Spatial Effects of Energy Consumption and Green GDP in Regional Agreements

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Abstract: One of the main factors in environmental degradation and climate change is the consumption of fossil fuels. For this reason, cooperation between countries to overcome environmental challenges is seen more than ever. In this regard, regional economic treaties are a good platform for advancing common policies in the development of renewable energy, because this type of energy has fewer external effects on the environment. Accordingly, the purpose of this paper is to investigate the spatial effects of energy consumption and green production in Shanghai Cooperation Organization member states. For this purpose, the spatial panel data econometric approach has been used. Spatial effects refer to the effects of neighboring countries. According to CO₂ emissions, the spatial effects of the positive or negative effects of these emissions and other determinants of neighboring countries are local. The results show that although both fossil fuels and renewable energy have a negative effect on green GDP, the impact of fossil fuels is almost four times greater. On the other hand, proximity and membership in the Shanghai Cooperation Organization have had a positive effect on green GDP in member countries, as countries have tried to coordinate their development policies in the field of renewable energy. Therefore, the development and strengthening of regional cooperation can play an effective role in controlling pollution caused by fossil fuel consumption and ultimately improve green production.

Keywords: green GDP; renewable energy; spatial effect; Shanghai Cooperation Organization

1. Introduction

Continuous use of fossil fuels leads to increased carbon levels in the atmosphere, global warming, and climate change [1]. Because of global warming, the use of renewable energy as an alternative to current energy sources has received much attention in many developing countries [2]. Currently, the renewable energy industry has received more and much attention from governments, companies and scientists in the world because of concerns caused by health problems, economic damage, climate change, sustainability issues, and fossil energy consumption. In addition, the renewable energy industry, as an emerging green industry, has a new mode of economic growth that can partially resolve or curb the negative effects of fossil energy consumption and create sustainable development methods [3]. The importance of renewable resources depends on their ability to provide security and energy independence and to create additional employment [4]. The use of renewable energy technologies is very widespread in developing countries due to ease of access, cheapness and reliability [5]. Also, renewable energies can protect regional economies against rising future prices of ordinary fuels by diversifying the energy basket. Most developing countries have a natural advantage in using these resources due to the abundance of renewable energy sources. This results in renewability being economically competitive as a solution to the energy challenges of developing countries, even in competition with rising types of traditional energy prices [6]. In addition, it should be noted that the use of different forms of renewable energies such as solar energy or wind power in one country, does not prevent other countries from using those types of energy sources [7].
Most pathways to a low carbon economy would require a rapid deployment of renewable energy and the doubling of energy efficiency, given that the energy sector accounts for two thirds of global emissions [8]. The protection of the environment and climate change promote the use of renewable energy. Renewable energy technologies could offer competitive cost options for the delivery of modern energy services in remote areas, while innovation and scale merit the continued achievement of cost savings [9]. On the other hand, renewable energy sources can be controlled regionally and do not require advanced energy transmission systems. In other words, all different regions of a country in terms of energy resources can be connected to each other through lines or other means of energy transmission. Based on this, countries can choose the type of energy used in that region with correct and logical planning, based on the characteristics of each region, and solve the problem of energy supply safely and with targeted investment and high efficiency. Also, this type of energy, in addition to its favorable effects, such as reducing the use of fossil fuels and consequently reducing greenhouse gas emissions and environmental pollutants, has adverse effects such as changes in the ecosystem of the region and population displacement caused by Hydropower plants, noise pollution, surface and groundwater pollution. These create thermal pollution, chemical pollution, and biological [10]. Renewable energy was estimated to be the fastest growing source of energy during the years 2003–2012 [11]. It is predicted that the use of the world’s renewable energy to generate electricity will increase at an average rate of 6.2% annually between years 2007 and 2035, going from 18% of total energy to 23% in that period [12].

According to the Intergovernmental Panel on Climate Change (IPCC) in 2014, carbon dioxide accounted for 76% of total greenhouse gases. Therefore, it can be said that reducing carbon dioxide emissions plays an important role in sustainable development and the protection of the environment (Omari, 2013). On the other hand, spatial effects are an important issue that should be mentioned when investigating the effects on CO\textsubscript{2} emissions or renewable energy development. Spatial effects refer to the effects of neighboring countries. According to CO\textsubscript{2} emissions, the spatial effects of the positive or negative effects of these emissions and other determinants of neighboring countries are local. CO\textsubscript{2} emissions can be affected by spatial effects in two ways: first, CO\textsubscript{2} emissions produced by other countries flow to the other country. Secondly, the process of energy transfers or the state of economic development of countries will affect its neighbors. For example, successful energy transfer in neighboring countries can facilitate local energy transfer, because the local country can adopt similar energy policies or import related equipment and techniques [13]. As a result, spatial effects must be considered in order to achieve more accurate results about the effects of energy transfer, CO\textsubscript{2} emission and renewable energy growth. The existence of spatial and neighborhood effects has more importance in countries that become members of unions or regional organizations since, in this situation, countries usually adjust their economic policies in harmony with each other. Regional convergences, while helping to improve economic growth, accelerate the process of countries joining the global economy. One successful example of convergence is the Shanghai Cooperation Organization, which was established in 2001 with the goal of security, economic, and cultural integration. Iran joined the Shanghai Cooperation Organization in 2005 as an observer member. The area of the member countries (Main and Observer) of the Shanghai Cooperation Organization is equivalent to 37 million square kilometers. These members are geographically close to each other and, in fact, they are each other’s natural business partners. This organization includes 43.62% of the world’s population, with 2.9 billion people in the member countries. Table 1 shows the statistical specifications of these countries in 2018.

In this organization, the two major Asian economies, those being China and India, do not have enough energy and import a large part of theirs for their growing economies. On the other hand, Iran and Russia are also members of this organization, and they are the two largest major energy producers with massive reserves of fossil energy. As a result, the member and observer countries of the Shanghai Cooperation Organization are the largest producers and consumers of energy in the world. Therefore, joint projects in the
field of energy will be a priority for this organization in achieving its goal of economic integration [14].

Table 1. Statistical specifications of Shanghai member countries in 2018.

| Country     | GDP Growth (Annual %) | Total Energy Consumption (kg of Oil Equivalent per Capita) | Renewable Energy Consumption (% of Total Final Energy Consumption) | Adjusted Savings: Carbon Dioxide Damage (Current US$) |
|-------------|------------------------|------------------------------------------------------------|---------------------------------------------------------------------|------------------------------------------------------|
| Belarus     | 3.14                   | 3116.6                                                     | 6.33                                                                | 2034                                                 |
| China       | 6.75                   | 2328.6                                                     | 13.3                                                                | 367,641                                              |
| India       | 6.12                   | 759.7                                                     | 33.18                                                               | 94,152                                               |
| Iran        | −6.02                  | 3745.5                                                     | 0.78                                                                | 24,957                                               |
| Kazakhstan  | 4.1                    | 3026.8                                                     | 2.13                                                                | 8776                                                 |
| Kyrgyzstan  | 3.76                   | 1585.8                                                     | 22.28                                                               | 383                                                  |
| Pakistan    | 5.84                   | 445                                                        | 44.88                                                               | 7702                                                 |
| Russia      | 2.54                   | 4399.9                                                     | 2.61                                                                | 62,090                                               |
| Tajikistan  | 7.3                    | 408.3                                                      | 22.92                                                               | 217                                                  |
| Uzbekistan  | 5.45                   | 1686.9                                                     | 3.1                                                                | 2915                                                 |

Source: world bank, 2020.

The amount of fossil and renewable energy consumption of the Shanghai Organization member countries in 2019 is shown in Figures 1 and 2. These numbers show the effects of proximity on energy consumption between these countries and that they have relied more on fossil fuels than on renewable energy. This fact is illustrated in Figures 1 and 2.

In 2013, China became the leading country in the world in terms of renewable energy production. The major share of this energy is taken from hydropower and wind energy [15]. Therefore, the outlook for the SCO is thought-provoking. It seems that this organization will provide a worthy and effective position for itself in light of the cooperation of members in the formation of the international system. This organization has the necessary capabilities to become a multilateral organization [16], and the issue of reducing energy pollution is an axis that must be paid attention to with regard to the future of energy. In this context, the replacement of fossil fuels is an inevitable prospect.
Energy is considered as the motive behind most economic activities, therefore this input plays an effective role in growth and economic development of countries [17]. But there is not exist global consensus on the role of renewable energy in economic growth [18,19]. For example, the results of some works show that there is no relationship between renewable energy consumption and economic growth [20–22]. However, other studies indicate a positive relationship between these two variables [23,24] or a negative relationship between these [25,26].

According to the objectives of the research, the literature review is classified into three categories. In the first, the relationship between energy consumption and economic growth is evaluated. For example, energy consumption and economic growth have a long-term relationship with each other, and there is a two-way causal relationship between them [28]. The Adjaye [29] study confirmed this relationship between energy consumption and income in India, Indonesia, Thailand and the Philippines. But the results of Lee’s [30] study show that there is a one-way causal relationship between energy consumption and GDP in the short and long term. The results of Al-Iriani [31] also show that energy consumption and GDP are not cointegrated and that there is a one-way causal relationship between GDP and energy consumption. Cheng and Lai [32] achieved a one-way causal relationship from GDP to energy consumption and a one-way causal relationship from energy to employment for Taiwan. In addition, the results of Stern [33] show that energy is a limiting factor for economic growth. This result confirmed Yu and Lv’s [34] findings in their study of the United States, where energy supply shocks reduce GDP.

The second category are studies that have reviewed the relationship between renewable and non-renewable energies with green GDP. For example, Marinko et al., [35] express that increasing energy consumption will increase GDP and Green GDP. Hongxian’s [36] research also shows that while the consumption of coal and the consumption of oil energy...
prevent green GDP, the consumption of natural gas contributes the most to green GDP. The results of Al-mulali [37] show that the consumption of renewable and non-renewable energy has a long-term positive relationship with all economic sectors in all regions. Also, it has been shown that the consumption of non-renewable energy has a remarkable effect more than the consumption of renewable energy in economic sectors.

The third category consist of studies that have calculated green GDP. For example, Hamilton and Lutz [38] stated that Green GDP is better than GDP for measuring sustainability and suggest policies to achieve sustainable development. Also, Figueroa and Calfucura [39] modified the Ordinary GDP criteria by adding human-made capital depreciation, plus the loss of total natural capital, whereas, XU et al. [40], by introducing a new method of accounting for green GDP, have entered the value of ecosystem services in GDP. Talberth and Bohara [41] tested the effects of economic openness on green GDP. Their results indicate a negative nonlinear relationship between economic openness and Green GDP growth and show that there is a positive nonlinear relationship between the openness of a country’s economy.

Studies have shown that there is a one-way causal relationship between energy consumption and green GDP, and that green GDP can be a better expression of the concepts of environmental sustainability than GDP. Also, renewable energies have less harmful effects on the environment than non-renewable energies. Therefore, this article investigates the impact of energy consumption on green GDP in the SCO member states. That is the main purpose of this study. The new approach of this paper is to investigate the effect of renewable and fossil energy consumption on green GDP by using the spatial econometric method. The research hypothesis is that energy consumption has a negative effect on the growth of green GDP, and that the proximity of countries has a positive effect on green GDP in SCO member states.

2. Materials and Methods

In this study, the panel data method has been used. Because this type of data provides a suitable environment for the development of estimation methods and theoretical results, researchers are able to study issues by combining cross-sectional data and time series, which cannot be studied in a cross-sectional or time series environment [42]. The general form of panel data regression is as follows:

\[ Y_{it} = \alpha_{it} + \sum_{k=2}^{k} \beta_{it} X_{it} + \mu_{it} + \nu_{it} \] (1)

In Equation (1), \( \nu_{it} \) was a component of the disorder and has a normal distribution and in return, all \( i \)'s and \( t \)'s are independent of \( X_{it} \). It must first be determined whether they are heterogeneous or whether there are individual differences. If there is heterogeneity in the panel data method and otherwise, the normal least squares (OLS) method is used to estimate the model. \( \mu_{it} \)'s express individual or heterogeneous effects in countries, which appear in the form of random effects or fixed effects and compared to the ordinary least squares method. The Hausman test is used to choose between fixed and random effects models. Also, the spatial econometric method has been used to measure the effects of proximity. In this approach, the relationship between spatial autocorrelation or spatial heterogeneity in regression models with cross-sectional data or panel data is investigated. Conventional econometrics does not consider “Spatial Dependence” and “Spatial Heterogeneity” because it violates the Gauss-Markov assumptions, and therefore the spatial econometric approach should be used. The general form of panel spatial econometrics is as follows:

\[ Y_{it} = c + \rho W Y_{it} + \beta X_{it} + U_{it} \] (2)

In Equation (2), \( Y_{it} \) represents the gross green product of country \( i \) at time \( t \), \( c \) is constant, \( X_{it} \) represents a matrix \( n \times n \) of the explanatory variables, \( W \) represents the spatial weight matrix, which is usually the first-order proximity matrix, the parameter \( \rho \) is
the coefficient of the spatial dependent variable, and $WY$ and the $\beta$ parameter represents
the effect of the explanatory variables on the deviation in the dependent variable. In this
paper, the proximity and correlation method are used to determine the proximity matrix.
Considering the spatial dependence, the countries that have the neighborhood relationship
should show a higher degree of dependence than the more distant neighborhoods. There
are various methods for forming an adjacency matrix, including Linear Contiguity, Rook
Contiguity, Bishop Contiguity, Double Linear Contiguity, Double Rook Contiguity, and
Queen Contiguity [43]. The $W$ matrix can be represented as follows:

$$W = \begin{bmatrix}
0 & w_{21} & \cdots & w_{1N} \\
w_{21} & 0 & \cdots & w_{2N} \\
\vdots & \vdots & \ddots & \vdots \\
w_{1N} & w_{2N} & \cdots & 0
\end{bmatrix} \quad (3)$$

The $W$ matrix is symmetric, where the elements on the main diagonal are zero and
the other elements take the number one or zero depending on whether the countries
are adjacent or not. In the following, by standardizing the adjacency matrix and then
multiplying by the vector of the dependent variable, a new variable is obtained that
shows the average of the observations from adjacent areas and is called the spatial lag
variable. In this study, the adjacency matrix has dimensions of $10 \times 10$.

Three main models are used in spatial econometrics, which are the Spatial Lag Model
or Spatial Autoregressive Model, the Spatial Error Model, and Spatial Durbin Model. In
the Spatial Lag Model, spatial effects are propagated through a dependent variable; while
in the Spatial Error Model, it is assumed that the error sentence is the main path of spatial
propagation. In the Spatial Durbin Model, the effect of spatial diffusion is considered both
through dependent variables and through independent variables [44].

Finally, experimental models are used to test the spatial effects of green GDP on
Shanghai member states. It is as follows:

$$\ln GGDPI_{it} = \alpha_0 + \alpha_1 \ln E_{it} + \alpha_2 \ln L_{it} + \alpha_3 \ln K_{it} + \alpha_4 W_{x_{it}} + \varepsilon_{it} \quad (4)$$

$$\ln GGDPI_{it} = \alpha_0 + \alpha_1 \ln F_{fuel_{it}} + \alpha_3 \ln Renew_{it} + \alpha_4 \ln L_{it} + \alpha_5 \ln K_{it} + \alpha_6 W_{x_{it}} + \varepsilon_{it} \quad (5)$$

In Relations (4) and (5), $i$ represents the country and $t$ represents the time. $GGDP$
Indicates Green GDP and $En$ is Energy Consumption, $L$ is Labor, $K$ is Capital, $F_{fuel}$ is
Fossil Fuel Consumption, and $Renew$ is Renewable Fuel and Bio Fuel Consumption, and
the $W_{x}$ Variable is the spatial lag of each member state of the Shanghai Cooperation
Organization. In Equation (4), we consider energy consumption in general and look for the
effect of total energy consumption on green GDP. However, in Equation (5), we consider
energy as both renewable and non-renewable energy, and examine how the consumption
of each of them affects green GDP. Equations (4) and (5) are estimated logarithmically in
two modes, conventional panel and spatial panel.

The statistical sample of this study includes 10 countries with eight main members
and two observers of the Shanghai Cooperation Organization. These include Russia, China,
Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, India, Pakistan, Iran and Mongolia, and
have been reviewed in the period 2019–1990. It should be noted that the information
required for this research has been collected from the World Bank [45].

3. Results

Before estimating the model, the statistical characteristics of the data related to the
Shanghai Organization member countries in the period 1990–2019 including the mean,
minimum, maximum, variance and standard deviation are shown in Table 2.
Table 2. Statistical characteristics of related data SCO member states in the period 1990–2019.

| Variable                                                  | Mean        | Minimum | Maximum        | Variance       | Standard Deviation |
|-----------------------------------------------------------|-------------|---------|----------------|-----------------|--------------------|
| Green GDP (US million $)                                  | 708,427     | 828     | 14,342,902     | $3.83 \times 10^{18}$ | 1,957,450          |
| Total Energy Consumption (kg of oil equivalent per capita)| 1923.18     | 283.5   | 5941.59        | 2,204,931      | 1484.9             |
| Fossil fuels energy consumption (% of total final energy consumption) | 80.61       | 33.94   | 99.97          | 354.5          | 18.83              |
| Renewable energy consumption (% of total final energy consumption) | 20.67       | 0.44    | 64.61          | 448.41         | 21.17              |
| Labor force                                               | 134         | 1.25    | 785            | $5.64 \times 10^{10}$ | 238                |
| Capital inventory                                         | 1039.24     | 79.67   | 5675.09        | 1,108,848.9    | 1053.02            |

Source: Research Findings.

In order to obtain the spatial latency variable, we must first obtain the proximity matrix and then convert it to the first standardized proximity matrix, after which the spatial lag variable can be determined. The proximity matrix for the member and observer countries of the Shanghai Organization is obtained by using the linear proximity method. In the following, this matrix is multiplied by the value of the dependent variable and the spatial lag variable is obtained. First, to estimate the nature of the panel data model, the F-Limer statistic in Table 3 and the Hausman test in Table 4 has been reviewed.

Table 3. F-Limer statistic to detect the use of panel data in estimating the equation.

| Normal Regression | The F-Limer Statistic | Prob | Result          |
|-------------------|-----------------------|------|-----------------|
| Equation (4)       | 26.25                 | 0    | Hypothesis $H_0$ is rejected |
| Equation (5)       | 27.04                 | 0    | Hypothesis $H_0$ is rejected |

Source: Research Findings.

In Table 3, the hypothesis $H_0$ is pooled data and the hypothesis $H_1$ is panel data. According to the results of Table 3, since the probability number for both relations is less than 0.05, the panel data method is preferred to the pooled data method. In the following, Hausmann’s chi-square test is used to detect the use of fixed effects or random effects, and if the probability value is less than 0.1, then the equation must be estimated using fixed effects.

Also, to ensure the suitability of the Spatial Durbin Model for both Equations (4) and (5), two tests have been used. As a result, the Spatial Durbin Model is not a suitable model for the research models of this research. Therefore, the Spatial Autoregressive Model for the two relationships has been estimated. Estimation of research models for Equation (4) with conventional regression and spatial regression (Spatial Durbin Model and Spatial Autoregressive Model) is shown in Table 5:
Table 4. Hausmann test results.

| Model  | Model Type                                                                 | $\chi^2$ Statistics | Prob |
|--------|----------------------------------------------------------------------------|----------------------|------|
| 1-1    | Normal Regression (dependent variable of green GDP and the main independent variable of total energy consumption) | 92.73                | 0    |
| 1-2    | Spatial Durbin Model (dependent variable of green GDP and the main independent variable of total energy consumption) | 92.73                | 0    |
| 1-3    | Spatial Autoregressive Model (dependent variable of green GDP and the main independent variable of total energy consumption) | 0.66                 | 0.984|
| 2-1    | Normal Regression (dependent variable of green GDP and main independent variables of fossil fuel consumption and renewable energy consumption) | 79.84                | 0    |
| 2-2    | Spatial Durbin Model (dependent variable of green GDP and the main independent variables of fossil fuel consumption and renewable energy consumption) | 26.35                | 0.001|
| 2-3    | Spatial Autoregressive Model (dependent variable of green GDP and main independent variables of fossil fuel consumption and renewable energy consumption) | 13.43                | 0.036|
| 2-4    | Spatial Autoregressive Model (dependent variable of fossil fuel consumption and the main independent variables of green GDP and renewable energy consumption) | 1.13                 | 0.98 |
| 2-5    | Spatial Autoregressive Model (dependent variable of renewable energy consumption and the main independent variables of green GDP and fossil fuel consumption) | 4.3                  | 0.636|

Source: Research Findings.

Table 5. Results of research model estimation (Equation (4)).

| Variable         | Normal Regression (Dependent Variable: Green GDP) | Spatial Durbin Model (Dependent Variable: Green GDP, Fixed Effects, Spatial Variables (Wx)) | Spatial Autoregressive Model (Dependent Variable: Green GDP, Random Effects Method) |
|------------------|--------------------------------------------------|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
|                  | Model 1-1                                        | Model 1-2                                                                                       | Model 1-3                                                                        |
| energy consumption | 0.062 (0.556)                                   | −0.12 (0.118)                                                                                  | 0.056 (0.492)                                                                   |
| Labor            | 2.47 (0.000) ***                               | −0.011 (0.960)                                                                                 | 0.817 (0.000) ***                                                              |
| Capital          | 0.75 (0.000) ***                               | 0.5 (0.000) ***                                                                                 | 0.459 (0.000) ***                                                             |
| W energy consumption | −0.258 (0.091) *                                |                                                                                  |                                                                                |
| W Labor          | 1.12 (0.000) ***                               |                                                                                              |                                                                                |
| W Capital        | 0.374 (0.000) ***                              |                                                                                              |                                                                                |
| rho              | 0.369 (0.000) ***                              | 0.533 (0.000) ***                                                                              |                                                                                |
| Constant         | −9.54 (0.000) ***                              | −2.470 (0.000) ***                                                                            |                                                                                |
| F Statistic      | 308.72 (0.000) ***                             |                                                                                              |                                                                                |
| $R^2$            | 0.985                                           |                                                                                              |                                                                                |

Source: Research Findings. * and *** show significance at the level of 1 and 10%, respectively.
In Model 1-1, the coefficient of energy consumption is positive, which indicates that by increasing energy consumption through increasing demand and increasing productivity, green GDP will increase. But since fossil fuels are one of the sources of carbon dioxide emissions and also cause environmental degradation, the increase in green GDP is not significant. The coefficient of labor force is positive and significant, which indicates that the labor has a positive environmental impact on green GDP. The effect of capital on green production is positive and significant. Therefore, more capital increases people’s ability to use new techniques and use environmentally friendly technologies, which will improve green GDP. In Model 1-2, the coefficient of the spatial lag variable is positive and significant, and as a result of the proximity of countries to each other has a positive effect on green GDP and should be estimated according to the method of spatial econometrics. The spatial effects of economic growth and energy consumption are statistically justifiable for the SCO member states. In particular, energy consumption for countries can be different, but the existence of a neighboring country that is a major producer of energy and rich in energy resources can have a significant impact on energy consumption of the neighboring country. Also, a country with increasing green GDP growth can increase it in the neighborhood countries by sharing its knowledge and technology.

An estimation of research models for Equation (5) with normal regression and spatial regression (Spatial Durbin Model and Spatial Autoregressive Model) is shown in Table 6:

**Table 6. Results of research model estimation (Equation (5)).**

| Variable               | Normal Regression (Dependent Variable: Green GDP) | Spatial Durbin Model (Dependent Variable: Green GDP, Fixed Effects) | Spatial Autoregressive Model (Dependent Variable: Green GDP, Fixed Effects Method) | Spatial Autoregressive Model (Dependent Variable of Fossil Fuel Consumption, Random Effects Method) | Spatial Autoregressive Model (Dependent Variable of Green GDP, Random Effects Method) |
|------------------------|-------------------------------------------------|-------------------------------------------------------------------|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Model 2-1              | Model 2-2                                       | Model 2-3                                                        | Model 2-4                                                                      | Model 2-5                                                                       |
| fossil fuel consumption| −1.152 (0.003) ***                             | −0.361 (0.174)                                                  | −0.718 (0.248)                                                               | −2.586 (0.245)                                                                |                                                                                  |
| renewable energy       | −0.262 (0.002) ***                             | −0.063 (0.292)                                                  | −0.198 (0.051) *                                                            | −1.04 (0.010) **                                                              |                                                                                  |
| Labor                  | 2.445 (0.000) ***                              | 0.024 (0.912)                                                  | 0.547 (0.141)                                                                | 0.051 (0.020) **                                                              | 0.353 (0.117)                                                                   |
| Capital                | 0.827 (0.000) ***                              | 0.492 (0.000) ***                                              | 0.491 (0.035) **                                                            | 0.085 (0.008) ***                                                            | 0.201 (0.047) **                                                                |
| W fossil fuel          | −1.261 (0.021) **                              |                                                                  |                                                                               |                                                                               |                                                                                  |
| W renewable energy     | 0.021 (0.898)                                  |                                                                  |                                                                               |                                                                               |                                                                                  |
| W Labor                | 1.071 (0.000) ***                              |                                                                  |                                                                               |                                                                               |                                                                                  |
| W Capital              | 0.342 (0.000) ***                              |                                                                  |                                                                               |                                                                               |                                                                                  |
| rho                    | 0.374 (0.000) ***                              | 0.582 (0.031) **                                               | −0.33 (0.008) ***                                                           | −0.156 (0.040) **                                                            |                                                                                  |
| Green GDP              | −6.943 (0.000) ***                             |                                                                  |                                                                              |                                                                                |                                                                                  |
| Constant               | 1.446 (0.150)                                 |                                                                  |                                                                              | 4.485 (0.838)                                                                |                                                                                  |
| F Statistic            | 246.4 (0.000) ***                             |                                                                  |                                                                              |                                                                                |                                                                                  |
| R²                     | 0.97                                           | 0.89                                                            | 0.81                                                                         | 0.76                                                                          |                                                                                  |

According to the results in Table 6, in which the green production is considered as a dependent variable, all coefficients are significant. Fossil fuel consumption has a negative and significant effect on the green GDP variable. Therefore, by increasing the consumption of fossil fuels 100%, green production decreases by 71.8%, because the consumption of such energies causes carbon dioxide emissions and affects green GDP. Consumption of
renewable fuels and biofuels shows a negative and significant effect on green GDP. Thus, increasing the consumption of this type of fuel by 100%, leads to a green GDP decrease of 19.8%. All renewable and biofuels are relatively expensive, and energy efficiency and the benefits of CO$_2$ savings from using them is variable. But in the end, they all compete with food production for land, water and other resources. For this reason, the impact of their consumption on green production is negative, and the undesirable effects of renewable and biofuels on the environment are greater than their desirable effects. Changes in the region’s ecosystem and displacement of population caused by hydropower plants, which create noise pollution, heat pollution, chemical pollution and biological pollution, are some of the desirable effects of renewable fuels on the environment. It is important to pay attention to this point that although both types of energy have a negative effect on green production, the negative effect of renewable and biofuel consumption is much less than the effect of fossil fuel consumption. As a result, renewable and biofuels, despite less environmental degradation, can be substituted for fossil fuels. Today, in most global programs, the use of renewable and biofuels is known as one of the appropriate solutions to replace fossil fuels and to prevent air pollution while preserving fossil fuel reserves.

The positive effects of labor on green GDP can be due to the fact that the most important factors in the production process and in labor productivity do not create environmental damage in the production process. As a result, with a 100% increase in labor, green GDP increases by 54.7%. The capital inventory coefficient is 0.49 and is significant, which indicates the positive effect of capital inventory on green GDP. The coefficient of spatial delay is positive and significant and should be estimated according to the method of spatial econometrics.

Because the conventional regression method can only obtain the direct effects, it may be because the neglect of indirect effects caused by spatial effects provides biased results and this not only affects the regression results, but also affects the direct and indirect effects of determinants. As a result, the proximity of countries to each other had a positive effect on green GDP and should be estimated according to the method of spatial econometrics. Furthermore, the effects of the spatial overflow of renewable energy are statistically significant for the SCO member states. Possible reasons are that the SCO countries can influence each other’s renewable energy consumption by sharing technologies for the production and consumption of renewable energy.

The main purpose of this study was to investigate the impact of energy consumption on green GDP in the SCO member states based on spatial econometrics. The results of estimating the research models indicate that the consumption of fossil fuels has negative and significant effects, and the spatial lag has a positive and significant effect on green GDP in the SCO member states. According to the findings of the study, there is a two-way negative relationship between green GDP and energy consumption, which is consistent with the studies of [28]. Also, the consumption of renewable and biofuels has had a much less negative effect on green GDP than the consumption of fossil fuels. This is consistent with the studies of Marinko et al., [35], Hongxian [36] and Al-mulali [37], and indicates that although the effect of renewable fuel consumption on green GDP is negative, their consumption remains preferable to fossil fuel consumption. Also, Kohansal and ShayanMehr [46] have suggested that it is not necessary to reduce energy consumption to reduce carbon dioxide emissions because this leads to a decline in GDP. However, it is better to replace fossil and non-renewable fuels with clean and green fuels in order to achieve the two goals of continued economic growth and the reduction of carbon dioxide.

The coefficient of spatial lag is positive and significant and is consistent with other studies [34,43,46–48]. In other words, the proximity of countries has a positive effect on the growth of green GDP, and this shows that the growth of green GDP in neighboring countries in the Shanghai Cooperation Organization is one of the most important factors in the growth of green GDP in these countries. The SCO members are the largest producers and consumers of energy in the world. Hence, these countries can trust their comparative advantage instead of imitating the economic structure of neighboring countries. Therefore,
economic growth in neighboring countries can have positive effects on the economic growth of the local country. In addition, SCO members can collaborate in the development of green economies because their creation benefits all countries by increasing economic growth and reducing CO₂.

4. Conclusions

By considering the problem that international organizations have become important actors in the world economy and have a direct and indirect impact on all global interactions and developments, regionalism and regional cooperation have provided a good platform for strengthening the power of the national economy. Different countries seek their comprehensive development through regional cooperation and know it is necessary to join regional unions, and in a way, the success of any country in playing an effective and constructive role in its surrounding areas can be considered as a prelude to the successful entry of that country into the global arena. Also, the global economy is undergoing a process that is making different countries closer and more interdependent. The role of proximity in trade and economic cooperation has been important in the transfer of capital, technology, and energy and, consequently, growth. The issue of reducing energy pollution is an axis that must be considered in the future of energy. In this context, the replacement of fossil fuels is an inevitable prospect. As a result, despite the prominent role that fossil fuels have played in the economic growth and development of countries, they have created widespread problems in the national and international arenas. These issues and problems have become so obvious that the need to turn to renewable energy is no longer hidden from anyone. Accordingly, many countries have turned to new energies that, in addition to economic growth and development, also have characteristics such as sustainability. As a result, investment and planning for this area should be a priority.

According to the results, the hypothesis of spatial dependence in the model is confirmed. In other words, there is a positive spatial relationship between the observations related to the green production flow of Shanghai member countries. It is suggested that in similar studies the spatial dependence be considered to obtain more accurate estimates of the variables. Thus, when governments and international organizations make policy decisions, they must not only consider their own circumstances, but also the influences of neighboring countries, such as economic growth and energy structure. In other words, governments and international organizations must emphasize cooperation on policies to increase the efficiency of renewable energy, reduce carbon and maintain the quality of the environment. In particular, countries can share common costs to develop technologies for the production and consumption of renewable energy, the reduction of carbon, and the exchange of carbon-related technology. As a result, governments and the SCO Council must continue to facilitate the development of a green economy in order to achieve sustainable development.

Since the negative impact of renewable and bioenergy has been less than the negative impact of fossil fuels on green production, renewable and bioenergy should replace fossil fuels. Accordingly, given the SCO’s extensive capacity in the field of renewable energy production, investment in this area should be a priority. These types of energies can reduce the environmental problems of this organization in achieving the goal of sustainable development. As a result, food tariffs, subsidies or renewable energy certificates must be provided to produce renewable energy. In addition, to reduce the cost of producing renewable energy, governments can adopt policies that encourage technological innovation in the renewable energy industry. Furthermore, in a situation where many countries are currently facing challenges with unemployment, investing in new energy can not only reduce dependence on fossil fuels and reduce many environmental problems, but can also increase the level of public employment.

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