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Green governance and the EKC hypothesis: Evidence from Vietnamese provinces

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Abstract: The Environmental Kuznets Curve (EKC) posits an inverted U-shaped relationship between environmental degradation and economic development, suggesting that while economic growth may initially harm the environment, it can ultimately lead to both economic and environmental benefits in the long run. Empirical evidence of this hypothesis strongly supports the Sustainable Development Goals (SDGs) such as SDG 1 (No Poverty), SDG 8 (Good Jobs and Economic Growth), and SDG 11 (Sustainable Cities and Communities). While the EKC literature focused more on national or cross-country analyses, limited studies examined this hypothesis at the regional or provincial level and often used data from the U.S. and China. This study revisits the EKC hypothesis in Vietnamese provinces by examining municipal solid waste (MSW), which is important to the SDGs but has attracted less attention compared to other pollutants. The role of green governance, measured via the provincial green index (PGI), is also examined. Findings indicate that the EKC exists at the provincial level in Vietnam, with the PGI reducing the GDP requirement for the EKC turning point, thereby accelerating environmental improvements. Consequently, promoting green governance is important for emerging countries such as Vietnam to achieve sustainable development and the SDGs.

Keywords: *Environmental Kuznets curve (EKC), Green governance, Provincial green index (PGI), Sustainable development goals (SDGs), Vietnam.*
JEL Classification: *C31; I38; O44; Q53; Q56.*

1. Introduction

Adopted by all United Nations members in 2015, the Sustainable Development Goals (SDGs) are universal goals encouraging international cooperation and solidarity in tackling global issues such as poverty, inequality, climate change, and environmental degradation [1]. Accordingly, there is an increasing trend in governance and policy implementation to balance economic development (which addresses SDG 1, SDG 2, SDG 8, and so on) and environment deterioration (e.g., SDG 6, SDG 11, and SDG 14). Such trade-off relationships have been well examined under the Environmental Kuznets Curve (EKC) hypothesis with intensive evidence around the world [2-4].

Particularly, the EKC hypothesis proposes that there is an inverted U-shaped relationship between environmental degradation and economic development. In its early stages, economic growth is associated with environmental degradation; however, after reaching a certain level of income, further growth leads to environmental improvement [5, 6]. There is empirical evidence, however, suggests that the EKC is not universal for all countries or pollutants, and that it is dependent on technological advancements, governance, and institutional quality, among others, rather than income alone [7-10]. Nevertheless, previous EKC studies mainly focused on national or cross-country settings [11-13], maybe due to the data availability issue [2]. Therefore, among the limited number of EKC studies using regional or provincial data, most of them examined China and the US where more data are available at the provincial level [6, 14, 15]. EKC research on other countries is consequently scarce.

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This paper, therefore, contributes to the literature in three ways. *Firstly*, it empirically re-visits the EKC hypothesis in Vietnam using its provincial data. Coined as 'the next Asian dragon' [16], Vietnam has been achieving high economic development with an average GDP growth rate of 6.22% for the last 20 years [17]. Also, according to the World Bank [17], the average GDP growth rate for Vietnam in the 2020-2023 period is 4.65%, ranked 26th in the world, showing its resilience amid the recent COVID-19 pandemic. As such, our study provides new evidence of the EKC hypothesis using novel data from an important emerging country that could set an example for other economies around the globe. *Secondly*, our study focused on municipal solid waste, an important target of SDG 12 (Responsible consumption and production) and SDG 15 (Life on land), as a new measure of environmental pollution. Consequently, it can be seen as an extension of the EKC hypothesis to different types of pollutants other than traditional ones (e.g., CO_2 and NO_x). *Thirdly*, this study is also the first study to utilizes the provincial green index (PGI) to measure the green governance of Vietnamese provinces. Specifically, the PGI evaluates the provinces' environmental policy from the perspectives of businesses on how governance helps promote their operations, including the application of new green technologies [18]. Therefore, this study could shed new light on the role of green governance regarding the EKC hypothesis, particularly at the provincial level.

The rest of the paper is structured as follows. Section 2 reviews the relevant literature on the EKC hypothesis. Section 3 introduces the method and data used in the analysis. The empirical results and relevant discussions are presented in Section 4 and Section 5 then concludes the study.

2. Literature Review

Extended from the Cuznets curve hypothesis regarding economic growth and inequality [19], the idea of an environmental Kuznets curve (EKC) was proposed in the early 1990s arguing that such an inverted U-shape Kuznets curve also exists between economic growth and the environment, i.e., the EKC hypothesis [20-22]. Since then, there has been a rich body of literature following and extending the EKC hypothesis [e.g., 23, 24] covering various samples (e.g., single and cross countries), data types (e.g., cross-sectional, time series, and panel data), methods (e.g., ordinary least squares, vector autoregression, and autoregressive distributed lag), and macro variable factors (e.g., governance, tourism, and energy). A recent systematic literature review on the EKC hypothesis for the 1991-2023 period by Guo and Shahbaz [25] found that, out of 109 articles reviewed, 91 articles (or 83.48%) supported the EKC hypothesis. Another review by Ekonomou and Halkos [26] with more focus on the energy sector also proved that 71.43% of the publications (i.e., 10 out of 14 articles) can confirm the existence of the EKC in the energy sector.

EKC studies at the regional or provincial level, however, are limited and mostly focused on China or the US [27-29], leaving a big research gap in the EKC literature. For instance, Keene and Deller [29] used cross-sectional US county data to examine the fine particular matter PM2.5 (as a measure of air pollution) under the influence of the county's specific condition such as per capita income, social capital index, ruralness level, and other socio-economic characteristics. Jiang, et al. [30] found the EKC between per capita income and per capita emissions in 31 provinces of China (1985-2005). In a similar vein, Azimi and Bian [28] examined 30 Chinese provinces using panel data (2006-2017) and also concluded that the EKC hypothesis holds true in China nationally and in the central region.

Among the regional EKC studies, studies on other countries are further limited, with several publications on Indonesia [31], Italy [32], Korea [33], and New Zealand [2]. In particular, the study of Rahman, et al. [31] focused on the air pollution in 30 Indonesian cities under the impacts of forest fires and volcanic eruptions – the authors rejected the EKC hypothesis and concluded that air pollution in Indonesia follows an increasing linear trend with respect to economic growth. In Italy, Baiardi [32] confirmed the EKC hypothesis for all three pollutants of CO, NMVOCs (non-methane volatile organic compounds), and SO_x. For the pollutants of SO_2 and NO_2, Park and Lee [33] found that each of the 16 metropolitan regions in Korea has its own EKC. For CO_2 generated from New Zealand airports, Ngo, et al. [2] also confirmed the regional EKC differed from each other.

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It is noted that different types of pollutants have been examined in the EKC literature, including CO and CO_2 [34-36], NO_x [37, 38], GHG [39, 40], and so on. The municipal solid waste (MSW), however, received less attention [41], maybe due to its data availability. Gnonlonfin, et al. [42] proved that the EKC only holds for 45 (high-income) of the 96 countries examined (1990-2010). Wu, et al. [43], on the other hand, examined 31 mainland Chinese provinces (1997-2011) and found that the EKC holds for MSW, and environmental policies such as MSW charges and collection systems help reduce the MSW. Cheng, et al. [41] extended the sample to 258 cities in China for the period of 2003-2016 but found no evidence supporting the traditional EKC hypothesis, although the (negative) relationship between environmental policy and MSW is confirmed. Nevertheless, the MSW literature using the EKC hypothesis is still scarce, and Vietnamese provinces are a novel and suitable sample set for such studies.

3. Methodology

3.1. Empirical Models

As discussed earlier, an apparent reason for this study to use the MSW generated by each Vietnamese province as a measure of environmental pollution is that the MSW is not well examined, especially under the EKC hypothesis. More importantly, MSW is an inevitable pollutant consequence of human activities [44], compounded by the challenges and inefficiencies associated with solid waste management [45]. According to the World Bank [46], by 2050, the world could generate approximately 3.40 billion tons of MSW per year, increasing from 2.01 billion tons in 2018, with at least one-third of them not managed in an environmentally safe manner. Of which, the total amount of MSW generated in developing countries is expected to triple in the next 30 years, with the East Asia and Pacific region generating 23% of the world's waste, and the South Asia region among the highest MSW generation region with double increase [46]. Vietnam is no doubt a key contributor to that increase, as its MSW increased by nearly 50% just in the last decade [47], making the country an ideal sample for this study.

In addition, this study follows a large body of the EKC literature [8, 48-50] to utilize cross-sectional data from Vietnamese provinces to examine the inverse U-shape relationship between economic development and environmental degradation (i.e., the MSW). Accordingly, we employ the traditional EKC model of

$$MSW = \alpha_0 + \alpha_1 GDP + \alpha_2 GDP^2 + \alpha_3 PGI + \varepsilon \tag{1}$$

where MSW measures the level of annual municipal solid waste (in million tons) of each Vietnamese province; GDP measures the gross domestic product per capita (in millions of Vietnamese Dong, VND) of each province; GDP^2 is the squared value of GDP reflecting the non-linear relationship between economic development and the environment; PGI is the green governance index; and e is the statistical error. Note that to measure the green governance quality of Vietnamese provinces, we utilize the newly introduced Provincial Green Index (PGI) published for the first time in 2024 by VCCI and USAID [18]. Accordingly, this study only examines the Vietnamese cross-province data for 2023.

Given that governance does not only affect the environment, as proved in the recent EKC literature [3, 5, 11], but also the socio-economic development of the provinces themselves [14, 51-53], it is interesting to further examine the impacts of governance in provinces with different levels of economic development. Consequently, Equation (2) is an extension of Equation (1), in which the interaction term $PGI \times GDP$ reflects the above relationship. Note that the provincial fixed effects are also controlled in this study, following the approach of Wooldridge [54] and de Chaisemartin and D'Haultfœuille [55]. To further account for the nonhomogeneous of the estimated variances, a heteroskedasticity approach [56, 57] is also applied.

$$MSW = \beta_0 + \beta_1 GDP + \beta_2 GDP^2 + \beta_3 PGI + \beta_4 (PGI \times GDP) + \varepsilon \tag{2}$$

Most EKC studies [2, 11, 25] estimated the optimal level of economic development (i.e., GDP) at the turning point of the EKC parabola (i.e., the highest level of the inverted U-shape curve where MSW startes to decrease) using the following formulae:

$$GDP_{turn} = -\frac{\alpha_1}{2\alpha_2} \quad (3)$$

Note that Equation (3) is calculated based on Equation (1) where there is no interaction between GDP and PGI. In case of our extended model as in Equation (2), this model can be re-written as

$$MSW = \beta_0 + (\beta_1 + \beta_4 PGI)GDP + \beta_2 GDP^2 + \beta_3 PGI + \varepsilon \quad (4)$$

and thus, the turning point is estimated by

$$GDP_{turn}^{PGI} = -\frac{(\beta_1 + \beta_4 PGI)}{2\beta_2} = -\frac{\beta_1}{2\beta_2} - \frac{\beta_4}{2\beta_2} PGI \quad (5)$$

Accordingly, we argue that when accounting for the provincial green governance, the turning point GDP_{turn}^{PGI} is a function of PGI, in which an improvement in PGI helps reduce the requirement for the economic development to reach the EKC turning point. Further empirical results and discussions on this issue are presented in Section 4.3 below

3.2. Data

According to Equations (1) and (2), our sample includes the 2023 data of 63 Vietnamese provinces on three variables MSW, GDP, and PGI. Except for PGI which is sourced from VCCI and USAID [18], data for GDP and MSW were extracted from the General Statistics Office of Vietnam [58]. Additionally, both the GSO [58] and VCCI and USAID [18] also grouped those provinces into six regions (Northern, Red River Delta, Central Coast, Central Highlands, Southeast, and Mekong River Delta – see Figure 1); this information is used to control for the random and fixed effects that may be unaccounted for in our analysis.

The descriptive statistics of the variables are further presented in Table 1. Accordingly, we observed that, in 2023, an average province in Vietnam generated about 470 million tons of MSW, although it differs across regions from the lowest MSW generated region (i.e., Central Highlands, around 1,350 million tons) to the highest one (i.e., Southeast, around 12,500 million tons). Notice that the Southeast and Red River Delta regions have the highest level of industrialization [18, 59, 60], it is reasonable that those two have the highest level of MSW generation. The diversion in MSW across the provinces and regions, as observed from Table 2, justifies this study to further examine the role of provincial governance in their regional EKC setting.

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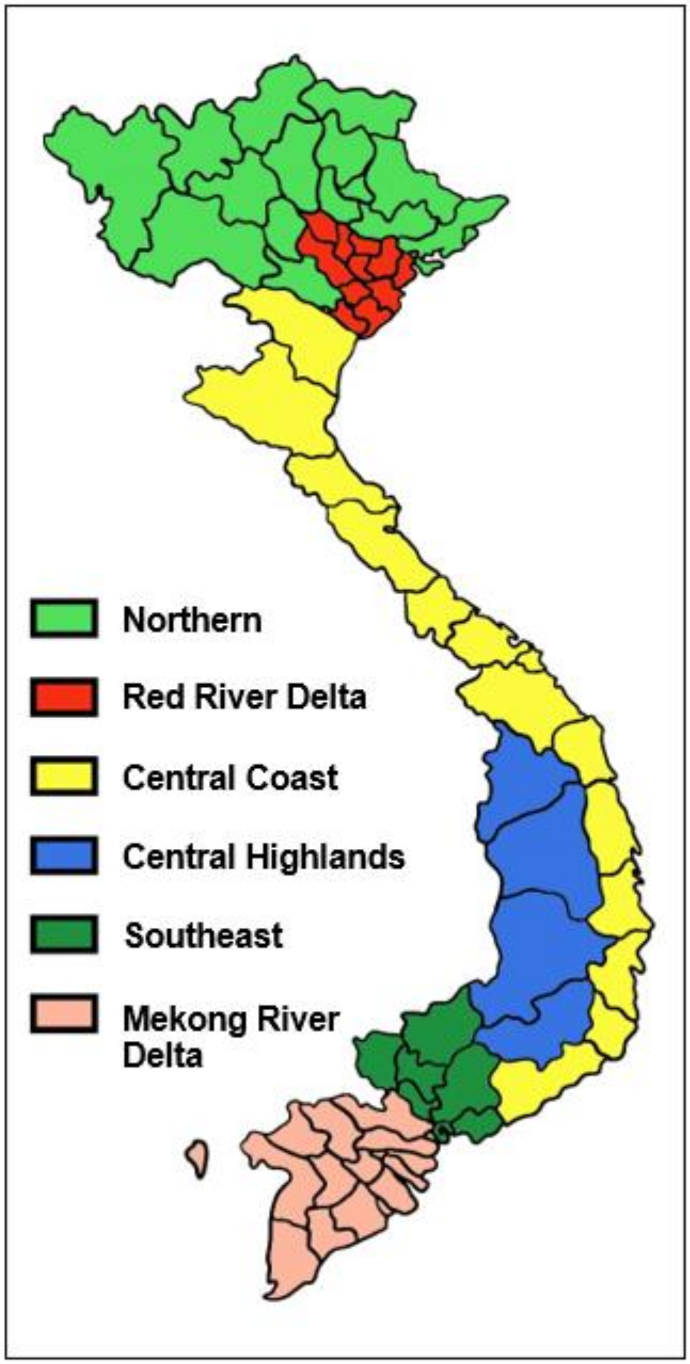

Figure 1.
The six regions of Vietnam.

Table 1.
Descriptive statistics.

All provinces	Mean	Standard deviation	Min.	Max.
MSW	470.72	1052.37	37.96	7735.45
GDP	82.41	49.97	33.70	357.20
PGI	14.83	1.22	12.52	17.67
By regions (Average values)	MSW	GDP	PGI	
Northern	2,036.70	815.70	216.87	
Red River Delta	6,046.59	,271.10	169.82	
Central Coast	4,262.11	1,059.90	203.48	
Central Highlands	1,347.58	301.80	71.32	
Southeast	12,474.61	890.60	87.63	
Mekong River Delta	3,487.58	852.60	185.04	

Note: MSW, the municipal solid waste of each province (in million tons); GDP, the gross domestic product per capita of each province (in million VND, with 1 USD = 24,254.20 VND as of 29/12/2023); PGI, the provincial green index of 2023.
Source: Authors' calculation from VCCI and USAID [18] and GSO [58]

4. Empirical Results

4.1. Results From the Base Model

We first report the estimated EKC results for our base model, i.e., Equation (1) in Table 2. It is noted that the EKC exists at the provincial level in Vietnam when the coefficients for GDP and GDP^2 are 24.81 and -0.07, respectively, for fixed effects regression. In other words, in the short run, there is a positive relationship between GDP and MSW whereas a 1% increase in GDP could lead to a 24.81% increase in MSW. However, via GDP^2 of the long run, such an increase of GDP can further reduce 0.07% of MSW. Consequently, we can argue that the economic development in Vietnam still helps improve the environment (in this study, the MSW).

Interestingly, our base model could not find statistical evidence that provincial governance improves MSW, although the coefficients for PGI show a negative relationship toward MSW. While one may argue that the quality of environmental institutions in Vietnamese provinces is not high (see Table 1), we believe that the insignificance of PGI is due to our regression model – it only examines an average province of the sample without consideration for the variation among those provinces. For instance, Table 1 shows that the PGI range from 12.52 to 17.67, i.e., more than four times the corresponding standard deviation of 1.22. More importantly, Figure 1 also shows the geo-economic similarity among provinces in the same region. These similarities as well as diversifications should be further examined using the extended model.

Table 2.
EKC analysis for equation (1).

	Heteroskedastic regression			Random effects			Fixed effects		
	Coeff.		SE	Coeff.		SE	Coeff.		SE
GDP	25.91	***	7.29	25.91	***	7.53	24.81	***	8.21
GDP^2	-0.06	***	0.02	-0.06	***	0.02	-0.07	***	0.02
PGI	-155.22		99.66	-155.22		102.98	-111.13		105.84
Constant	1198.82		1468.50	1198.82		517.46	722.54		1548.96
Model statistics									
Observations	63			63			63		
Regions	n.a			6			6		
Log-likelihood	-520.4			n.a			n.a		

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Wald χ^2_3	15.41***	14.43***	n.a
F(3,54)	n.a	n.a	3.48**

Note: The dependent variable is MSW, the municipal solid waste of each province (in million tons). GDP, the gross domestic product per capita of each province (in million VND, with 1 USD = 24,254.20 VND as of 29/12/2023); GDP^2, the squared value of GDP; PGI, the provincial green index of 2023. *Coeff.* stands for coefficient; *SE* stands for standard error; ** and *** represent the significance levels at 5% and 1%, respectively.

4.2. EKC Results of the Extended Model

Table 3 reports the results of Equation (2) where the EKC still holds for Vietnamese provinces. As expected, we also found that while the PGI itself is still insignificant, its interaction with GDP is now an important factor that can reduce MSW. Particularly, the adverse effect of PGI on MSW is stronger in provinces with higher GDP; this effect is statistically consistent across all three models, although the magnitude of its coefficient is smaller in the fixed effect model after accounting for the differences across the provinces. Consequently, we argue that green governance plays an important role in environmental protection and improvement in Vietnamese provinces.

Table 3.
EKC analysis for equation (2).

	Heteroskedastic regression			**Random effects**			**Fixed effects**		
	Coeff.		***SE***	***Coeff.***		***SE***	***Coeff.***		***SE***
GDP	112.97	***	35.11	112.97	***	36.59	82.17	**	36.16
GDP^2	-0.06	***	0.02	-0.06	***	0.02	-0.06	***	0.02
PGI	334.12		215.47	334.12		224.57	220.78		229.03
PGI × GDP	-5.76	**	2.27	-5.76	**	2.37	-4.13	**	1.93
Constant	-6168.12	*	3230.64	-6168.12	*	3367.01	-4250.13		3415.10
Model statistics									
Observations	63			63			63		
Regions	n.a			6			6		
Log-likelihood	-520.4			n.a			n.a		
Wald χ^2_4	23.38***			21.52***			n.a		
F(4,53)	n.a			n.a			3.36**		

Note: The dependent variable is MSW, the municipal solid waste of each province (in million tons). GDP, the gross domestic product per capita of each province (in million VND, with 1 USD = 24,254.20 VND as of 29/12/2023); 〖GDP〗^2, the squared value of GDP; PGI, the provincial green index of 2023. Coeff. stands for coefficient; SE stands for standard error; *, ** and *** represent the significance levels at 10%, 5% and 1%, respectively.

4.3. The Turning Point of the EKC

Utilizing the results from Table 2 and Equation (3), we have calculated that $GDP_{turn} = 176.94$, for the case of no influence from PGI. In this sense, it is suggested that in Vietnam, provinces with per capita income greater than 176.94 million VND in 2023 are experiencing environmental improvement. However, as further illustrated in Figure 2, the number of provinces with high economic development is very limited, and most provinces are still in the first phase of the EKC where economic development brings more MSW, i.e., the left side of the EKC parabolas in Figure 3 below.

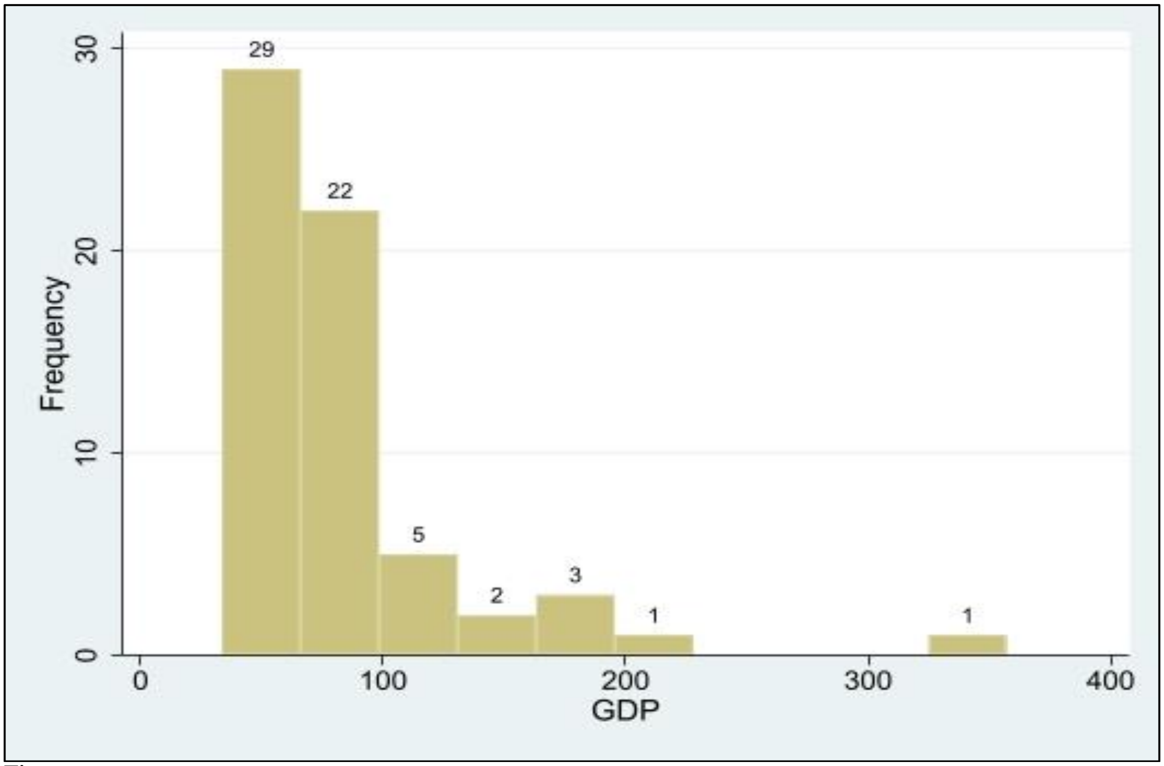

Figure 2.
The distribution of Vietnamese provinces in terms of GDP per capita (2023)

Importantly, when PGI is accounted for, the turning point is now estimated as $GDP_{turn}^{PGI} = 633.44 - 31.84PGI$ using Equation (5). Accordingly, a 1-point increase in PGI helps reduce the per capita income requirement by 31.84 million VND. Given that the average value of PGI in 2023 was 14.83 and ranging from 12.52 to 17.67 (see Table 1), the average reduction amount could be estimated at 472.13 million VND and within the range of 398.59 and 562.55 million VND. In short, for the average province (i.e., with $PGI = 14.83$), the turning point is now estimated at $GDP_{turn}^{PGI} = 161.31$ million VND, lower than the case without PGI influences above. Additionally, the MSW level at the turning point decreased from 1269.12 to 711.82 million tons (see Figure 3). These results, therefore, strengthen the argument that green governance is important for Vietnamese provinces in reducing their MSW and promoting sustainable development. Particularly, the provincial green governance helps reduce the GDP requirement for the EKC turning point and thus, speed up the movement of Vietnamese provinces to the right side of the EKC parabola.

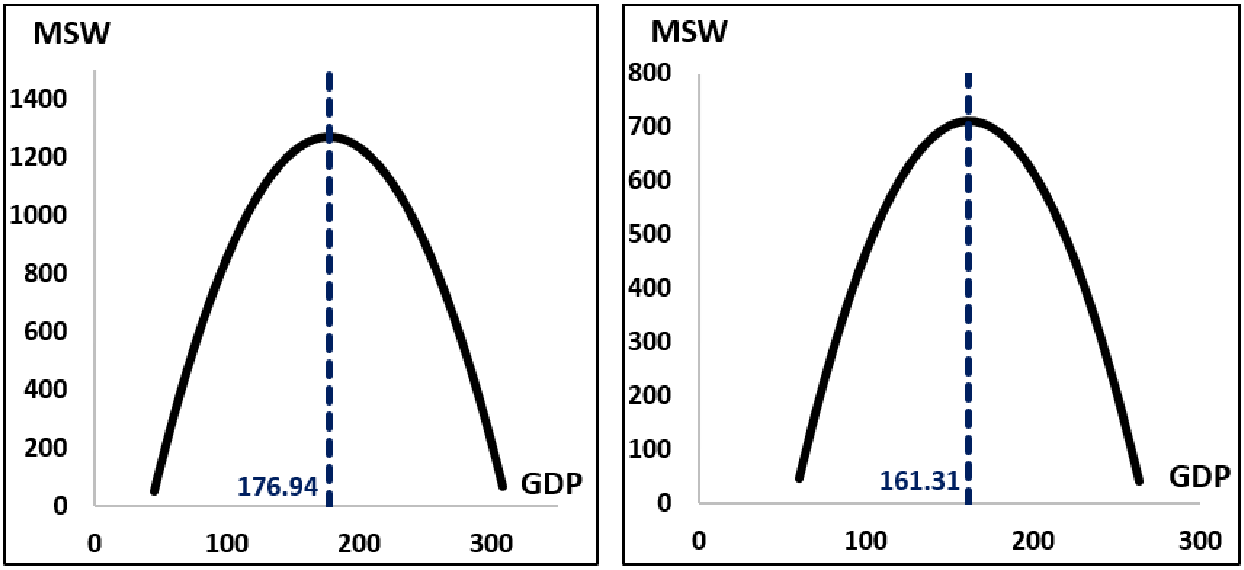

Figure 3.
The EKC of MSW in Vietnam: without PGI (left) versus with PGI (Right).
Note: MSW, the municipal solid waste of the average province (in million tons); and GDP, the gross domestic product per capita of the average province (in million VND, with 1 USD = 24,254.20 VND as of 29/12/2023)..

5. Conclusions

The Environmental Kuznets Curve (EKC) hypothesizes that the trade-off between environmental degradation and economic development follows an inverted U-shaped relationship, in which economic development may harm the environment in the short run but in the long run, one can achieve both economic and environmental improvements. Empirical evidence for the EKC hypothesis is, therefore, important to support the Sustainable Development Goals (SDGs) such as SDG 1 (No poverty), SDG 8 (Good jobs and economic growth), and SDG 11 (Sustainable cities and communities). While the EKC literature is rich (Qureshi et al., 2017; Kisswani et al., 2019; Mardani et al., 2019), it mainly focused on national or cross-country settings due to the data availability issues (Ngo et al., 2024); regional/provincial EKC studies usually utilize Chinese and US data (Zhang and Gao, 2016; Ongan et al., 2019; Tzeremes, 2019; Chan and Wong, 2020).

This study empirically revisited the EKC hypothesis in Vietnam using its provincial data; the country has been considered 'the next Asian dragon' (Hayton, 2020) and could be a case study for future works on other emerging economies around the world. By focusing on municipal solid waste (MSW), an important target of the SDGs (e.g., SDG 12 and SDG 15) but was not well examined, compared to other pollutants such as CO_2 or NO_x, this study also helps paint a more comprehensive picture on the environmental issue. As the first to utilize the provincial green index (PGI) to measure the green governance of Vietnamese provinces, this study also sheds new light on the role of green governance regarding the EKC hypothesis, particularly at the provincial level.

Our empirical results show that the EKC exists at the provincial level in Vietnam, in which the PGI helps reduce the per capita income (i.e., GDP) requirement for the EKC turning point (i.e., the highest point of the inverted U-shape curve where MSW started to decrease) and thus, speeds up the movement of Vietnamese provinces to the right side of the EKC parabola. For instance, for an average level of PGI=14.83, the GDP at the turning point reduces from 176.94 to 161.31 million Vietnamese Dongs, allowing more provinces to benefit from their economic development regarding environmental improvement.

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