Original Research

Consumption and Territory Based CO$_2$ Emissions, Renewable Energy Consumption, Exports and Imports Nexus in South America: Spatial Analyses

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Abstract

The present research investigates the environmental effects of trade, Renewable Energy Consumption (REC), and industry value-added in South America, doing spatial analyses from 1990-2018. The income per capita has a positive effect on the local CO$_2$ emissions. Further, it has negative environmental spillovers in neighboring countries regarding consumption-based CO2 emissions but not in terms of territory-based CO$_2$ emissions. Exports have negative and positive effects on consumption and territory-based CO$_2$ emissions, respectively. Moreover, exports carry positive environmental spillovers in neighboring countries in case of both consumption and territory-based CO$_2$ emissions. Imports have a positive effect on consumption-based CO$_2$ emissions but could not affect territory-based CO$_2$ emissions. Industry value-added has negative environmental spillovers in the case of consumption-based CO$_2$ emissions. REC helps to reduce consumption and territory-based CO$_2$ emissions in both local and neighboring countries.

Introduction

South America has a dynamic energy market that has considerable potential for further growth. With a high dependency on hydropower, South America's power market needs to diversify its fuel portfolio so that proper arrangements can be made to meet the upcoming needs of energy in the region. Many countries, including Brazil, Mexico, Chile, Brazil, and Peru, are making their way to improve their energy portfolio, and investment in the sector is improving. From 2010 through 2015, $120 billion investment has been made in the region while $38 billion was separately invested just for hydro. In many Latin American countries, solar and onshore hydropower energy is accelerating [1], and it also supported the economic growth in the region [2]. Arango-Aramburo et al. [3] analyzed South

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America's renewable energy trends and found that thermal capacity installations are on a positive trend in the region. However, the share of renewable energy is still not enough to meet sustainable energy usage goals. It is because the countries need to meet their electricity demand, which requires them to burn more fossil fuel than switching to renewables. Deng et al. [4] also argued that the use of non-renewable is increasing in South America due to increasing urbanization and economic growth in the region. It raises a need for South American governments to focus more on acquiring higher renewable energy levels to meet the sustainable economic growth requirements.

Vargas Gil et al. [5] discussed the dynamics of solar penetration into the market and mentioned that the South American energy mix is diverse. In a region with abundant sunlight resources, it is a time that photovoltaic penetration should get the deserved attention. Brazil and Chile have great solar resources and have more than 50% of all South America region's solar energy. Other countries have to strive to make the regulatory and structural mechanisms more comfortable, and aspects like ancillary services, capacity auctions, rate mechanisms, microgrids, centralized energy systems, and smart grids need attention. The South American region is attempting to transform its policies towards renewable energy integration. Wind power has taken the largest share of the renewable energy mix compared to solar and other renewables. Brazil is at the top of the list regarding renewable energy integration plans in the region [6].

In 2002, Brazil was the first South American country to implement the feed-in-law. Later, in 2004 and 2006, Ecuador and Argentina followed. This law aimed to bring a revolution in the energy sector and to improve the country's overall environmental profile. The purpose was to improve the sector's competitiveness and make progressive strides in efficient energy consumption and sustainable power generation. Considering the economic conditions and energy profiles of these countries, there have been some challenges, but the nations have made some progress while following the lead of the developed countries and their energy policy [7]. With all the improvements being made in the South American energy sector, it must be noted that this sector is not a standalone domain and is strongly linked to other sectors, including economy, policy, geopolitical demographics, financial market, trade, environment, and many more. Therefore, countries need to consider a holistic picture and ensure that multiple aspects are being considered that the country makes steady and subsequent progress. Saravia-Matus et al. [8] argued that in Latin America, environment-specific policies might help other sectors improve over the years, leading to the inference that these countries should incorporate the environment in their development plans and implement climate-change mitigation policies.

In a pursuit to become an environmentally more sustainable region, Latin American countries should focus on driving forces for CO_2 emissions to control the activities that lead to environmental degradation. Talking about renewable consumption in the South American region, it is crucial to understand the energy sector dynamics and its effects on the environment. In that aspect, some studies have covered the topic from some dimensions in a particular South American context [4, 9-11]. For instance, Deng et al. [4] investigated the role of economic growth and non-Renewable Energy Consumption (REC) on Greenhouse Gases (GHGs) emissions. Sadorsky [9] examined the effects of exports, imports, and output on energy consumption. Hdom [10] explored the role of economic growth and fossil and renewable electricity production on CO_2 emissions. Moutinho et al. [11] studied the effects of economic growth and energy intensity on energy-related CO_2 emissions. In the present state of the art, a comparison of the territory and consumption-based CO_2 emissions is missing in the South American literature, which is necessary due to the patterns of exports and imports of the region [12]. Moreover, the literature has signified the importance of testing the separate effect of exports and imports on consumption-based CO_2 emissions [13-15]. Due to globalization and trading and economic linkages, the importance of doing spatial analyses in environmental studies has also been highlighted in the literature [16-21]. However, the aspects of spatial dimensions and investigation of consumption-based CO_2 emissions are ignored in South American literature. Hence, there is a need for extensive research on the topic. Considering spatial effects in the model, the present study explores the relationships among industrial value-added, exports, imports, REC, and consumption and territory-based CO_2 emissions in 10 South American countries to claim an empirical contribution in the literature.

Literature Review

There is vast literature on the trade and pollution emissions nexus. However, the latest strand of literature is testing the determinants of territory and consumption-based CO_2 emissions separately. Peters et al. [12] divided the CO_2 emissions data into territory-based and consumption-based CO_2 emissions, adjusting exports and imports. In this context, increasing exports would accelerate the production-based CO_2 emissions. But, on the other hand, growing imports could raise the consumption-based CO_2 emissions. Hence, trading activities would shift the CO_2 emissions from one country to another. Thus, trade is responsible for spatial linkages of CO_2 emissions in trading and neighboring countries. Following this idea, Liddle [13] investigated a large panel and found that trade did not affect the territory-based emissions, but it affected consumption-based CO_2 emissions. Moreover, they found that exports have a negative effect, and imports positively

affect consumption-based CO_2 emissions. Afterward, literature corroborated the evidence of a positive effect of economic growth and opposite direction of effects of exports and imports on consumption-based CO_2 emissions in oil-exporting countries [14] and G-7 countries [15]. In addition, Liddle [13] suggested incorporating the Industrial Value Added (IVA) and fossil fuel consumption in analyses, which were found responsible for increasing emissions. Moreover, Khan et al. [15] proposed to use REC in place of fossil fuel in the model and found the negative effect of REC on emissions.

A massive literature has investigated pollution-related studies around the globe. Therefore, we focus mostly on the studies conducted in Latin America and the Caribbean (LAC). Bhattarai and Hammig [24] initiated and corroborated the Environmental Kuznets Curve (EKC) validity in Latin America. In the research of Zilio and Reclade [25], the relationship of Gross Domestic Product (GDP) and its pressure on the environment in LAC was investigated from 1970-2007. In the panel data analysis, the energy EKC hypothesis was tested, and energy consumption and GDP were used as indicators of human-environmental pressure and economic activity. No evidence was found for a long-term relationship between these variables, which rejected the validity of EKC. On the other hand, Poudel et al. [26] corroborated the EKC by finding the N-shaped relationship between income and pollution variables in Latin America.

Sapkota and Bastola [27] worked on 14 Latin American countries from 1980-2010 to test the existence of EKC and Pollution Haven Hypothesis (PHH). It was proved that PHH and EKC both existed in these countries. The study had diverse variables, including physical capital, population density, human capital, energy, and unemployment. It was suggested that policies needed to be designed to focus on cleaner energy and Foreign Direct Investment (FDI) to promote clean energy in the region to ensure sustainable growth. Albulescu et al. [28] analyzed FDI, income, and pollution nexus in 14 Latin American countries from 1980-2010. The purpose was to re-investigate the EKC hypothesis in Latin American countries and explore how economic and financial development play a role in the countries' environmental profiles. FDI seemed to have no apparent influence on the pollution levels in the selected countries, implying that a higher level of investment from foreign countries did not increase pollution in low-income countries. Moreover, EKC's existence was partially validated in the analysis.

Jardón et al. [29] analyzed economic growth and CO_2 emissions nexus in LAC from 1971-2011. The EKC was confirmed in the selected countries, but that was with the assumption of cross-independence. However, the study gave opposite results when the assumption was removed, and for the long-term, EKC did not hold for the sample countries. Alvarado et al. [30] tested

the relationship between energy consumption, non-sustainable energy, and output in Latin America. An association was found between output and renewable energy. Hence, it was suggested that Latin America should use cleaner technologies and alternative ways of creating energy so that the benefits from this power generation can be obtained to the optimal level and economic growth is not halted due to unsustainable activities in the energy sector.

Al-mulali et al. [31] analyzed LAC from 1980-2010 and proved causality between GDP, CO_2 emissions, and financial development. They argued that economic and financial growth could be proved to be a promising factor in reducing CO_2 emissions, while additions of renewable energy can assist the situation as well. Zhang et al. [32] analyzed the total factor efficiency and REC in Latin America from 2005-2014. The total factor efficiency turned out to be 0.808 and showed a positive incline. For some countries, this number was higher and over 1.302 indicating a high potential of REC. It was suggested that pollution levels could be reduced to a significant extent using REC. Ozturk [33] investigated interrelationships among oil rents, nuclear and fossil energy, CO_2 emissions, FDI, and economic growth in Latin America from 1975-2013. The nuclear and fossil energy and CO_2 emissions were found supportive for FDI and economic growth in Latin America. However, the effect of oil rents was found insignificant. Román-Collado and Morales-Carrión [34] investigated and found that population, fossil fuel, and energy intensity played their role in increasing CO_2 emissions in Latin America.

Energy efficiency is something widely discussed in the literature of South America. This concept has a widespread impact on developing a sustainable economy to protect the region's environmental health [35]. Energy efficiency can play a role in developing the industrial and production sectors. Latin American countries need to focus on their trade relations since they would help establish the production and industrial sector through a healthy trade collaboration [36]. Kuntsi-Reunanen [37] investigated 5 Latin American countries from 1970-2001 and reported that the level of CO_2 emissions was increasing. The CO_2-intensive changes in the energy sector have substantial implications for the other sectors in these countries. With changes in the levels of energy use, these countries are making progress in their sustainable energy utilization rates. However, strict and rigorous policy implementation should be followed to ensure that an energy-efficient environment would be developed. Additionally, the degree of competition in the sector increased between energy producers, paving the way and intensifying the need for further development. Mardones and Baeza [38] studied the economic and environmental effects that CO_2 taxes could have in 3 Latin American countries. They argued that these taxes could be used to reduce CO_2 emissions since they can be used as a tool to put a cap on unclean and unsustainable energy production.

Some literature has particularly focused on South America. For instance, Deng et al. [4] investigated the dynamic relationship among economic growth, non-REC, and GHGs emissions in 10 South American countries from 1971-2014. A causality was found from non-REC to emissions in 3 countries and from GDP to emissions in agricultural South American countries. Sadorsky [9] conducted a panel cointegration analysis in 7 South American countries from 1980-2007 and found the long-term relationships among trade variables, output, and energy consumption. Moreover, bidirectional causality was reported between exports and energy consumption and between trade variables and output. Hence, environmental policy to shrink energy consumption would have an adverse effect on trade. Hdom [10] analyzed and corroborated a long-run relationship among CO_2 emissions, electricity, and GDP in 8 South American countries from 1980-2010. In the long-term, fossil fuel electricity generation was not significant, and electricity generation from renewable sources proved to reduce CO_2 emissions, which was a reasonable replacement in the long term. In the country-specific discussion, Paraguay seemed to have the highest CO_2 emissions. However, emissions from the energy sector were the highest in Venezuela. It was mentioned in the paper that just a 0.533% decline in these emissions could help to reduce environmental degradation and to avoid temperature rises of 2-degrees by 2050. Hence, it is crucial for these South American countries to switch to more renewable sources and cut down on fossil fuels. In this regard, REC would help portray a clear picture of the relationship between CO_2 emissions and energy consumption. In their decomposition analyses, Moutinho et al. [11] investigated the energy-related CO_2 emissions in South America from 1993-2017. They found that falling GDP and energy intensity helped to reduce the energy-related CO_2 emissions.

Literature has signified the importance of considering spatial analyses in pollution-related studies. For instance, Murshed et al. [39] investigated the disaggregated EKC in 12 OPEC economies during 1992-2015, applying spatial econometrics. The authors corroborated the existence of aggregated EKC and disaggregated EKC in the construction sector. However, the EKC could not be validated in the other investigated sectors. Khezri et al. [40] studied the 31 Asian economies in spatial analysis of financial growth and CO_2 emissions relationship. They found the positive effect of economic growth, urbanization, financial growth, and trade on CO_2 emissions. On the other hand, the positive environmental spillovers of financial growth were found due to the increasing quality of energy use in neighboring countries. Zeng et al. [41] did the spatial analyses in a large panel of world economies. They found that urbanization, economic growth, fossil fuel trade, and industrial growth contributed to CO_2 emissions. However, REC reduced the emissions. Moreover, fossil fuel imports showed spatial spillovers

effects, which were different with different levels of development.

Mahmood et al. [42] investigated the determinants of CO_2 emissions in North Africa, doing spatial analyses. They found the positive effects of economic growth, imports, and energy consumption on CO_2 emissions and exports helped to reduce emissions. Moreover, positive environmental spillovers of economic growth and imports and negative environmental spillovers of exports were also corroborated. Murshed [22] investigated the relationship between intra-regional trade and REC in South Asia from 1992-2015, considering the cross-sectional dependency. The author found that about 20% of intra-region trade was from renewable electricity and energy consumption. Moreover, intra-regional trade caused both renewable energy proxies. Murshed [23] studied the effect of trade on REC transition in 71 countries from 2000-2007. Trade openness accelerated the REC in low-income countries and clean cooking technologies in lower-middle-income countries.

It can be observed from the literature review that a spatial angle is vital for CO_2 emissions-related studies but ignored in South American literature, which is something that this current paper aims to cover in-depth to provide a more holistic picture of the energy sector of the South American region. Moreover, the analysis of consumption-based CO_2 emissions is missing in the South American literature. Hence, this study contributes to South America's environment literature by investigating the effects of REC, exports, imports, and industrial value-added on the territory and consumption-based CO_2 emissions in 10 South American countries, considering spatial dimensions.

Material and Methods

In framing the CO_2 emissions model, income level is the most significant driver of pollution emissions. Increasing income of any economy puts pressure on the environment by the scale effect [43]. Thus, economic growth requires more energy consumption to fuel economic activities and may damage the environment. Moreover, Chiu and Chang [44] argued that a suitable proportion of renewable energy in total energy consumption could mitigate pollution emissions. Hence, the testing of REC is essential in the pollution emissions model. Copeland and Taylor [45] argued that dirty industry might shift from developed to developing countries due to trade openness and weak environmental regulation. Therefore, industrial value-added and trade are vital determinants of pollution emissions. Moreover, trade may damage the environment due to the scale effect as trade increases the economy's size [46]. In the trade and emissions relations, Liddle [13] argued that the use of exports and imports separately in the emissions model is essential as both can have opposite effects on the emissions. Moreover, Peters et al. [12] developed the data set of consumption-based CO_2 emissions

by adjusting production-based CO$_2$ emissions with exports and imports. Hereafter, literature signifies the importance of using consumption-based CO$_2$ emissions and separate exports and imports in the trade and emissions model [13, 14, 15]. Following the theoretical discussions, the model for the study is as follows:

$$CE_{it} = f(GDPC_{it}, EXP_{it}, IMP_{it}, RE_{it}, IND_{it}) \quad (1)$$

i shows 10 South American countries, t shows a period 1990-2018, GDPC$_{it}$ is GDP per capita, EXP$_{it}$ is exports percentage of GDP, IMP$_{it}$ is imports percentage of GDP, RE$_{it}$ is renewable energy consumption percentage of GDP, and IND$_{it}$ is an industry-value added percentage of GDP. The data are collected from World Bank [47]. CE_{it} is CO$_2$ emissions per capita and breaks down into territory-based CO$_2$ emissions (TCO2) and consumption-based CO$_2$ emissions (CCO2) to make the analysis simpler and easy to understand with theoretical context. Data on CO$_2$ emissions are sourced from Global Carbon Atlas [48]. The natural logarithm form of all series is utilized to find the elasticities. Guyana, Falkland Islands, French Guiana, and Suriname are ignored due to the unavailability of data. We regress the equation with pooled Ordinary Least Square (OLS) and Fixed Effects (FE) models. After that, we may test possible spatial effects in the models by applying Lagrange Multiplier (LM) tests [49, 50]. Testing possible spatial effects are significant, as South American countries are geographically close to each other. Therefore, any country's economic or environmental profile may affect the neighboring country as well. In the presence of statistical spatial autocorrelation, Spatial Durbin Model (SDM) may be utilized in the following way:

$$CE_{it} = \alpha_{10} + \alpha_{11}GDPC_{it} + \alpha_{12}EXP_{it}$$
$$+ \alpha_{13}IMP_{it} + \alpha_{14}RE_{it} + \alpha_{15}IND_{it} + \beta_{11}W.GDPC_{it}$$
$$+ \beta_{12}W.EXP_{it} + \beta_{13}W.IMP_{it} + \beta_{14}W.RE_{it}$$
$$+ \beta_{15}W.IND_{it} + \delta_1 W.CE_{it} + v_{1i} + u_{1t} + \varepsilon_{1it} \quad (2)$$

W is weighting matrix and capturing the spillovers from neighboring countries. It is a 10*10-dimension matrix and is normalized, using a maximum value in each row suggested by Kelejian and Prucha [51]. The SDM may be verified for its suitability testing H_{01}: $\beta = 0$ and H_{02}: $\beta + \delta. \alpha = 0$ [52]. Both hypotheses' rejection would justify that SDM is the most appropriate method and is preferable over Spatial Autoregressive (SAR) or Spatial Error Model (SEM). Moreover, the Likelihood Ratio (LR) may also be utilized to verify the Wald test's conclusions. SAR specification is provided as follows:

$$CE_{it} = \alpha_{20} + \alpha_{21}GDPC_{it} + \alpha_{22}EXP_{it} + \alpha_{23}IMP_{it}$$
$$+ \alpha_{24}RE_{it} + \alpha_{25}IND_{it} + \delta_2 W.CE_{it} + v_{2i} + u_{2t} + \varepsilon_{2it} \quad (3)$$

In Equation (3), the spatial dimension would be captured by $\delta_2 W.CE_{it}$. Moreover, time and country-specific heterogeneity can be captured by u_{2t} and v_{2i} respectively. In addition, SEM specification is mentioned as follows:

$$CE_{it} = \alpha_{30} + \alpha_{31}GDPC_{it} + \alpha_{32}EXP_{it} + \alpha_{33}IMP_{it}$$
$$+ \alpha_{34}RE_{it} + \alpha_{35}IND_{it} + v_{3i} + u_{3t} + \varepsilon_{3it} \quad (4)$$

$$\varepsilon_{3it} = \theta W \varepsilon_{3it} + e_{it} \quad (5)$$

The error term in Equation (5) would facilitate the spatial dependence in Equation (4). Both Equation (4) and (5) represent the SEM specification. After selecting suitable spatial specifications from SEM, SAR, or SDM, the Hausman test may also be utilized to choose FE or Random Effects (RE) in the selected spatial model specification.

Results and Discussion

At first, we conduct the non-spatial analysis to test the spatial autocorrelation in the models. Table 1 reports the results of TCO2 and CCO2 models, applying pooled OLS and FE methods. The spatial lag effect is corroborated in all estimated models through both LM tests. Moreover, these tests also confirm the existence of spatial error effect in TCO2's models. Besides, the LM test corroborates it in the estimated models of CCO2, but LM robust test could not validate it in the models of CCO2. In the regression analyses, GDP per capita has a positive effect, and renewable energy use has a negative effect on both TCO2 and CCO2 in all estimates. Except for FE-time estimates, exports show a positive impact on the TCO2 and negatively affect the CCO2. Imports have a positive effect on the CCO2 but have insignificant effects on the TCO2. Lastly, Industrial Value-Added (IVA) has mixed types of effects on TCO2 and CCO2. The estimated non-spatial models may be claimed as biased because of spatial effects in estimated models, and these are run to test the spatial autocorrelation.

Table 2 shows the results of SDM applied on TCO2 and CCO2 models. At first, we use the Hausman test to check the suitability of FE or RE in SDM, which favors the FE specification. Then, we test the suitability of SDM for our models, applying the Wald test. H_{01}: $\beta = 0$ and H_{02}: $\beta + \delta. \alpha = 0$ are rejected, and Wald test corroborates that SDM is the most suitable specification. Moreover, the LR test also validates Wald test's conclusion that SDM is more consistent over SEM and SAR. Hence, SDM is chosen for the estimations of both TCO2 and CCO2 models.

In the regression analyses, GDP per capita positively affects the local and neighboring countries' CCO2. Therefore, increasing economic growth carries an adverse environmental impact in terms of CCO2 in both local and neighboring economies. However, it

Table 1. Non-spatial models.

Variables	TCO2				CCO2			
	Pooled OLS	FE-Country	FE-Time	FE-Both	Pooled OLS	FE-Country	FE-Time	FE-Both
$GDPC_{it}$	0.622 (0.000)	0.636 (0.000)	0.650 (0.000)	0.632 (0.000)	0.681 (0.000)	0.941 (0.000)	0.679 (0.000)	0.686 (0.000)
EXP_{it}	0.016 (0.816)	0.085 (0.024)	0.084 (0.314)	0.155 (0.001)	-0.114 (0.020)	-0.169 (0.000)	-0.064 (0.267)	-0.118 (0.027)
IMP_{it}	0.115 (0.119)	-0.050 (0.345)	0.113 (0.213)	-0.099 (0.114)	0.367 (0.000)	0.169 (0.007)	0.338 (0.000)	0.159 (0.027)
RE_{it}	-0.678 (0.000)	-0.269 (0.000)	-0.698 (0.000)	-0.248 (0.000)	-0.456 (0.000)	-0.208 (0.000)	-0.464 (0.000)	-0.186 (0.002)
IND_{it}	0.114 (0.155)	-0.200 (0.003)	0.026 (0.768)	-0.157 (0.043)	-0.228 (0.000)	-0.008 (0.917)	-0.287 (0.000)	-0.049 (0.580)
Spatial Error								
LM	462.055 (0.000)	232.828 (0.000)	434.407 (0.000)	196.398 (0.000)	161.294 (0.000)	142.099 (0.000)	167.911 (0.000)	150.673 (0.000)
Robust LM	34.846 (0.000)	74.547 (0.000)	26.303 (0.000)	3.261 (0.071)	0.605 (0.437)	0.615 (0.433)	0.974 (0.324)	0.542 (0.462)
Spatial Lag								
LM	497.661 (0.000)	295.828 (0.000)	489.894 (0.000)	294.115 (0.000)	329.033 (0.000)	295.175 (0.000)	328.700 (0.000)	303.400 (0.000)
Robust LM	70.452 (0.000)	74.547 (0.000)	81.790 (0.000)	100.978 (0.000)	168.343 (0.000)	153.6690 (0.000)	161.762 (0.000)	153.269 (0.000)
Sigma-square	0.047	0.011	0.048	0.011	0.024	0.015	0.023	0.015
R^2	0.884	0.973	0.891	0.975	0.913	0.946	0.914	0.953

positively impacts local TCO2 but has a statistically insignificant effect on neighboring TCO2. Hence, increasing economic growth pollutes the local economy, but it could not affect the neighboring TCO2. Thus, economic growth accelerated both CCO2 and TCO2. The literature also found the positive effect of economic growth on pollutant emissions in South America in the non-spatial analysis [10, 11] and a large panel of world economies in spatial analyses [21].

Exports show a positive effect on local TCO2 but a negative effect on the neighboring TCO2, hence have positive environmental spillovers in terms of reducing TCO2 in neighboring countries. Further, the negative indirect effect is found greater than the positive direct effect. It seems from positive environmental spillovers of exports that South American countries are competitors in exports' production. Therefore, the production of exports in one country reduces the chance of TCO2 emissions in the neighboring countries. In the CCO2 results, exports have negative effects on both local and neighboring countries' CCO2 emissions. Therefore, exports are helping to shift CCO2 from South American countries to the importing countries. Moreover, the production of exports is done in exporting countries and increases the local TCO2 emissions. Nevertheless, the consumption of exports is not done in producing countries and reduces CCO2 emissions in exporting countries. Therefore, exports are increasing

local TCO2 and reducing local CCO2 in the exporting countries. The negative effect of exports on CCO2 is also reported in a large panel of world economies [13], oil-exporting countries [14], and the G-7 countries [15].

In the imports and emissions relationship, imports have statistically insignificant direct and indirect effects on TCO2. Besides, imports positively affect the local CCO2 but have a statistically insignificant effect on the neighboring CCO2. A positive direct effect of imports on CCO2 emissions is corroborating that the consumption of South American imports is pollution-oriented. The literature investigating the determinants of TCO2 and CCO2 also reported the insignificant effect of imports on TCO2 and the positive effect of imports on CCO2 emissions [13, 14].

The direct and indirect effects of REC are found negative on both TCO2 and CCO2. Hdom [10] reported the negative impact of REC on the CO_2 emissions in South America. On the other hand, Deng et al. [4] found that non-REC was responsible for increasing GHGs emissions in South America. Thus, REC helps improve the local environment and has positive environmental spillovers in neighboring countries. Hence, renewable energy helped the entire South American region to reduce production and consumption-based CO_2 emissions. On the other hand, industrial value-added has a statistically insignificant

Table 2. SDM results.

Variables	TCO2 model				CCO2 model			
	Point	Direct	Indirect	Total	Point	Direct	Indirect	Total
$GDPC_{it}$	0.603 (0.000)	0.610 (0.000)	-0.136 (0.129)	0.473 (0.000)	0.706 (0.000)	0.697 (0.000)	0.317 (0.002)	1.014 (0.000)
EXP_{it}	0.100 (0.014)	0.105 (0.009)	-0.179 (0.003)	-0.074 (0.193)	-0.181 (0.000)	-0.177 (0.000)	-0.158 (0.021)	-0.335 (0.000)
IMP_{it}	-0.045 (0.418)	-0.042 (0.440)	0.074 (0.370)	0.032 (0.652)	0.204 (0.001)	0.215 (0.001)	-0.135 (0.160)	0.080 (0.334)
RE_{it}	-0.326 (0.000)	-0.312 (0.000)	-0.389 (0.017)	-0.701 (0.000)	-0.258 (0.000)	-0.247 (0.000)	-0.317 (0.096)	-0.564 (0.006)
IND_{it}	-0.097 (0.189)	-0.096 (0.179)	0.043 (0.714)	-0.053 (0.666)	0.105 (0.225)	0.092 (0.260)	0.450 (0.001)	0.542 (0.000)
Spatial Factors								
$W*GDPC_{it}$	-0.007 (0.959)				0.557 (0.003)			
$W*EXP_{it}$	-0.192 (0.005)				-0.237 (0.006)			
$W*IMP_{it}$	0.087 (0.397)				-0.102 (0.390)			
$W*RE_{it}$	-0.571 (0.007)				-0.458 (0.053)			
$W*IND_{it}$	0.021 (0.879)				0.565 (0.000)			
$W*TCO2_{it}$	-0.270 (0.056)							
$W*CCO2_{it}$					-0.250 (0.058)			
Wald Test								
Spatial Lag	15.07 (0.010)				21.73 (0.001)			
Spatial Error	14.70 (0.012)				24.12 (0.000)			
LR Test								
Spatial Lag	14.62 (0.012)				21.34 (0.001)			
Spatial Error	14.72 (0.012)				24.79 (0.000)			
R^2	0.751				0.858			
Sigma-square	0.010 (0.000)				0.013 (0.000)			
Hausman	141.226 (0.000)				285.415 (0.000)			

effect on both local TCO2 and CCO2. Further, it has a statistically insignificant impact on neighboring countries' TCO2 but positively affects neighboring countries' CCO2. Hence, industrial value-added shows negative spillovers through increasing consumption-based CO_2 emissions in neighboring countries. Khan et al. [15] also reported that industrial value-added accelerated the CO_2 emissions in G-7 countries.

Conclusions

We explore the determinants of TCO2 and CCO2 in the South America region, conducting spatial analyses during 1990-2018. Economic growth is increasing local TCO2 and CCO2 emissions. Further, it also increases the CCO2 in the neighboring countries, but it could not affect the neighboring countries' TCO2. Hence, economic growth has negative local environmental

effects in terms of TCO2 and CCO2. It has negative environmental spillovers in the neighboring countries in terms of CCO2. The exports have a positive effect on the local TCO2 but help to reduce TCO2 in neighboring countries. Hence, exports have positive environmental spillovers for neighboring countries in terms of lowering TCO2. Moreover, exports have negative effects on both local and neighboring countries' CCO2. Hence, exports are helping to reduce the consumption-based CO_2 emissions in the entire South American region. Imports have statistically insignificant effects on local and neighboring countries' TCO2. However, imports are responsible for increasing the local CCO2 emissions but have no spillovers on neighboring countries regarding both TCO2 and CCO2. The IVA could not affect local or neighboring TCO2 emissions and could not affect the local CCO2 emissions. However, IVA has a positive effect on the neighboring countries' CCO2. Pleasantly, REC showed negative effects on both local and neighboring countries' TCO2 and CCO2 emissions. Hence, REC helps clean the local and neighboring countries' environments and is a blessing for the entire South American environment. Based on the results, we recommend the South America region to increase the renewable energy share in the energy mix to support the concept of a sustainable environment in the local and neighboring countries of South America. Moreover, growing exports might also have pleasant effects on the environment, and imports should be discouraged to avoid consumption-based CO_2 emissions.

Conflict of Interest

The authors declare no conflict of interest.

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