serves to further amplify the patterns of greenhouse gas (GHG) emissions. The phenomenon of globalization heralded for its facilitation of economic well-being through the transfer of technological prowess, investment infusion, and the removal of trade barriers, has also engendered fresh challenges, most notably ecological degradation and the spectre of global warming [1]. It is incontestable that globalization, while precipitating strides in economic advancement across economies, particularly fostered through regional coordination, liberalized trade accords, and movement of capital, has ushered forth a distinct set of emergent challenges. The profound realization of escalating pollution levels has conferred an unprecedented exigency upon the arena of sustainable environmental development, an exigency that has called for the attention of all global stakeholders.

The intricate tapestry interlinking the dimensions of the environment, energy, income paradigms, and the trajectory of carbon emissions underscores a compelling thematic matrix within the gamut of the sustainability discourse. Studies have traversed the pathways underlying the intricate nexus between economic growth, energy consumption, and the intricate interplay of carbon emissions. Reference [2], for instance, delved into the intricate causal underpinnings binding economic growth and environmental degradation through the lens of econometric analysis. Reference [3], meanwhile, unearthed empirical evidence bolstering the tenets of the environmental Kuznets curve (EKC) hypothesis, albeit with a notably inconsequential association discernible between structural modifications and carbon emissions.

Currently, the body of research investigating the determinants of environmental sustainability is growing. Nonetheless, the escalating deterioration of ecosystems persists, underscoring the presence of deficiencies in the practical execution of strategies to implement low-carbon intensity. In light of this, the pursuit of low-carbon objectives is posited to materialize through two distinct avenues. The first entails the advancement of renewable energy deployment, entailing a gradual substitution of fossil fuels [4] [5]. The second trajectory revolves around the development of high-efficiency technologies, with the objective of augmenting the marginal yield per energy unit, thereby precipitating a reduction in pollutant emissions [6]. However, it is imperative to acknowledge that both these overarching solutions necessitate substantial governmental backing [7].

Within the contextual backdrop delineated above, Public-Private Partnership has emerged as a prevailing strategy, primarily aimed at alleviating the government's load with respect to infrastructure establishment, research and development initiatives, and the promotion of environmentally friendly initiatives. At present, infrastructure development (specifically in the transportation sector) is characterized by excessively high consumption of fossil fuels thereby rendering the prevalent patterns of economic growth unsustainable.

Financial development, on the other hand, reduces environmental degradation by enabling companies to use updated, cleaner technologies [8]. Literature also shows that financial development leads to more industrialization, thereby negatively affecting the environment [8]. Studies highlight that economic growth causes environmental degradation through increased consumption and purchase. However, after a threshold is reached, the effect of economic growth has been indicated to reduce environmental degradation- highlighting the presence of the inverted EKC curve [9]. Further, an increase in the use of renewable energy sources leads to reduced pollution levels [10]. Against this, the present study will also check for the presence of the EKC hypothesis in the Asian context.

Against this backdrop, the paramount objective of this study is to explore the linkages between economic growth, financial development, PPPs, and environmental sustainability in Asia. The study will also test the presence of Environmental Kuznet's Curve (EKC) in the selected countries.

Research gap: At present, the number of studies exploring the critical nexus between PPPs and environmental degradation is scarce. Next, most studies use CO_2 emissions as a measure of environmental degradation, which is not an inclusive measure of environmental degradation. Last, Asia has not been researched extensively through the lens of EKC, despite being the world's largest polluter. This study will focus on filling these research gaps.

There are two rationales for selecting the ecological footprint to capture the environmental quality. First, the ecological footprint embodies the core aspect of ecologically assessing sustainable development; specifically, it assesses the ecological impact of human actions. This metric serves as a robust representation of the Sustainable Development Goals (SDGs) [11]. Second, the utilization of natural resources through economic endeavours encompasses various elements such as trees, water and land. Conventional indicators neglect such facets, whereas the ecological footprint is a more inclusive measure [12].

Review of Literature

PPPs and environmental degradation

The impact of PPP Investments (PPPI) on the environment, specifically in terms of infrastructure and energy, holds significant importance. However, the existing literature concerning the correlation between PPPI and environmental degradation is quite limited. A study conducted in Pakistan by [10] investigated the link between PPPI and environmental degradation and found a positive relationship between these two variables and EF. According to [11] [12], PPPI exhibits a positive influence on environmental degradation. Reference [13] demonstrated that PPPI in transport increases the level of carbon emissions, prompting policymakers to devise PPP-based strategies to address this issue. Based on the literature, a positive relationship is expected between investments and environmental degradation.

Economic Growth and environmental degradation

The theoretical foundation of the EKC hypothesis asserts that the association between economic activity and environmental degradation follows a nonlinear trajectory until a specific income threshold is achieved. Beyond this point, deterioration in environmental quality becomes apparent. This phenomenon suggests that in the early developmental phases of a nation, environmental deterioration intensifies until a specific threshold level. After this threshold, countries/economies experience a reduction in environmental degradation. This trend can be elucidated by an “inverted U-shape”, as postulated by the EKC hypothesis [13]. This pattern illustrates how economic growth influences the environment through three effects: scale, technical, and composition [14]. The scale effect underscores that an initial upswing in industrial production exacerbates environmental quality. Subsequent developmental phases see a shift towards heavy industries, intensifying this degradation before transitioning to lighter manufacturing, culminating in enhanced environmental quality, which pertains to the composition effect. The technical effect encompasses the adoption of cleaner technologies during the later developmental stages. Alternative investigations explore diverse adaptations of this model (for an exhaustive review, refer to [25]). Literature also reveals the presence of the N-shape of the EKC, wherein the association between economic growth and ecological deterioration is positive and follows an upward trend until the initial inflection point, followed by a negative trend until the subsequent inflection point. Beyond this, the relationship turns positive once more. It implies that after a particular economic level, environmental degradation will begin to increase once more. However, sans appropriate measures, economies might revert to an escalation in pollution [15]. The ultimate phase in this trajectory is characterized by a stable developmental process, accompanied by a reduction in economic growth due to inadequate policies for environmental preservation. This phase materializes when the sequence of advancements becomes slow, necessitating the adoption of new pollution-reducing technologies [23].

Financial Development and environmental degradation

A robust financial sector plays a pivotal role in the economic advancement of a country, making the evaluation of the effect of Financial Development (FD) on the environment critical. Existing research on the correlation between FD and environmental conditions presents varying outcomes; primarily, the literature is divided into three strands. One stream of literature argues that FD bolsters environmental preservation by curbing the ecological footprint. In this context,

[24] highlighted that FD plays a significant and positive role in improving environmental quality by reducing pollution in their sample of the BRICS countries. Similarly, [27] identified FD as a mitigating factor for carbon emissions. Additionally, [16] investigated the interplay between FD and environmental quality across 23 nations, revealing that FD fosters ecological well-being by alleviating environmental deterioration.

Conversely, another strand of the literature suggests a positive connection between FD and environmental deterioration. For instance, [25] [23] and [26] are select studies that have highlighted that increase in the level of FD has a positive impact on environmental degradation.

A third perspective within the domain of the FD-environmental degradation nexus argues that FD has minimal impact on environmental quality. For instance, [17] and [18] identified no relationship between FD and environmental conditions.

Based on this discussion, it is expected that the relationship between FD and environmental degradation is positive.

Renewable Energy and Environmental degradation

The relationship between renewable energy consumption and environmental degradation has become a prominent area of study in recent years. [19] assessed the impact of renewable energy on Nigeria's sector-specific environmental quality. [21] investigated the linkages between renewable energy and environmental degradation in the context of Pakistan and concluded the presence of a significant and positive relationship between the two factors. [8] scrutinized the implications of renewable energy on ecological footprint keeping into consideration the role of globalization in affecting both these variables. [20] probed the interplay of fossil fuel energy and ecological footprint in the context of the USA. Their results indicated that in the short and long run, fossil fuel energy causes environmental degradation. Hence, the literature underlines that environmental degradation faces a significant decline after renewable energy is introduced. Thus, the positive impact of renewable energy on environmental sustainability is highlighted in the literature.

Methodology and data

In order to investigate the nexus between Public-private partnerships, Environmental Kuznet's curve, and environmental degradation, the dataset for analysis consists of 15 developing Asian countries for the period 2011-2022.

The basic model to be estimated is provided in Equation (1).

$$EF_{vit} = \partial + \sum_{a=1}^{a} \beta_a X_{it}^{a} + \sum_{b=1}^{b} \beta_b X_{it}^{b} + \sum_{c=1}^{c} \beta_c X_{it}^{c} + \sum_{d=1}^{d} \beta_d X_{it}^{d} + \sum_{e=1}^{e} \beta_e X_{it}^{e} + \sum_{f=1}^{f} \beta_f X_{it}^{f} + \sum_{g=1}^{g} \beta_g X_{it}^{g} + r_{it} \qquad (1)$$

where, EF_vit is the measure of ecological degradation. X_it^a, X_it^b, X_it^c, X_it^d, X_it^e, X_it^f, and X_it^g are the vectors that capture PPP investments, financial development, renewable energy consumption, economic growth, and population, respectively. r_it represents error term and ∂ is the constant. Further, β_a,β_b,β_c,β_d,β_e,β_f,and β_g are the coefficients.

Specifically, the following empirical model (2) is applied for the empirical analysis.

$$EF_{it} = \partial + \beta_1 PPP_{it} + \beta_2 FD_{it} + \beta_3 RE_{it} + \beta_4 GDPPC_{it} + \beta_5 GDPPC_{it}^2 + \beta_6 GDPPC_{it}^3 + \beta_7 Pn_{it} + \omega_{it} \quad (2)$$

Where ∂ is the constant term; i and t refer to the country (1-15) and time (2011-2022), respectively. PPP, FD, RE, GDPPC, and Pn refer to PPP investments, financial development, renewable energy consumption, economic growth (GDP per capita), and population, respectively. Further, GDPPC2 and GDPPC3 are used to test the Environmental Kuznet curve hypothesis in the long run. Environmental degradation is captured by Ecological Footprint (EF), which is the footprint per person global hectares of land. ω_it is the error term. β1, β2, β3, β4, β5, and β6 are coefficients, and μ is the stochastic error term. The data on economic growth (GDP per capita constant), level of financial development (domestic credit extended to the private sector), and population density has been sourced from the World Bank's database; data pertaining to the ecological footprint (kilogram of oil equivalent per capita) is extracted from the Global Ecological Footprint Network (NFA, 2023). All the data series have been converted into natural logs to ensure consistency and efficiency in estimation [21].

For the analysis, static panel data estimation (fixed effects, random effects) and dynamic model (Generalized Method of moments (GMM)) are used. In our investigation, the primary rationale for employing the GMM for estimation in addition to the static panel estimation models arises from its ability to yield accurate and robust estimates, free from the influence of serial correlation within stochastic elements. This methodology addresses unobserved fixed effects and alleviates endogeneity in the model by transforming the stochastic error into white noise. Furthermore, the GMM considers all the variables of the model as exogenous factors, rendering them viable instruments. This technique effectively heteroskedasticity as well, thereby producing efficient parameter estimates as indicated by [22]. Hence, it is considered to be superior to static panel estimation methods [22, 23]. The selection of GMM for our study is based on several factors: firstly, in the absence of Maximum Likelihood Estimation, GMM acts as a clear alternative to other estimation methods; secondly, it encompasses numerous classical estimators, enabling comparative evaluation; thirdly, its robustness originates from its independence from the stochastic errors; and finally, it is an unbiased estimator, proficiently managing heteroskedasticity even when dealing with a matrix containing pairwise orthogonal elements.

The employment of GMM in estimation is followed by two post-estimation tests that check for the robustness of the results. These are Arellano-Bond AR(2) test for serial correlation and the Hansen-J test. AR(2) test tests the null hypothesis that there is no second-order serial correlation in the residuals of the model. If the p-value of this test is significant, then there is evidence of serial correlation in the residuals, which could invalidate the results of the model.

The Hansen-J test tests the null hypothesis that the instruments used in the model are valid. A significant p-value indicates that the instruments are not valid, which could also invalidate the results of the model.

Finally, the Wald test statistic is used to test the significance of the estimated coefficients in the model. The null hypothesis, in this case, is that the coefficients are equal to zero.

Findings and results

Table I shows the results of the empirical analysis.

The results indicate that PPP investments (PPI) and Financial Development (FD) have significant and positive impact on EF. This implies that an increase in PPI and the level of financial development in a country will have a deterring

TABLE I Empirical results

Variable	Fixed Effects	Random Effects	GMM	GMM
EF(t-1)			-0.032 (0.019)	-0.057 (0.072)
FD	0.133** (0.026)	0.278 (0.037)	0.179 (0.049)*	0.348 (0.18)**
RE	-0.143** (0.024)	-0.343 (0.004)	-0.287 (0.012)*	-0.163 (0.069)***
GDPPC	0.875 (0.003)	0.989 (0.000)*	0.951 (0.009)**	1.245 (0.018)*
Pn	0.264*** (0.069)	0.324 (0.077)*	0.281(0.008)***	0.374 (0.005)**
$GDPPCI^2$	- 0.245(0.044)	-0.879 (0.071)*	-0.216 (0.003)**	-0.547 (0.000)*
$GDPPCI^3$				0.0132 (0.004)*
N	150	150	150	150
Hansen-J (p-value)			0.251	0.357
AR (2)			0.236	0.287
Chi^2	211.1 (0.003)	263.3 (0.004)	248.4 (0.003)	298.55 (0.00)
Shape of EKC			U-shaped	N-shaped

Note: Robust standard errors in parentheses. p<0.05, **p<0.01, ***p<0.001

impact on environmental sustainability. An increase in renewable energy consumption (RE) will have a negative impact on the level of EF. The results are in line with [5] and [15] and highlight the importance of renewable energy consumption in ensuring and sustaining environmental sustainability in the organisation.

With reference to the economic growth and environmental sustainability debate, our results emerging from the quantitative analysis indicate that GDPPC has a positive and significant impact on EF, and GDPPC squared has a negative and significant coefficient, implying the presence of an inverted U-shaped curve. In this case, as the economy grows, the environmental quality starts deteriorating. The deterioration keeps on increasing as income rises. Once a particular income level is reached, the extent of deterioration begins to decline, which is in line with [9]. In order to test the presence of the N-shaped EKC hypothesis, we included GDPPC3in our analysis. The results indicate that GDPPC3 has a positive and significant impact on EF. Hence, and β_4, β_5, and β_6 are positive, negative, and positive, respectively. These coefficients validate the N-shape of the EKC. The emerging shape is supported by [1] [3]. The result implies that the degradation of environmental quality initiates during the initial phases of economic expansion, intensifies in tandem with income growth, and subsequently begins to decline after a specific income threshold is attained. In the concluding stage, distinguished by elevated development coupled with a sluggish growth rate, the pollution levels undergo a resurgence owing to the technology becoming obsolete and outdated [28]. At inflection point within the income spectrum, a gradual reduction in environmental safeguarding becomes evident, attributed to the renewed prominence of the scale effect [15].

Table I additionally showcases the p-values derived from the post-estimation analyses. The findings yielded by the Hansen-J test imply the absence of substantial proof to dismiss the null hypothesis, thus implying that the instruments used for GMM are valid. The p-value of AR (2) confirms that there is exist no serial correlation at AR(2). Furthermore, the Wald test statistic consistently retains its significance across multiple models, accentuating the model's inherent capability for prediction.

Conclusion and Policy Implications

Drawing implications from our findings, economic growth driven by sustainable initiatives should be the critical focus of governments in Asia. Initially, it's crucial to prioritize the advancement of new energy sources. When striving for industrialization and faced with a constant overall energy consumption, the focus should shift towards reshaping the energy consumption framework. This involves elevating the proportion of clean energy utilization, thereby achieving the twin objectives of sustaining rapid economic expansion while mitigating environmental strain in regions categorized as upper-middle-income. In these areas, collaborative efforts are required to steer traditional fossil energy towards a declining phase, and it's essential to emphasize environmental preservation and the alleviation of ecological burdens prior to this decline. Throughout the course of propelling development and maintaining momentum, special attention must be dedicated to bolstering the growth of novel energy avenues through fiscal strategies. Concurrently, support for economic advancement should be extended by reshaping developmental approaches and fostering environmentally conscious growth, which is often referred to as "green growth".

To reduce the negative effect of PPPs on the environment, governments should actively pursue the PPP strategy in the renewable energy sector and greener transportation projects. Further, the presence of an N-shaped EKC curve underlines the need for strategic policies aimed at protecting the environment, adopting new technologies that reduce pollution, and modernising current industries.

[23] and [28] found that public investment in energy Research and Development (R&D) as well as renewable energy significantly contributes to enhancing environmental sustainability in the OECD region.

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