

Article

Is the Sharing Economy Green? Evidence from Cross-Country Data

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Abstract: Using cross-sectional data from 165 countries, this study takes a fresh look at whether or not the sharing economy is a green solution for countries. This study relies on the Timbro sharing economy index and uses both carbon emission and environmental performance index as proxies for the greenhouse gas effect and overall environment, respectively. Due to limited sample size and non-normal distribution of the sample, this paper applies the Bayesian regression model, which is based on posterior distribution. The findings suggest the following: (1) a high sharing economy level has a negative relationship to carbon emissions but a positive relationship to overall environmental performance; (2) the joint variables show that a high sharing economy level together with high broadband access, urbanization, and high education level reduces carbon emissions; and (3) for manufacturing countries, a high sharing economy level together with high urbanization is associated with comparatively low carbon emissions and high environmental performance. In general, these findings allow us to conclude in favor of the contribution made by a high sharing economy level to sustainability.

Keywords: sharing economy; carbon emission; overall environment; cross-country data; Bayesian analysis



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1. Introduction

The sharing economy is one of the most important stylized facts of the new business models of our century. The concept of the sharing economy, in which assets and services are shared among individuals, has become very popular since it was introduced as an economic system. The sharing economy is defined as peer-to-peer-based activity of obtaining, giving, or sharing access to goods and services, coordinated through community-based online services [1]. Many synonymous names are used for the term 'sharing economy', such as gig economy, platform economy, access economy, and collaborative consumption [2]. Put simply, a sharing economy is used as an umbrella term for many apps, services, and products.

The main drivers of the growth of the sharing economy are population growth, urbanization, scarce resources, and the advent of technology. Many people have started to become aware of new ways to leverage the unused capacity of the things that they own or the services that they can provide. Consequently, there has been a move toward the sharing economy and it is now getting easier for platforms to connect people, foster sharing, and grow using smartphones, apps, and advanced online platforms. With the advent of technology, the sharing economy has changed the form of economic activities across many industries. The common practices of short-term rental platforms and car sharing have raised the public's awareness of the concept of the sharing economy [3]. Indeed, examples of the sharing economy are not limited to car or room rentals. A wide range of services are now provided by the sharing economy, including tourism, transportation, labor, delivery, short-term loans, retail, and consumer goods.

The sharing economy is not only attractive for financial reasons, but also because it creates social ties while leading to more sustainable practices. The sharing economy

provides a sustainable perspective by aggregating the environmental, social, and economic aspects, and it addresses resource utilization through the temporary access rights to ownership of products or services [4,5]. At this point, the sharing economy positions itself as an environmentally friendly economy. With the efficient use of resources, sharing practices may reduce the adverse effects of human activities on the environment because the use of existing goods reduces the demand for new goods and hence leads to lower levels of waste. However, it is difficult to quantify how environmentally friendly the sharing economy is. In many industries, from short-term rental platforms to crowdfunding, it does not seem to be feasible to gauge how much energy, water, and greenhouse gas emissions people save by sharing. Perhaps only the transportation industry quantifies the potential reduction of energy consumption and emissions due to the fall in car purchases. The existing literature also supports the idea that car, bike, and motorbike sharing practices can help to promote the green environment [6–8].

Despite intense scholarly interest in the sharing economy, the nexus between the sharing economy and environmental degradation has not yet undergone a comprehensive review. The existing literature has examined the impact of the sharing economy on the environment, either for specific industries ([9] for bike sharing; [10] for car sharing) or for specific regions ([11] for Switzerland; [12] for the United States; [13] for China). Although a micro-level analysis of the sharing economy is interesting, it lacks the ability to make a comparison across countries. To date, there has been no study on the relationship between the sharing economy and environmental degradation using cross-country data. The current study attempts to fill this gap, which will have many implications for policy makers, practitioners, and academicians.

The aim of this study is to examine the relationship between the sharing economy level and environmental degradation. This study uses cross-country data from 165 countries, and it applies a Bayesian regression model. The level of the sharing economy is defined with the Timbro Sharing Economy Index (*TSEI*), which is the first global index of the sharing economy and has been available since 2018. *TSEI* provides a new definition of sharing economy that incorporates the use of excess capacity (e.g., labor, spare rooms, unused cars, etc.), large decentralized digital networks, and trust between strangers facilitated by infrastructure. These factors are used to create an economy that is characterized by micro-transactions, ad hoc matchmaking, and decentralized supply [14]. For environmental degradation, CO_2 emissions per person (CO_2pc) and the Environment Performance Index (*EPI*) are used. In previous studies, carbon dioxide has been widely used to measure the quality of the environment (e.g., [15,16]). Meanwhile, the *EPI* is a ranking system that indicates a country's efforts toward a sustainable future and is calculated by using 32 environmental performance indicators across 11 issue categories, as follows: air quality, health impacts, water and sanitation, water resources, agriculture, forests, fisheries, biodiversity and habitat, climate, and energy.

The development of the sharing economy has significantly changed production and consumption patterns all over the world. This leads us to ask whether the sharing economy practices have a significant impact on CO_2 emissions and the overall environment. It is well-known that there has been no consensus regarding environment and sustainability issues internationally. However, the consequences of environmental degradation affect the entire globe, and this pushes us to be aware of how the sharing economy affects the environment from a global perspective. Using sharing economy index and environmental performance indicators in 165 countries, this paper empirically examines the impact of the sharing economy on countries' CO_2 emissions and overall environment. Furthermore, this study is also interested in analyzing the joint effects of the sharing economy level and countries' different characteristics (e.g., income level, education, urbanization, etc.) to give a broader view of whether or not the sharing economy level is green.

The key findings of this paper are as follows. First, a high sharing economy level is associated with low CO_2 emissions and high environment quality. This finding reflects that sharing economy practices can help to decrease carbon emissions and improve the

overall environmental performance. Second, the development of information and Internet technology infrastructure has extended the positive impact of the sharing economy level on environmental performance. In particular, the use of the Internet helps people to access sharing economy platforms and broadband access enhances the capability of the sharing economy to reduce air pollution and improve environment quality. Third, there is a positive and significant relationship between carbon emissions and the joint variable of the sharing economy index, together with urbanization and education. This finding implies that urbanization improves the efficiency of sharing economy practices with a scale effect, and education raises awareness and concern for the environment. Moreover, one of the most striking findings of this paper is that major manufacturing countries that also have high sharing economy practices and high urbanization have comparatively low carbon emissions and high environment quality. The rest of this paper proceeds as follows. Section 2 reviews the literature. Section 3 describes the methodology and data. Section 4 discusses the empirical findings. Finally, Section 5 draws a conclusion and provides policy implications.

2. Literature Review

In attempts to contribute to the sharing economy literature, a considerable number of scholars have advanced our understanding of sharing economy platforms. There are large number of sharing economy platforms that provide a wide range of services, from job platforms to crowd funding platforms. The common feature of these platforms is the accessibility of products and services, rather than buying them. These platforms have revolutionized many conventional industries through decreasing transaction costs and enabling sharing economy companies to grab a significant market share [17–19]. The sharing economy is pushed by platform leverage, peer-to-peer interaction, and underutilized resources [20], as well as reciprocity norms and the social value of sharing [21]. The incumbent big firms have also played a crucial role in popularizing the sharing economy [22].

An extensive body of literature has analyzed the impact of the sharing economy on consumption. With the help of the sharing economy, the traditional methods of consumption have evolved from localized activities to global sharing activities. The sharing economy has altered the consumption patterns of individuals, and it has extended the incumbent business model of producers and consumers [1,23–28]. In addition, the widespread adoption of mobile phones and the rise of social media platforms has enabled individuals to become involved in more digitally connected economic activities and has also developed direct communication between suppliers and consumers [29].

The concept of the sharing economy and its practices also link to the circular economy. Sharing products or putting multi-functional products on the market can increase resource use efficiency [30]. Taking advantage of sharing information along the value chain can enhance collaboration in the circular economy [31]. Except for industry, the circular economy contributes to the sustainability of cities, in which sharing platforms are driving factors [32]. Sharing data is helpful for manufacturing companies to implement circular strategies [33]. In addition, the sharing vision is important for the local government's contribution to the implementation of the circular economy [34]. Hjaltadóttir and Hild [35] point out that sharing and circularity are both crucial in setting new economic models for the sustainability of the building industry in Europe. The sharing economy has had a considerable impact on the overall environment of many countries through the production side.

Education and income level are closely linked to the preference of sharing economy platform users. Many consumers are motivated by satisfaction, such as saving money or convenience. Sharing economy platforms provide additional choices, particularly to wealthy, educated citizens on the consumer side. In the eyes of many educated people, sharing platforms can act as a way of using a collaborative mindset, while trying to make life easier for users and for others. The findings of Andreotti et al. [36] reveal that the young generation with relatively higher income and higher education are more likely to participate in sharing economy activities. For instance, college graduates are found to

be more likely to use car-sharing or home-sharing platforms. Meanwhile, lower income individuals can enjoy the increased availability of shared services and earn money by providing goods on sharing platforms to generate additional income. A minimum wealth level is necessary to render the platform users' own shareable property and maintain their active participation. Similarly, Eichhorn et al. [37] point out that education level and social capital are linked to digital inequality in the sharing economy.

Of additional interest from a scholarly point of view is the relationship between the sharing economy practices and environmental issues. While some of the existing literature supports the positive impact of sharing practices on the environment, some studies suggest that some sharing economy practices do not favor better environmental performance. In their paper, Bucher et al. [38] find that the sharing economy promotes more sustainable consumption. Ala-Mantila et al. [39], who find that sharing practices raise the awareness of environment quality, also support this view. Meanwhile, Paundra et al. [40] draw attention to the link between sustainability and sharing practices. They posit that, even if it is not intentional, consumers still use sustainable products and services through sharing platforms. Belk [41] argues that some features of the sharing economy are shared in common with hyper-capitalist marketplaces. To some extent, the sharing economy can bring remarkable benefits to society (e.g., environmental, socio-economical, community-related, and consumption-related benefits). For example, in the Chinese construction industry, sharing economy platforms have had a positive impact on the environment [42,43]. Cao and Shen [9] show that there is a negative relationship between the use of bike sharing and CO₂ emissions in Beijing, where the riding distance of shared bikes is one of the most important factors behind the reduction of emissions. Moreover, Chen and Kockelman [10] show that sharing practices have reduced transportation energy use and greenhouse gas emissions by 51% in the United States. For Europe, Rydén and Morin [44] document that car sharing can lead an average decrease of 3000 km per year, and a 40–50% decrease in CO₂ and 28% and 45% reduction in car use in Brussels and Bremen, respectively. Doka and Ziegler [11] compared the environmental impact of privately owned cars and car sharing in Switzerland and concluded that the overall footprint of a shared car is 39% less than that of a privately owned car. In a relatively recent study, Nijland and Meerkerk [6] surveyed car sharing in the Netherlands and their results reveal that there is a 15–20% decrease in car kilometers and 240 to 390 kg reduction in CO₂ per person.

In contrast, some studies argue that the sharing economy has stimulated additional consumption and that the quality of the environment is not really a main concern of sharing economy platform users [45–47]. A similar conclusion comes from Lai and Ho [48], who state that the sharing economy can hardly reduce unnecessary consumption by consumers who are not ready to voluntarily accept an eco-friendly culture. Similarly, Hu et al. [49] argue that only the sharing economy system together with corporate social responsibility practices can effectively lead to a “green” result. Moreover, Tussyadiah and Pesonen [50] suggest that the boost in the accommodation and transportation industries is due to the affordability of the sharing economy. However, the amount of travel has increased significantly, which places more pressure on the environment. In their study, Czepkiewicz et al. [51] found that, although Airbnb has reduced accommodation costs, the carbon footprints of travelers has increased because of additional energy consumption and goods. In another study, Fishman et al. [52] cast some doubts on the sharing economy's environmental benefits. The authors of this paper argue that bike sharing actually increases motor vehicle usage, which can be observed from the reckless use of dockless bike sharing in China.

To ensure the environmental benefits of the sharing economy, the existing literature points to the gap in regulating sharing economy-based industries. Stemler [53] argues that existing laws cannot effectively regulate the sharing economy. Consequently, there is a need to balance the protection of users, service providers, and also of the workers of the existing businesses. Furthermore, Ganapati and Reddick [54] and Baumber et al. [55] suggest that the government should play a significant role in regulating and monitoring the sharing business models. This view is also supported by Mi and Coffman [56], who

state that the government should regulate sharing economy activities and place priority on using taxes from sharing activities to promote sustainability.

3. Methodology and Data

This study first applies OLS regression and it then uses Bayesian regression. Unlike the classic linear regression coefficient estimation, Bayesian analysis treats regression parameters as random variables based on providing entire posterior distribution. This makes the Bayesian analysis superior at dealing with a small sample [57,58].

Denote X as the independent variables. $X = (x_1, x_2, \dots, x_k)'$, where k stands for k variables. x_i ($i \in (1, 2, \dots, k)$) is the $1 \times n$ vector, where n stands for n countries. Denote Y as the environment-dependent variable. The basic Bayesian regression model is written as follows:

$$Y = \alpha + \beta X + \varepsilon \quad (1)$$

In Equation (1), α and β are unknown parameters, $\varepsilon \sim N(0, \sigma^2)$. X and Y are observed samples. According to Bayesian regression method, the joint posterior distribution of α , β , and σ^2 is given as follows:

$$\begin{aligned} P(\alpha, \beta, \sigma^2 | Y, X) &\propto P(\alpha, \beta, \sigma^2) \prod_{m=1}^n p(y_m | \alpha, \beta, \sigma^2, x_m) \\ &\propto P(\alpha, \beta, \sigma^2) \exp \sum_{m=1}^n \left[-\frac{1}{2\sigma^2} (y_m - \alpha - \beta x_m)^2 \right] \end{aligned} \quad (2)$$

where $x_m = (x_1^m, x_2^m, \dots, x_k^m)$. Assume that α , β , and σ^2 are independent of each other. The prior distributions of these parameters are given as $p(\alpha) \propto N(0, 10^4)$, $p(\beta) \propto N(0, 10^4)$, and $p(\sigma^2) \propto \text{Inverse Gamma}(0.01, 0.01)$, respectively. According to conjugate distribution method, the conditional posterior distribution of α can be estimated as $N(\bar{\alpha}, S_0^2)$, where

$$\bar{\alpha} = \frac{1}{n} \sum_{m=1}^n (y_m - \alpha - \beta x_m), \quad S_0^2 = \frac{\sigma^2}{n} \quad (3)$$

Using the same method, we can get the conditional posterior distribution of β is $N(\bar{\beta}, S_1^2)$, where

$$\bar{\beta} = (X'X)^{-1} X'(Y - \alpha), \quad S_1^2 = (X'X)^{-1} \sigma^2 \quad (4)$$

The conditional posterior distribution of σ^2 is still inverse gamma distribution, which can be written as:

$$\sigma^2 \sim \frac{1}{\Gamma} \sum_{m=1}^n (y_m - \alpha - \beta x_m)^2 \quad (5)$$

Following the previous studies [59,60], we use the Markov Chain Monte Carlo (MCMC) to explore the posterior distribution of parameters to solve the bias caused by the small sample and extreme values. We set two variables as a proxy for environmental degradation, which are CO₂ emissions per person and the Environment Performance Index. The key independent variable is the TSEI. X stands for the control variables. The benchmark regression models are designed as follows:

$$\ln CO_2 pc_i = \alpha_0 + \alpha_1 TSEI_i + X\gamma + \mu_i \quad (6)$$

$$EPI_i = \beta_0 + \beta_1 TSEI_i + X\delta + \varepsilon_i \quad (7)$$

In Equations (6) and (7), two dependent variables are used to measure the environmental degradation, which are CO₂ emissions per person ($CO_2 pc$) and EPI , respectively. In previous studies, carbon dioxide has been widely used to measure the quality of the environment (e.g., [15,16]). The EPI data came from the Yale Center for Environmental Law and Policy, which is an index evaluation system that includes 32 performance indicators across 11 issue categories (e.g., air quality, wastewater, agriculture etc.), ranking 180 countries on environmental health and ecosystem vitality (further details can be accessed at epi.yale.edu/, accessed on 20 April 2020). The EPI has a distribution from 0 to 100, which

indicates that the higher values indicate a higher quality environment. The key variable standing for sharing economy is the *TSEI*. Timbro is a famous and large free market think tank that was established in 1978 in Sweden. Given that the sharing economy index was released in 2018, the sampling period only covers the year 2018 for 165 countries. The *TSEI* index takes values ranging from 0 to 100, in which the higher value indicates a higher sharing economy level. This index was compiled using traffic volume data and scraped data. In particular, monthly data were collected for 286 services in 213 countries. For 23 of the 286 services, Timbro used automated web scraping techniques (further details can be found at timbro.se/ekonomi/timbro-sharing-economy-index/, accessed on 18 April 2020).

Following the previous studies, six control variables are included in Equations (6) and (7). The variable of *GDPpc* stands for real GDP per capita, which measures the macro effect on the environment (e.g., [16]). The *Industrial* variable measures the ratio of value added in secondary industry production over GDP, which reflects the impact of the industrial structure on environment (see [61,62]). *Popdensity* is the density of the population, which is found to be highly linked to CO₂ emissions [62,63]. Education is found to be a factor related to the environment [64,65]. This paper uses the average years of schooling of a country to represent the average education level. *Tradefreedom* is the trade freedom index of each country, which is given by the US Heritage Foundation (further details can be found on www.heritage.org/, accessed on 20 April 2020). A higher trade freedom value indicates a higher trade freedom [66]. *Urban* refers to the proportion of people living in urban areas [67]. To overcome the potential endogeneity problem, the lagged values of *GDPpc*, *Industrial*, *Popdensity*, *Education*, and *Tradefreedom* were used (L stands for lagged terms). Equations (6) and (7) can be rewritten as follows.

$$\begin{aligned} \ln CO_2 pc_i = & \alpha_0 + \alpha_1 TSEI_i + \alpha_2 L.Ln(GDPpc)_i + \alpha_3 L.Industrial_i + \alpha_4 L.Popdensity_i \\ & + \alpha_5 L.Education_i + \alpha_6 L.Tradefreedom_i + \alpha_7 L.Urban_i + \mu_i \end{aligned} \quad (8)$$

$$\begin{aligned} EPI_i = & \beta_0 + \beta_1 TSEI_i + \beta_2 L.Ln(GDPpc)_i + \beta_3 L.Industrial_i + \beta_4 L.Popdensity_i \\ & + \beta_5 L.Education_i + \beta_6 L.Tradefreedom_i + \beta_7 L.Urban_i + \varepsilon_i \end{aligned} \quad (9)$$

In further regressions, we set a dummy variable to distinguish different groups of countries. Top10broadband represents the top 10 countries by Internet use per person in 2018. Variable broadband, which is measured by broadband access use per person, was set as an instrument in the robustness check.

The data were extracted from several sources. The carbon dioxide emission data came from the Emissions Database for Global Atmospheric Research (EDGAR) and the *EPI* data were collected from Yale Center for Environmental Law and Policy. *TSEI* is published by Timbro. The trade freedom data for these countries came from the Heritage Foundation database (available at www.heritage.org/, accessed on 20 April 2020). The education data came from “Our World in Data” (ourworldindata.org/, accessed on 18 April 2020). Other data were collected from the World Bank database.

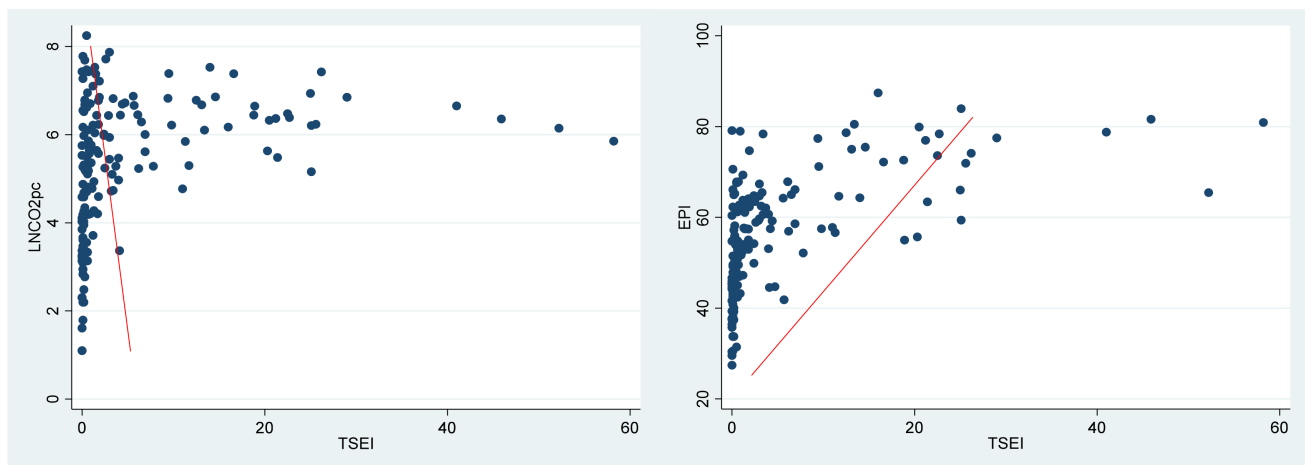
The sample is one of the main limitations of this study because it is not appropriate for time series analyses. *TSEI* data were only available for the year 2018. This led us to deal with cross-sectional data and use regression analyses. The definitions of the variables and summary statistics are given in Table 1.

The scatter graph in Figure 1 shows that, while the relationship between *LnCO₂pc* and *TSEI* is weakly positive, the relationship between *EPI* and *TSEI* is strongly positive. Therefore, it seems that the environmental performance will be better when the sharing economy level is higher. However, the graph also suggests that, while the sharing index is high, the carbon emissions also appear to be high. Further evidence will be presented in the empirical part of this paper.

Table 1. Variable definition and summary statistics.

Variable	Definition	Unit	Mean	S.D.	Max	Min	Have
CO_2pc	CO ₂ emissions per person	Kilo/person	4758.848	5962.382	38,190.000	30.000	165
EPI	Environment performance level	-	56.182	12.942	87.420	27.430	165
$TSEI$	Sharing economy level	-	5.178	9.800	58.200	0.000	165
$GDPpc$	Real GDP per capita	USD/person	13,697.560	19,535.760	109,453.000	214.140	165
Industrial	Value added in secondary industry/GDP	%	26.817	11.998	77.541	2.311	165
Popdensity	Population density	Thousand/sq.km	0.202	0.658	7.916	0.002	165
Education	Average years of schooling	Year	8.505	3.137	14.100	1.500	165
Tradefreedom	Trade freedom level	-	75.721	10.686	90.000	40.000	165
Urban	Urban population/total population	%	58.676	22.268	100.000	12.706	165
Top10broadband ^a	Dummy variable, Top10 Broadband access use per person countries in the world = 1, otherwise = 0	-	0.061	0.239	1	0	165
Broadband	Broadband access use per person	-	0.126	0.135	0.463	1×10^{-5}	165

Note: ^a According to the World Bank's WDI database, the top 10 countries ranked by broadband access per person in 2018 were Switzerland, France, the Netherlands, South Korea, Malta, Norway, Germany, Sweden, the United Kingdom, and Belgium.

**Figure 1.** Scatter graph for the relationships of $LnCO_2pc$ -TSEI and EPI -TSEI.

4. The Empirical Findings

4.1. OLS Regression Results and Model Selection

Tables 2 and 3 report the benchmark regression results using OLS linear regression model (We used an OLS bootstrap regression (500 times) method as a robustness check and our results remained the same. The results are available from the authors upon request). While $TSEI$ is negatively correlated with CO₂ emission, it is positively correlated with overall environmental performance (EPI). Regressions (1)–(6) in Tables 2 and 3 provide stable results for the independent variables. This paper further checks the existence of a heterogenous problem by using B-P test and White test. The results are given in Table 4. Both tests show no heteroscedasticity in the regressions.

Table 2. The sharing economy level and carbon emissions using OLS.

	(1) <i>LnCO₂pc</i>	(2) <i>LnCO₂pc</i>	(3) <i>LnCO₂pc</i>	(4) <i>LnCO₂pc</i>	(5) <i>LnCO₂pc</i>	(6) <i>LnCO₂pc</i>
<i>TSEI</i>	−0.028 *** (0.006)	−0.018 *** (0.007)	−0.018 *** (0.007)	−0.017 *** (0.006)	−0.017 *** (0.006)	−0.017 *** (0.006)
LnGDPpc	1.030 *** (0.044)	0.971 *** (0.045)	0.977 *** (0.045)	0.753 *** (0.065)	0.758 *** (0.066)	0.654 *** (0.078)
Industrial		0.018 *** (0.005)	0.018 *** (0.005)	0.021 *** (0.005)	0.021 *** (0.005)	0.020 *** (0.005)
Popdensity			−0.061 (0.081)	−0.027 (0.076)	−0.024 (0.077)	−0.036 (0.076)
Education				0.123 *** (0.027)	0.129 *** (0.028)	0.130 *** (0.028)
Tradefreedom					−0.004 (0.006)	−0.002 (0.006)
Urban						0.008 ** (0.003)
Constant	−8.005 *** (0.364)	−8.044 *** (0.350)	−8.071 *** (0.352)	−7.284 *** (0.374)	−7.080 *** (0.486)	−6.779 *** (0.496)
Observations	165	165	165	165	165	165
R-squared	0.797	0.814	0.815	0.836	0.837	0.842

Note: ** significant at 5%; *** significant at 1%; values in parentheses are standard deviations.

Table 3. The sharing economy and overall environmental performance using OLS.

	(1) <i>EPI</i>	(2) <i>EPI</i>	(3) <i>EPI</i>	(4) <i>EPI</i>	(5) <i>EPI</i>	(6) <i>EPI</i>
<i>TSEI</i>	0.213 *** (0.060)	0.120 * (0.063)	0.111 * (0.062)	0.114 * (0.060)	0.105 * (0.059)	0.107 * (0.059)
LnGDPpc	6.942 *** (0.407)	7.487 *** (0.416)	7.659 *** (0.416)	6.280 *** (0.617)	6.102 *** (0.610)	5.392 *** (0.731)
Industrial		−0.170 *** (0.044)	−0.181 *** (0.044)	−0.163 *** (0.043)	−0.157 *** (0.043)	−0.166 *** (0.043)
Popdensity			−1.789 ** (0.739)	−1.579 ** (0.725)	−1.679 ** (0.714)	−1.758 ** (0.710)
Education				0.759 *** (0.255)	0.548 ** (0.264)	0.557 ** (0.262)
Tradefreedom					0.141 *** (0.055)	0.153 *** (0.055)
Urban						0.056 * (0.032)
Constant	−4.572 (3.389)	−4.209 (3.256)	−4.980 (3.223)	−0.132 (3.545)	−7.561 * (4.521)	−5.502 * (4.646)
Observations	165	165	165	165	165	165
R-squared	0.754	0.774	0.782	0.794	0.802	0.806

Note: * significant at 10%; ** significant at 5%; *** significant at 1%. Values in parentheses are standard deviations.

Table 4. Results of the heteroscedasticity test of the OLS linear regression model.

	<i>LnCO₂pc</i>	<i>EPI</i>
Breusch–Pagan/Cook–Weisberg test	1.95 (0.1630)	1.91 (0.1675)
White test	45.56 (0.1091)	30.04 (0.7064)

Note: The values in the table are chi-squared statistics for Breusch–Pagan/Cook–Weisberg test and White test. Values in parentheses are probabilities corresponding to the statistics.

We then have a normal distribution check on the residuals of the two regressions. The results are presented in Figure 2, suggesting that the residual distributions are not normally distributed. To get more accurate results, this paper applies a Bayesian regression model, which is based on posterior distribution, to solve the distribution problem.

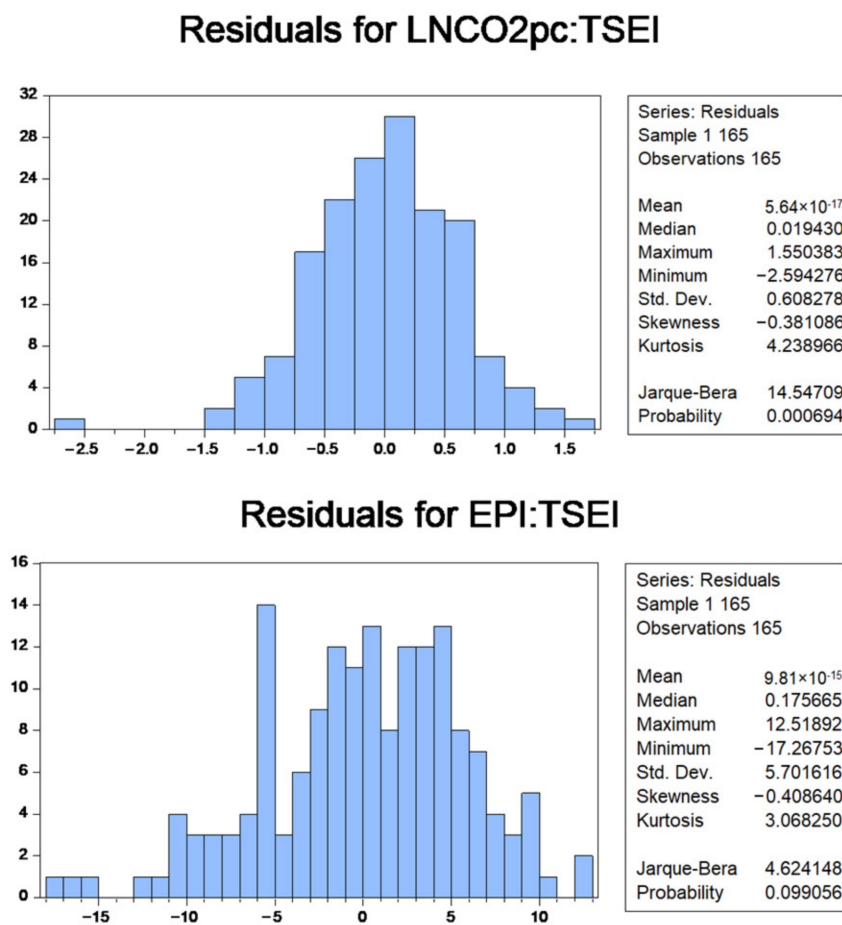


Figure 2. Normal distribution test of OLS linear regression model.

4.2. Benchmark Regression Results with a Bayesian Model

This paper used Gibb's sampling with 12,500 MCMC iterations on the sample, while excluding the first 2500 samples to avoid the biased influence on the initial value (The unreported Pearson correlation test indicates multicollinearity between GDPpc and Education (with a correlation value of 0.807). However, the Bayesian regression is free of the multicollinearity problem. The results are available upon request.) The benchmark regression results of the Bayesian model are given in Table 5.

Table 5. The sharing economy level, carbon emissions, and overall environmental performance.

	<i>LnCO₂pc</i>				<i>EPI</i>			
	Mean	S.D.	MCSE	95% Cred Interval	Mean	S.D.	MCSE	95% Cred Interval
<i>TSEI</i>	-0.017	0.006	0.000	[-0.029, -0.005]	0.107	0.059	0.001	[0.012, 0.223]
LnGDPpc	0.655	0.079	0.001	[0.499, 0.807]	5.401	0.734	0.007	[3.969, 6.846]
Industrial	0.020	0.005	0.000	[0.011, 0.029]	-0.165	0.043	0.000	[-0.249, -0.082]
Popdensity	-0.036	0.077	0.001	[-0.185, 0.116]	-1.749	0.719	0.007	[-3.181, -0.344]
Education	0.130	0.028	0.000	[0.075, 0.185]	0.556	0.259	0.003	[0.037, 1.060]
Tradefreedom	-0.002	0.006	0.000	[-0.014, 0.009]	0.153	0.054	0.001	[0.047, 0.259]
Urban	0.008	0.003	0.000	[0.001, 0.015]	0.056	0.032	0.000	[-0.007, 0.121]
C	-6.782	0.501	0.005	[-7.764, -5.803]	-5.595	4.640	0.046	[-14.423, 3.699]

Table 5 reports the Bayesian results for the value of mean, posterior standard deviation (S.D.), MCSE, and 95% credible interval. The results indicate low Monte Carlo standard errors (MCSEs) in both models, which suggests that the parameter estimated by the MCMC simulation is stable. Furthermore, given that MCSE is a function of the number of iterations

in the simulation, using 12,500 iterations is an appropriate choice. In Table 5, *TSEI* shows a negative relationship with *LnCO₂pc*. The mean of *TSEI* is -0.018 . The estimation range of the posterior mean for *TSEI* is $[-0.030, -0.006]$. This suggests that high sharing economy index reduces carbon emissions. For environmental performance, the sharing economy index still has a positive correlation with a mean of 0.102 , and the 95% credit interval falls between 0.014 and 0.221 . This result indicates that high sharing economy level can help to improve the general environment quality.

The findings in Table 5 show that *LnGDPpc* has a positive impact on the dependent variables. Developed countries with higher GDP per capita usually have a heavier burden to decrease CO₂ emissions than developing countries. However, the overall environment of developed countries is, on average, better than that of developing countries. Table 5 presents that, while the industrial variable has a positive relationship with *LnCO₂pc*, it has a negative relationship with *EPI*. This result posits that a higher proportion of the industry sector is associated with higher CO₂ emissions and lower environmental performance. The reason for this is that the industrial sector is dominated by manufacturing of finished products, while high carbon emissions and low environmental performance indicate environmental degradation. Similar to previous studies [67], a high education level has a positive effect on carbon emissions. Therefore, education has a positive relationship with *EPI*. Furthermore, *Urban* also has positive impact on carbon emission proxy variables. Consistent with Madlener and Sunak [68], urbanization will aggravate air pollution, due to high energy consumption and low efficiency.

Regarding the *Popdensity*, the results show that higher population density is linked to lower carbon emissions. In fact, the dense clustering of people enables economies of scale through providing goods and services more cost effectively. Infrastructures in urban areas enable people to benefit from shared services and thus induce lower environmental degradation. Consequently, countries with large population densities may have lower carbon emissions in comparison with suburban areas. This can be attributed to public transport services and walking accessibility. Large cities with a high population density tend to have more comprehensive transit systems and lower reliance on personal vehicles. In particular, vehicular population decreases because people live closer together in densely populated areas [69–71]. It is also important to note that, overall, a dense population threatens the environment through the consumption of resources. Finally, the findings on trade freedom suggest that free trade decreases the carbon emission and increases environmental performance. In line with the argument of Grossman and Krueger [66], international trade brings new technology, which helps the home country to improve production efficiency and decrease the energy consumption.

Figure 3 illustrates the efficiency check of MCMC simulation of *TSEI* to *LnCO₂pc*. The vast majority of the lines drawn in the trace graph are vertical and dense. This indicates that the MCMC chain does not have convergence problems. The autocorrelation problem does not exist. The histogram plot shows a normal distribution of marginal posterior, which is consistent with our assumption for prior distribution. In the density graph, the three density curves are close to each other. This suggests that the MCMC chain has converged and mixed well. Figure 4 reports similar results of effective convergence for the MCMC simulation of *TSEI* to *EPI*.

4.3. Joint-Effect Analysis with a Bayesian Model

Given that the sharing economy is highly dependent on the information and Internet technology [72], it is important to measure the impact of this joint variable on the environment. Table 6 documents the results for the variable of *TSEI*Top10broadband* (Because the broadband access level has significant impact on the *TSEI* (see the report “Timbro sharing economy index”, pages 34 and 35), we set a dummy variable of Top10broadband access countries instead of taking it as a continuous variable at the expense of the selection bias problem), which represents the joint effect of sharing economy level and Internet usage per person. The results show that *TSEI*Top10broadband* variable is negatively associated

with $\ln CO_2pc$, with a 95% credible interval estimation range of $[-0.037, -0.003]$. This implies that broadband access supports sharing economy activities, and thus helps to decrease carbon emissions. The next thing to consider is the impact of this joint variable on overall environmental performance. At this point, the $TSEI*Top10broadband$ variable has a positive impact on EPI (with a mean of 0.179) with a 95% credible interval estimation range of $[0.016, 0.347]$. This result supports the notion again that broadband access enhances the sharing economy activities, and thus helps to improve the overall environmental performance.

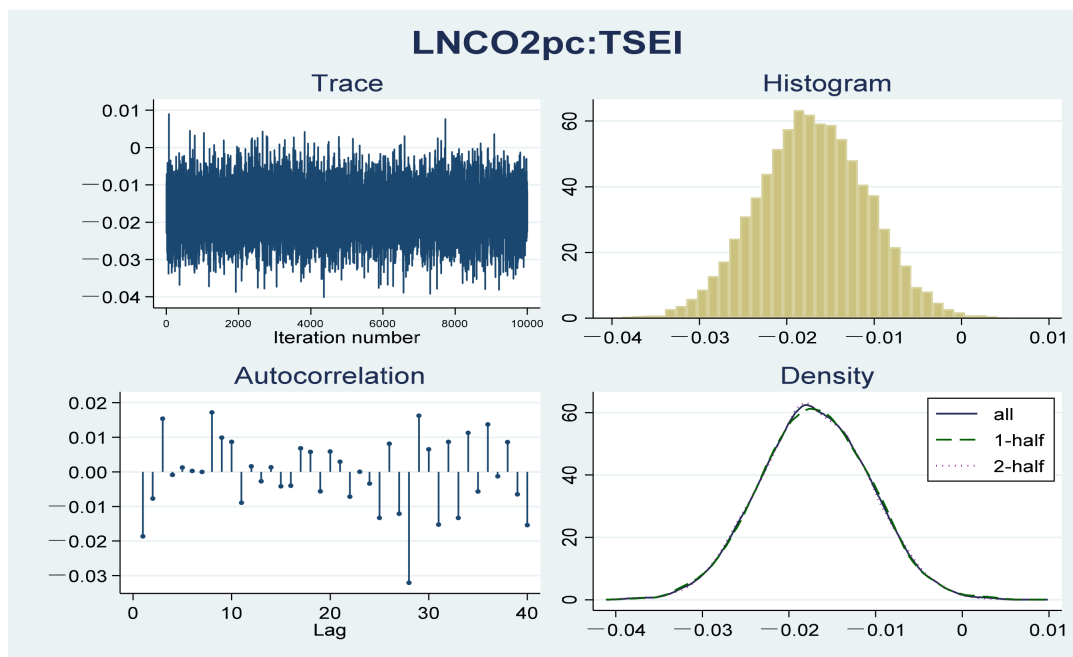


Figure 3. An efficiency check of the MCMC simulation of $TSEI$ to $\ln CO_2pc$.

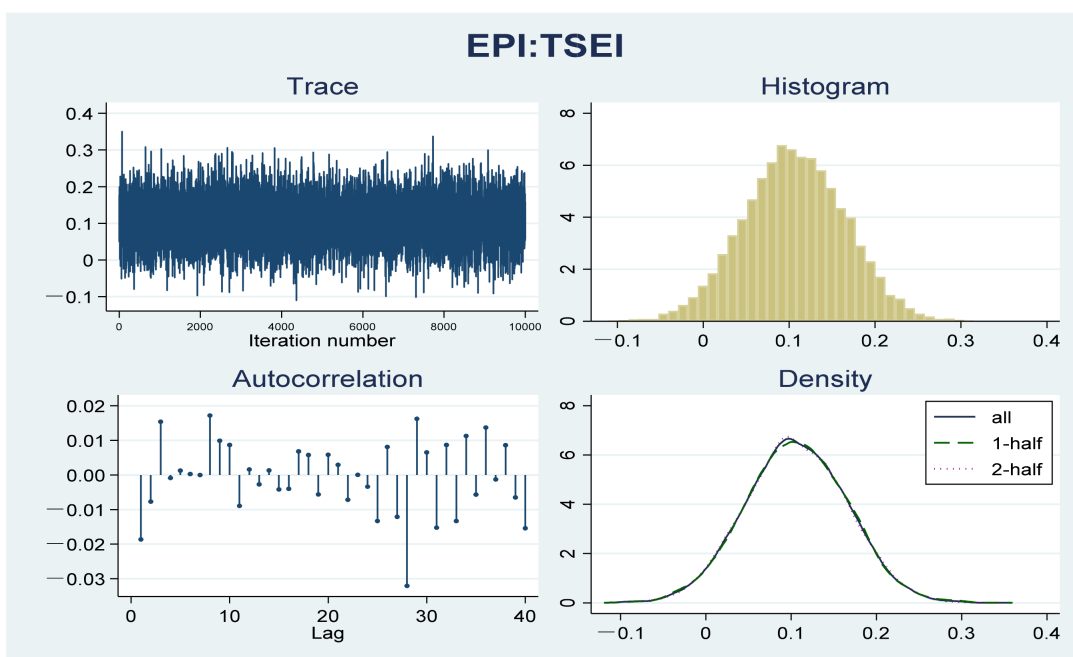


Figure 4. An efficiency check of the MCMC simulation of $TSEI$ to EPI .

Table 6. Joint effect of *TSEI* and Internet popularity on carbon emissions and overall environmental performance.

	<i>LnCO₂pc</i>				<i>EPI</i>			
	Mean	S.D.	MCSE	95% Cred Interval	Mean	S.D.	MCSE	95% Cred Interval
<i>TSEI</i>	−0.006	0.007	0.000	[−0.020, 0.008]	0.030	0.070	0.001	[−0.106, 0.165]
<i>TSEI</i> × Top10 broadband	−0.024	0.009	0.000	[−0.042, −0.007]	0.170	0.085	0.001	[0.005, 0.338]
LnGDPpc	0.648	0.077	0.001	[0.498, 0.800]	5.428	0.721	0.007	[4.035, 6.845]
Industrial	0.020	0.004	0.000	[0.011, 0.029]	−0.168	0.043	0.000	[−0.250, −0.084]
Popdensity	−0.023	0.075	0.001	[−0.171, 0.126]	−1.837	0.717	0.007	[−3.237, −0.439]
Education	0.127	0.028	0.000	[0.072, 0.181]	0.586	0.261	0.003	[0.074, 1.103]
Tradefreedom	−0.002	0.006	0.000	[−0.013, 0.009]	0.151	0.055	0.001	[0.045, 0.258]
Urban	0.009	0.003	0.000	[0.002, 0.016]	0.050	0.032	0.000	[−0.013, 0.114]
C	−6.796	0.492	0.005	[−7.770, −5.828]	−5.386	4.593	0.047	[−14.362, 3.637]

Table 7 shows the joint effect of variable *TSEI*Urban* on carbon emissions and overall environmental performance. *TSEI*Urban* has a negative impact on *LnCO₂pc* with a 95% credible interval estimation range of [−0.001, −0.000], which supports the notion that urbanization tends to enhance the negative effect of the sharing economy level on carbon emissions. Sharing economy activities can reduce transaction costs and create more social values [73]. The *Urban* variable has a positive impact on *LnCO₂pc*, which suggests that the development of the sharing economy is a possible solution to limit carbon emissions. The *EPI* result also shows that *TSEI*Urban* has a positive mean with a 95% credible interval estimation ranging from −0.002 to 0.010. An increase in sharing economy activities contributes to the sustainability of cities.

Table 7. Joint effect of *TSEI* and urbanization on carbon emission and overall environmental performance.

	<i>LnCO₂pc</i>				<i>EPI</i>			
	Mean	S.D.	MCSE	95% Cred Interval	Mean	S.D.	MCSE	95% Cred Interval
<i>TSEI</i>	0.050	0.025	0.000	[0.002, 0.097]	−0.209	0.238	0.002	[−0.676, 0.259]
<i>TSEI</i> × Urban	−0.001	0.000	0.000	[−0.001, −0.000]	0.004	0.003	0.000	[−0.002, 0.010]
LnGDPpc	0.638	0.077	0.001	[0.484, 0.792]	5.478	0.735	0.007	[4.036, 6.900]
Industrial	0.019	0.004	0.000	[0.010, 0.028]	−0.162	0.043	0.000	[−0.246, −0.079]
Popdensity	−0.017	0.075	0.001	[−0.165, 0.129]	−1.832	0.718	0.007	[−3.241, −0.437]
Education	0.124	0.027	0.000	[0.070, 0.178]	0.583	0.266	0.003	[0.062, 1.111]
Tradefreedom	−0.002	0.006	0.000	[−0.013, 0.010]	0.152	0.056	0.001	[0.042, 0.262]
Urban	0.011	0.004	0.000	[0.004, 0.018]	0.040	0.034	0.000	[−0.027, 0.107]
C	−6.794	0.488	0.005	[−7.750, −5.844]	−5.486	4.644	0.046	[−14.461, 3.665]

Table 8 reports the impact of *TSEI*Education* joint variable on both air quality and overall environmental performance. Education level can be used as a proxy to indicate the public's ability to adapt to a new technology or a new lifestyle, which also makes sense for the sharing economy activities (e.g., providing accessible communication between organizations and their users) [74]. Therefore, a joint variable of *TSEI*Education* was used to examine whether or not education together with sharing economy level contributes to a greener environment. The findings suggest that the interaction variable of *TSEI*Education* has a posterior mean of −0.002 and a 95% credible interval estimation range of [−0.003, −0.001] for *LnCO₂pc*. This result implies that a high education level together with a high sharing economy index lowers carbon emissions. Countries with high sharing economy index scores and a high education level tend to decrease carbon emissions and increase environmental performance, mainly because education raises awareness about the environment.

Table 8. Joint effect of *TSEI* and education on carbon emissions and overall environmental performance.

	<i>LnCO₂pc</i>				<i>EPI</i>			
	Mean	S.D.	MCSE	95% Cred Interval	Mean	S.D.	MCSE	95% Cred Interval
<i>TSEI</i>	0.110	0.039	0.000	[0.033, 0.187]	0.016	0.388	0.004	[−0.755, 0.761]
<i>TSEI</i> × Education	−0.011	0.003	0.000	[−0.018, −0.004]	0.008	0.033	0.000	[−0.056, 0.075]
LnGDPpc	0.639	0.077	0.001	[0.488, 0.789]	5.391	0.744	0.007	[3.910, 6.866]
Industrial	0.022	0.004	0.000	[0.013, 0.031]	−0.167	0.043	0.000	[−0.255, −0.083]
Popdensity	−0.043	0.074	0.001	[−0.188, 0.104]	−1.763	0.713	0.007	[−3.181, −0.376]
Education	0.150	0.028	0.000	[0.096, 0.206]	0.547	0.271	0.003	[0.014, 1.077]
Tradefreedom	−0.002	0.006	0.000	[−0.013, 0.010]	0.153	0.055	0.001	[0.045, 0.261]
Urban	0.008	0.003	0.000	[0.001, 0.014]	0.056	0.033	0.000	[−0.008, 0.120]
C	−6.889	0.482	0.005	[−7.848, −5.933]	−5.359	4.707	0.047	[−14.517, 3.936]

In spite of the fact that large manufacturing countries usually have more CO₂ emissions (see the CO₂ emissions data of World Bank database), the current study is particularly interested in whether or not a high sharing economy level can decrease the negative impact of manufacturing on the environment. Therefore, this paper used a joint variable of *TSEI*Urban*Industrial* to examine the interactive impact of the sharing economy level together with urbanization and manufacturing level. The results given in Table 9 indicate that the joint variable of *TSEI*Urban*Industrial* is negatively associated with CO₂ emissions. It is clear that the *industrial* variable has a negative impact on the environment. Surprisingly, the findings show that the manufacturing countries with a high sharing economy index together with high urbanization have comparatively low carbon emissions. The result of *EPI* shows that *TSEI*Urban*Industrial* has a positive mean. This result documents that major manufacturing countries (i.e., China, the USA, Japan, Germany, Korea, India, Italy, France, the UK, and Brazil) contribute positively to the overall environmental performance, due to their environmentally friendly high value-added production and high-tech policy implications. Another possible explanation is that people are motivated by environmental benefits offered by sharing economy activities, claiming reduced environmental hazards [75]. Contrary to expectations, the major manufacturing countries with high sharing economy practices and high urbanization have comparatively low carbon emissions and high environmental performance. This finding underlines the importance of sharing economy practices in large manufacturing-oriented countries, where people can also easily access sharing economy platforms.

Table 9. Joint effect of *TSEI*, urbanization, and industrialization on carbon emissions and overall environmental performance.

	<i>LnCO₂pc</i>				<i>EPI</i>			
	Mean	S.D.	MCSE	95% Cred Interval	Mean	S.D.	MCSE	95% Cred Interval
<i>TSEI</i>	0.024	0.015	0.000	[−0.005, 0.052]	0.060	0.139	0.001	[−0.217, 0.337]
<i>TSEI</i> × Urban * <i>Industrial</i>	-3×10^{-5}	0.000	0.000	$[-5 \times 10^{-5}, -1 \times 10^{-5}]$	-3×10^{-5}	0.000	0.000	$[-1 \times 10^{-4}, 2 \times 10^{-4}]$
LnGDPpc	0.675	0.077	0.001	[0.526, 0.828]	5.357	0.736	0.007	[3.909, 6.824]
Industrial	0.022	0.005	0.000	[0.013, 0.031]	−0.168	0.043	0.000	[−0.253, −0.083]
Popdensity	−0.050	0.075	0.001	[−0.196, 0.099]	−1.736	0.715	0.007	[−3.131, −0.335]
Education	0.127	0.027	0.000	[0.074, 0.181]	0.565	0.265	0.003	[0.037, 1.080]
Tradefreedom	−0.001	0.006	0.000	[−0.012, 0.010]	0.151	0.056	0.001	[0.041, 0.259]
Urban	0.009	0.003	0.000	[0.002, 0.015]	0.055	0.033	0.000	[−0.008, 0.120]
C	−7.105	0.502	0.005	[−8.094, −6.117]	−5.010	4.802	0.049	[−14.587, 4.378]

Similarly, this paper used a joint variable of *TSEI*Education*Industrial* to examine the relationship between the sharing economy level, education level, and manufacturing on carbon emissions and environmental performance (see Table 10). The result of the joint variable has a mean of -1×10^{-5} negative impact on CO₂ emissions. Given that both the *Education* and *Industrial* variables have positive relationship with *LnCO₂pc*, it is clear that a

high level of sharing economy and education in manufacturing countries can be helpful to limit carbon emissions.

Table 10. Joint effect of *TSEI*, education, and industrialization on carbon emissions and overall environmental performance.

	<i>LnCO₂pc</i>				<i>EPI</i>			
	Mean	S.D.	MCSE	95% Cred Interval	Mean	S.D.	MCSE	95% Cred Interval
<i>TSEI</i>	−0.006	0.013	0.000	[−0.018, 0.031]	0.110	0.120	0.001	[−0.123, 0.351]
<i>TSEI</i> × Education	−1 × 10 ^{−5}	0.000	0.000	[−2 × 10 ^{−4} , −8 × 10 ^{−6}]	−1 × 10 ^{−5}	0.000	0.000	[−9 × 10 ^{−4} , 9 × 10 ^{−4}]
*Industrial								
LnGDPpc	0.666	0.078	0.001	[0.513, 0.818]	5.382	0.734	0.007	[3.942, 6.847]
Industrial	0.022	0.005	0.000	[0.012, 0.031]	−0.165	0.045	0.000	[−0.255, −0.077]
Popdensity	−0.048	0.076	0.001	[−0.199, 0.098]	−1.762	0.719	0.007	[−3.161, −0.324]
Education	0.135	0.028	0.000	[0.078, 0.188]	0.564	0.264	0.003	[0.047, 1.079]
Tradefreedom	−0.002	0.006	0.000	[−0.013, 0.010]	0.152	0.056	0.001	[0.043, 0.261]
Urban	0.007	0.003	0.000	[0.000, 0.014]	0.056	0.033	0.000	[−0.009, 0.121]
C	−6.948	0.497	0.005	[−7.928, −5.966]	−5.427	4.759	0.048	[−14.935, 3.935]

4.4. Robustness Check

Table 11 reports the robustness results. The countries with 0 *TSEI* were excluded from the sample and the analyses were re-run. The findings show the posterior mean of *TSEI* is negative (−0.015), with a 95% credible interval ranging from −0.026 to −0.003. *TSEI* has a positive posterior mean (0.121), with a 95% credible interval range from 0.012 to 0.229. Overall, the results are similar to those reported in Table 5, even if the countries with 0 *TSEI* were excluded. The efficiency checks of the MCMC simulation also gave similar results. The graphs are illustrated in the Appendix A (Figures A1 and A2).

Table 11. Robustness check of excluding the zero *TSEI* sample.

	<i>LnCO₂pc</i>				<i>EPI</i>			
	Mean	S.D.	MCSE	95% Cred Interval	Mean	S.D.	MCSE	95% Cred Interval
<i>TSEI</i>	−0.014	0.006	0.000	[−0.026, −0.002]	0.114	0.061	0.001	[0.005, 0.232]
LnGDPpc	0.620	0.083	0.001	[0.454, 0.782]	4.787	0.817	0.008	[3.172, 6.373]
Industrial	0.023	0.005	0.000	[0.013, 0.032]	−0.166	0.046	0.000	[−0.257, −0.074]
Popdensity	−0.030	0.073	0.001	[−0.173, 0.113]	−1.436	0.724	0.007	[−2.866, −0.035]
Education	0.127	0.029	0.000	[0.069, 0.186]	0.726	0.283	0.003	[0.169, 1.273]
Tradefreedom	−0.004	0.006	0.000	[−0.016, 0.007]	0.187	0.058	0.001	[0.072, 0.301]
Urban	0.008	0.003	0.000	[0.001, 0.015]	0.051	0.034	0.000	[−0.016, 0.119]
C	−6.321	0.534	0.005	[−7.373, −5.282]	−4.072	5.246	0.052	[−14.265, 6.221]

Note: The sample size was reduced to 147 after excluding countries with 0 *TSEI*.

To test whether the potential endogeneity problem (the sharing economy variable might be correlated with causally important omitted variables in the error term) makes the regression biased, this paper used the *Broadband* variable as an instrument, with 2SLS (two stage least square) (because Markov Chain Monte Carlo is used to explore the posterior distribution, the instrument variable cannot be involved in the Bayesian regression) as a robustness check. Regressions (1) and (2) of Table 12 report the results for *LNCO₂pc* in the first- and second-stage regressions. Regressions (3) and (4) provide the results for the *EPI*. The results in the second stage are similar to the results of the Bayesian regressions, in which *TSEI* has negative relationship with CO₂ emissions and a positive impact on the overall environmental performance. The regressions with the instrument support the robustness of the Bayesian regressions.

Table 12. Robustness check with 2SLS.

	(1)	(2)	(3)	(4)
	2SLS—First	2SLS—Second	2SLS—First	2SLS—Second
	<i>TSEI</i>	<i>LnCO₂pc</i>	<i>TSEI</i>	<i>EPI</i>
<i>TSEI</i>		−0.053 ** (0.025)		0.320 (0.223)
Broadband	30.544 *** (8.761)		30.544 *** (8.761)	
Constant	−8.447 (7.314)	−7.652 *** (0.790)	−8.447 (7.314)	−0.370 (7.006)
Control variables	YES	YES	YES	YES
Observations	165	165	165	165
R-squared	0.423	0.809	0.423	0.790
F-statistic	16.470		16.470	

Note: ** significant at 5%; *** significant at 1%; values in parentheses are standard deviations.

5. Conclusions

Using cross-country data from 165 countries and Bayesian analysis, this paper addresses the impact of the sharing economy level on CO₂ emissions and overall environmental performance. The findings reveal that while a high sharing economy level is negatively associated with CO₂ emissions, it is positively associated with overall environmental performance. Using cross-sectional analysis, the results lead us to conclude that sharing activities help to improve the environment more than the negative effect from additional consumption stimulated by the sharing economy practices [9,10,30,41]. Our analysis further suggests that, while secondary industries and population density have a negative impact on environmental performance, high income, education, and trade freedom improve the quality of the environment. These results support the view that countries with a high population and a high portion of secondary industries threaten the environment. In addition, the results show that trade freedom improves both air quality and overall environmental performance.

The results of the joint effect of sharing economy level with countries' characteristics have interesting results for policy implications. As expected, the joint effect of both urbanization and the education level with the sharing economy index is negative on carbon emissions and positive on overall environmental performance. Sharing economy platforms are more popular when there are high levels of urbanization and education [36,37,66]. Moreover, Internet access enhances the impact of the sharing economy index on environment quality, which is consistent with the common expectation that online sharing activities highly depend on Internet broadband access [65]. One of the striking findings of this paper is that a high sharing economy index together with high urbanization or high education level in manufacturing countries tends to lead to comparatively low carbon emissions and high overall environmental performance. This finding can be attributed to the production policies of the main manufacturing countries. In particular, many of these countries are developed nations and are likely to invest in more technology. The other countries are emerging economies, which are moving from labor-intensive to capital-intensive manufacturing.

An immediate implication of this paper is that we can recommend that policy makers and practitioners should move beyond traditional ownership and consumption patterns to understand the impact of the sharing economy level on the environment. The findings suggest that environmental degradation can decrease when the high sharing economy level becomes an integral part of society thanks to broadband access and education level.

For future studies, it would be interesting to investigate in greater depth in which industries and how the sharing economy practices could reduce environmental degradation. In this context, policy makers should provide guidelines to regulate sharing economy

business models, together with changing ownership and consumption patterns, to improve the quality of the environment.

6. Limitations

Sample size was the limitation of the current study. Unfortunately, *TSEI* data are only available for the year 2018 and this leads us to deal with cross-sectional data and use regression analyses. The data from Timbro have not yet been updated. Hence, we cannot carry out further analyses using time series or panel data. However, based on the available current cross-sectional data, this paper tries its best to fill the gap in the existing literature given that only a very few studies have attempted to estimate the impact of the sharing economy practices on the environment at a national level. It also gives an example for further studies.

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Data Availability Statement: Data that we used in the paper are attached.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

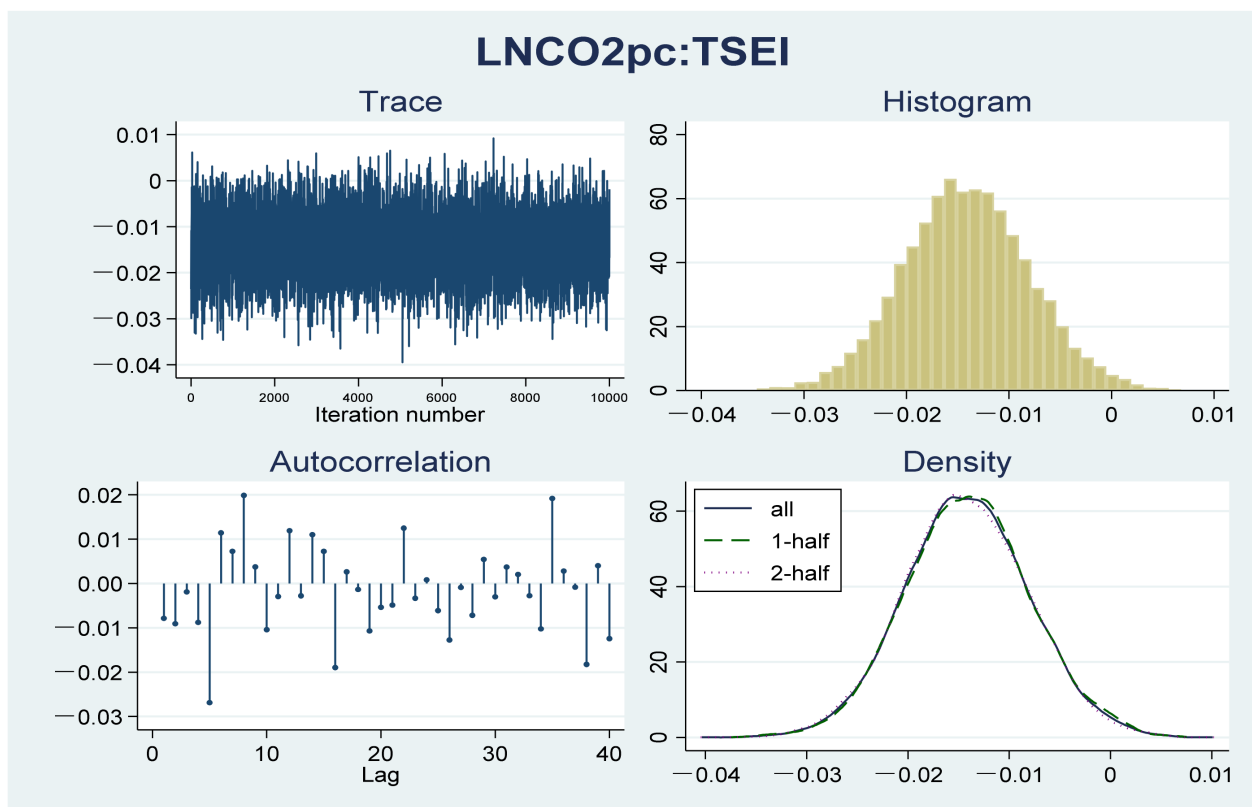


Figure A1. Efficiency check for the MCMC simulation of *TSEI* to $LnCO_2pc$ when excluding the *TSEI* zero sample.

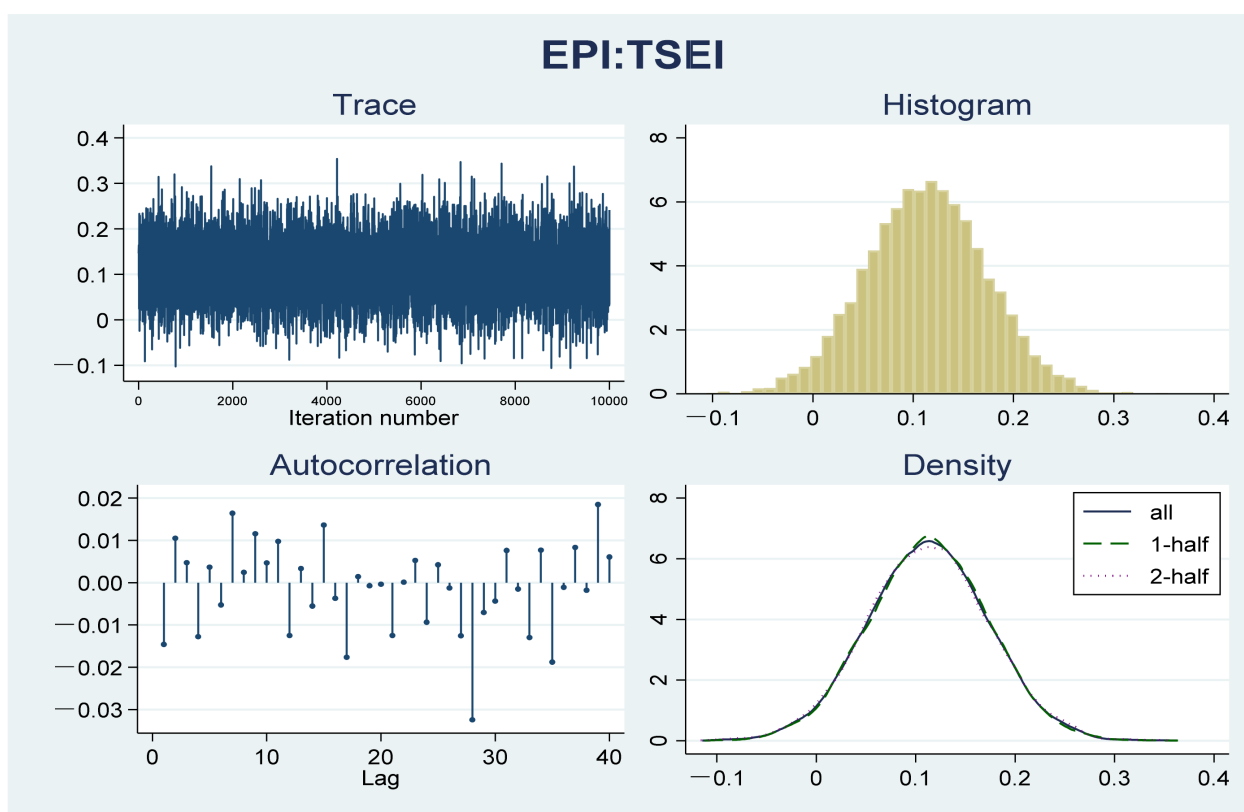


Figure A2. Efficiency check for the MCMC simulation of *TSEI* to *EPI* when excluding the *TSEI* zero sample.

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