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Original Research

Effect of Economic Complexity on CO_2 Emission: a Selection of Shanghai Cooperation Organization Member Countries

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Abstract

The composition of commodities that are produced by a country is a key factor for its environmental performance. High economic complexity implies the transition from a lowly productive agricultural economy to highly productive sectors and the production of more sophisticated commodities. This transition needs an increased level of energy consumption, which in turn entails an increased level of CO_2 emission and environmental degradation. The present research aims to explore the effect of economic complexity on CO_2 emission in some Shanghai Cooperation Organization (SCO) member countries using the GMM method. According to the results, CO_2 emission in these countries is affected by the variables of economic complexity, industry, human capital, and population growth rate negatively and significantly and by the variable of energy consumption positively and significantly. Also, the variables of trade openness and economic growth rate have negative but insignificant effects on CO_2 emission in these countries. It is also found that economic complexity in these countries will significantly reduce CO_2 emission in the long run.

Keywords: CO_2 emission, economic complexity, generalized method of moments, Shanghai Cooperation Organization

Introduction

The Earth's atmosphere is mainly composed of oxygen (O2), nitrogen (N2) and carbon dioxide (CO_2). However, the rapid processes of economic development, urbanization and industrialization that have taken place over the past 30-40 years have significantly disrupted the composition and quality of the atmosphere due to the release of various pollutants [1]. So air pollution has become a global problem today and poses significant risks to human health and natural ecosystems, and makes a million people die every year [2-3]. Air pollution can be defined as the presence of one or more pollutants in the air in quantities and over a period of time that can be harmful to humans, animals and plants' life. It can cause damage to commercial or personal property and

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environmental quality [3]. The most common organic and inorganic air pollutants are ozone (O_3), sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon dioxide CO_2, hydrogen fluoride, carbon monoxide (CO) and formaldehyde (HCHO) [1].

Although mineral resources are extremely important for socio-economic development; the exploitation of minerals and their use in various industrial processes play a significant role in increasing environmental pollution especially air and water pollution [2-3]. The world population has increased significantly over the past century and the most important problems of our time are population growth and population concentration in urban areas. Environmental pollution in cities is becoming more and more severe and widespread due to population growth, urbanization and industrialization. In other words; The demands and needs of the growing population are diverse and growing according to the requirements of the age, and industrial production to meet these needs also increases the requirements for raw materials and energy. The waste generated by industrial production in this process causes excessive air, water and soil pollution. Global climate change and urbanization are identified as the biggest irreversible problems of our time, and environmental pollution is considered the most important problem threatening the life and ecosystem. Especially in densely populated areas, air pollution is one of the most serious problems threatening human life [4-5] Sveik et al. (2020) in their study concluded that population growth causes an increase in heavy metal concentrations [1]. In particular, carbon dioxide (CO_2) and other global warming pollutants have recently come into the spotlight. CO_2 is very important for human health. Increasing of carbon dioxide levels are the result of human activities, not natural global cycles [6].

The effects of climate change are increasingly concerning. Floods, droughts, storms, heat waves, sea level rise, crop growth changes, and disruptions in water systems are some of its damages. Some oceanic coral islands will disappear due to sea level rise and severe waves by the mid-21st century. This environmentally degrading phenomenon may originate from CO_2 emissions caused by human activities. There is a close relationship between CO_2 and economic activities. [7]. Climate scientists have approved that the atmospheric concentrations of CO_2 which has appeared in the last century, negatively affected the global climate system [8]. Increasingly fossil fuels consumption which produces CO_2 leading that climate change is assumed to be an unparalleled global challenge [9]. Due to its impact on the global environment and economic activities, carbon dioxide (CO_2) emissions and methods for reducing it have remained a topic of discussion in the relevant literature [10-11].

Huge developments in the global economy in recent decades have provided developing countries with both opportunities and challenges. Whereas some countries have successfully accepted the changing conditions and have used the opportunities, others have failed to compromise with the changes and have found it increasingly difficult to keep their sustainable growth rate. In today's more complicated and globalized economic system, it is necessary to adopt new production methods and create value to keep up with other parts of the world. Recently, new literature has emerged about the term economic complexity that emphasizes the significance of increasing production capabilities and diversification for economic growth. This literature, which was initiated by Hidalgo and Hausmann (2009), shows that the improvement of economic complexity can have different advantages for a certain country, including higher economic growth [12-13], lower production fluctuations [14-15], and lower income inequality [16]. In addition, research shows that economic complexity can help countries escape from the trap of average income [17-18].

The concepts of high-technology export, export diversity, and economic complexity have drawn significant attention in the literature in recent years. High-technology exports refer to products with high R&D intensity, such as aerospace, computer, pharmaceutical, scientific tools, and electric machinery products [19]. Although it has been proven that these concepts are important for growth and development, there are substantial differences in their definitions and measurements. In a general sense, export diversity refers to different policies that are implemented to change the share of commodities in export packages [20], which is mostly assessed by indices such as Herfindahl-Hirschman index, Theil's index, Gini-Hirschman Index, and Shannon entropy. Nonetheless, it is argued that these actions cannot capture the differences among countries in production capabilities [16]. Recently, Hidalgo and Hausmann (2009) analyzed these capabilities and productive knowledge among countries and introduced the concept of economic complexity for explaining the complicated structure of an economy. Economic complexity encompasses an economy's production knowledge and capability level. It is naturally not easy to quantify these intangible elements. Therefore, Hidalgo and Hausmann (2009) proposed a method based on the assumption that productive knowledge is reflected in the combination of products that are produced by a country. They created the economic complexity index (ECI) based on international trade data. ECI measures the production structure of a country using the concept of diversity and ubiquity [21]. By definition, complex economies are those that are highly diverse but have lower ubiquity. Hidalgo and Hausmann (2009), who developed the concept of ECI, calculated the productive complexity of a country by interpreting trade data as a two-faced network (ubiquity and diversity) in which countries were related to products that they exported. These authors assert that economic complexity is correlated with the country's income level and biases from it are a prediction of its future growth. While gross domestic product is related to production volume, economic complexity can be said to be related to production quality. Some authors have found that countries can change their production structure according to their exportation goals [22].

Therefore, the process of acquiring the ability to produce and export more sophisticated products can be a rational explanation for the process of economic development. On the other hand, economic complexity contributes to the expansion of effective products, such as renewable energy, inside a country. Knowledge management in large production networks produces knowledge-sensitive primary products. Economic complexity shows a higher capacity for the production and export of more complicated products with higher added value and this explains why developed countries enjoy relative advantages in commodity production [23]. The economic complexity of countries has been ignored in empirical studies. Therefore, this research mainly aims to investigate the relationship between economic complexity and CO_2 emission using data on seven selected member countries of the Shanghai Cooperation Organization (SCO) for the period of 2000-2020 in which data were available for the studied variables. It is very important to be expressed that this kind of research, with these types of variables and research methodology, has never been done for member countries of the Shanghai Cooperation Organization (SCO).

SCO covers about 40 percent of the world's population. In terms of energy, this organization has 23.8 percent of global oil, 50 percent of global gas, 36 percent of reserves for power generation, 23 percent of reserves for natural gas production, and 60 percent of reserves for coal production. It is also the largest gas and energy producer and consumer in the world. Iran and Russia have the highest energy capacity in SCO. Iran has the third rank in oil reserves and second rank in gas reserves in the world and is geographically located in the neighborhood of Russia which is the largest gas owner in the world and is an oil-possessing country. SCO has four announced goals, i.e., '(1) strengthening mutual confidence and good-neighborly relations among the member countries, (2) promoting effective cooperation in trade and economics, politics, science and technology, energy, transportation, tourism, environmental conservation, culture, and education, (3) making joint efforts to maintain and ensure peace, security, and stability in the region, and (4) moving towards the establishment of a new, democratic, just, and rational political and economic international order.' To achieve these goals, SCO has approved the establishment of an energy club whose objectives are to expand dialogue among the member countries for the supply of energy security, to update the websites of the energy sector, and to increase cooperation in the field of energy. Accordingly, the SCO member countries are the largest energy producers and consumers in the world and can be in place that they can manage and control a large part of the energy requirement of the world if they employ coordinated policies. Therefore, this organization considers energy security as a key factor of its security policy in addition to military and political issues [24].

Material and Methods

Theoretical Background

The Concept of Economic Complexity

Since 2006, some researchers have started to extensively investigate economic growth based on the ideas of 'space of products' and 'economic complexity.' These studies led to the extraction of the economic complexity index (ECI) [25]. Based on this thought, the most important determinant of the extent of development in a country is the knowledge shaped by the country. Knowledge means a series of experiences, values, information, and organized expert views that provide a framework for evaluating and using new experiences and information [26]. Based on their analysis, the knowledge level of countries is directly related to the types of products produced by them. The production of any product needs specific knowledge. The more diverse the products of a country are, the more extensive the knowledge shaped and accumulated in that country will be. Therefore, complex economies are those that can accumulate a great volume of relevant knowledge in the form of large people networks and produce a diverse set of knowledge-intensive commodities that needs smaller networks of interactions [27].

Complexity is defined as 'a dynamic and constantly emerging set of processes and objects that not only interact with one another but are also defined by those interactions' [28]. Complex systems have fuzzy boundaries. Their mutual factors function based on internal rules that are not always predictable. They also interact with other compatible systems and evolve [29]. Economic complexity implies the production and export of commodities that are based on accumulated and concentrated knowledge and skill, and consequently, commodity specialization in countries. The secret of modern societies is not that people have greater productive knowledge than those in traditional societies, but the secret is that modern societies use a great deal of knowledge by employing a network of society members. This network allows its members to gain specialty, share their knowledge with others, and increase accumulated knowledge and skill. Here, with accumulated knowledge and skill, we mean capabilities [30].

ECI has been built upon two principles of 'diversity' and 'ubiquity.' Diversity implies the number of different commodities produced by a country and ubiquity implies the number of countries producing a certain commodity. It can be observed that complex commodities – commodities that encompass various forms of knowledge – are less ubiquitous. Thus, ECI can be regarded as the result of the diversity of products and the ubiquity of commodities among other countries.

Therefore, a country with a higher ECI shows its higher ability to produce diverse and distinctive (less ubiquitous) commodities [31].

Economic Complexity and CO_2 Emission

The composition of commodities produced by a country is an important factor in its environmental performance. High economic complexity means the transition from a lowly productive agricultural economy to sectors with higher productivity and production of more complex commodities. This transition needs the consumption of energy resources, which in turn aggravates CO_2 emissions and environmental degradation. On the other hand, ECI is associated with the structural development of the economy and reflects the quantity of knowledge and advanced capabilities hidden in the production process. Therefore, more sophisticated countries provide better conditions for the development of technology solutions that are environmentally-friendly. Green innovations caused by more person bytes in the economy replace old environmentally-harmful technology and make the production process cleaner and more efficient [32].

Can and Gozgor (2017) were the first who introduced ECI as an economic model. Their results revealed that higher economic complexity would suppress the CO_2 emission level in the long run and that the increase in economic complexity would reduce the overall CO_2 emission [33].

Neagu and Teodoru (2019) investigated the relationship between ECI and environmental pollution in a panel of 25 EU states for the period of 1995-2016. The results showed a positive relationship between economic complexity and greenhouse gas emissions. Also, it was revealed that countries with higher economic complexity would experience a faster decline in CO_2 emissions due to the difference in energy composition and energy productivity. However, the increase in economic complexity may bring about more environmental degradation due to the increase in production and energy demand [34].

Using a panel of 25 EU states from 1995 to 2017, Neagu (2019) investigated the nonlinear effect of economic complexity on the environment and described this relationship as an inverse U-shaped curve similar to EKC for income. This result implies that the environment of a country tends toward degradation until reaching a certain level of economic complexity beyond which the environmental quality starts to improve. Therefore, economic complexity aggravates pollution at the early stages of exports (due to the extensive use of resources for maintaining exporting commodities). After a certain point, it helps reduce pollution by using less pollutant resources and technologies [35].

In their study in 2014, Doğan et al. showed that ECI differently affects CO_2 emissions at different steps of development and income [36].

In lieu of using pollutant emissions as the dependent variable, Yilanci and Pata (2020) selected ecological footprint (EF) to study the effect of ECI on the environment during the period of 1965-2016 and showed that China produced and exported environmentally-unfriendly commodities [37].

In a study in Brazil, Swart and Brinkmann (2020) showed that forest fires linearly increased with ECI in Brazil, whereas garbage production decreased. However, they found no evidence of a relationship between ECI and deforestation or air pollution. According to what was already said, it is clear that ECI as a major index of structural developments and a representative of the innovative output of a country is a determinant of environmental performance [38].

Estimation Method Selection

The Generalized Method of Moments (GMM) proposed by Arellano and Bover (1995) was adopted for this research. The Generalized Method of Moments (GMM) provides a computationally practical method for estimating statistical model parameters based on information about the population moment terms. This method is an estimation technique that states that the unknown parameters should be estimated by matching the population moments (which are functions of the unknown parameters) with appropriate sample moments. The reason for using the GMM method is the advantages of this method compared to other econometric methods. In calculating the system estimator, while the variables in differences are instrumented by the lags of their own levels, the variables in levels are instrumented by lags in their own differences [39]. It is argued that this estimator improves efficiency by allowing the use of more instruments. Arellano and Bond (1991) proposed two tests for the assessment of the instrument's power. The first is the Sargan test for testing over-identifying restrictions in which the null hypothesis is that the instruments are valid. The second is the serial correlation tests for error terms in which the null hypothesis is that there is no second-order serial correlation. The refutation of the null hypothesis in both tests raises concerns over the validity of the instruments [40].

Given the variables and the fact that the model is a dynamic panel, Equation (1) was used to estimate the effect of economic complexity on CO_2 emission.

$$CO_{2it}=\beta_0 CO_{2it}+\beta_1 Ice_{it}+\beta_2 Indu_{it}+\beta_3 Hum_{it}+\beta_4 E_{it} +\beta_5 Trade_{it}+\beta_6 GDP_{it}+\beta_7 POG_{it}+\varepsilon_{it} \quad (1)$$

The studied model is composed of the dependent variable of CO_2 emission (CO_{2it}), the independent variable of *Ice*, and the controlling variables of industry (*Ind*), actual growth rate (*GDPg*), trade openness (*Trade*), population growth rate (*Popg*), human capital (*Hum*), and energy consumption (*E*). In Equation (1),

Table 1. The list of research variables.

Symbol	Variable	Definition	Source
CO_2	Carbon dioxide	Per capita CO_2 emission (metric tons)	WDI (2021)
ICE	Economic complexity	Economic complexity index	Global Atlas of Economic Complexity (2021)
IND	Industry	The added value of the industry (including construction), percent of GDP	WDI (2021)
GDPG	Actual economic growth rate	Actual growth of GDP (annual variation percent)	IMF (2021)
Trade	Trade openness	Sum of exports and imports measured as a fraction of GDP	WDI (2021)
Hum	Human capital	Human development index	HDI (2021)
E	Energy consumption	Per capita initial energy consumption (per capita gigajoule)	BP Statistical Review (2021)
Popg	Population growth rate	Population growth (annual %)	WDI (2021)

Table 2. Expected signs of the research variables.

Symbol	Variable	Expected sign
ICE	Economic complexity	(-) Negative
IND	Industrial activities	(+) Positive
GDPG	Economic growth	(-) Positive
Trade	Trade openness	(+/-) Positive/negative
Hum	Human capital	(-) Negative
E	Energy consumption	(+) Positive
Popg	Population	(+) Positive

(Source: Research findings)

CO_{2it} represents CO_2 emission for country i at time t, Ice_{it} represents economic complexity index for country i at time t, Hum_{it} represents the human capital index for country i at time t, Ind_{it} represents the added value of the industrial sector as a percent of GDP for country i at time t, E_{it} represents the initial energy consumption in per capita gigajoule for country i at time t, $GDPg_{it}$ represents the actual rate of economic growth, $Trade_{it}$ represents trade openness of a set of imports and exports as a percent of GDP for country i at time t, and $Popg_{it}$ represents the rate of population growth for country i at time t, which was used by the panel data. Since there was no time series data for a long period, the research used the panel data for the SCO member countries. The time period is from 2000 to 2020. Tajikistan and Kirgizstan were excluded from the statistical population due to the lack of data on the studied variables for the target time period.

Expected Signs of Variables

Table 2. presents the expected signs of the variables as per the theoretical framework and empirical studies.

Table 3. The descriptive statistics of the variables.

Variables		Main source of data	Observations	Standard deviation	Min	Max	Median	Mean
CO_2	Carbon dioxide	WDI (2021)	147	4.152873	0.683731	15.04736	5.431610	5.953411
ICE	Economic complexity	http://atlas.media.mit.edu/en (2021)	147	0.798012	-1.190440	1.977124	-0.091537	0.087119
Indu	Industry	WDI (2021)	147	8.973940	17.54846	49.63725	30.92724	31.96907
Hum	Human capital	HDI (2021)	147	0.103358	0.447000	0.825000	0.700000	0.675613
E	Energy consumption	BP Statistical Review (2021)	147	62.36356	12.11832	206.5789	81.76040	88.86517
Trade	Trade openness	WDI (2021)	147	17.18523	25.30628	105.6997	48.03540	50.62019
Rgdp	Actual growth rate	IMF (2021)	147	4.050813	-8.000000	14.10000	5.800000	5.385034
Popg	Population growth rate	WDI (2021)	147	0.781431	-0.460025	2.647399	1.175829	1.074718

(Source: Research findings, Eviews 11)

Descriptive Statistics

Descriptive statistics include methods for collecting, summarizing, categorizing, and reporting numerical factors. These statistics, indeed, describe the data and reveal information about central parameters and data distribution. To provide an overall view of the main characteristics of the calculated variables, Table 3 presents some concepts of descriptive statistics including mean, median, standard deviation, minimum, maximum, and distribution of variables. Table 3 is the descriptive statistics of the research variables for seven SCO member countries for the period of 2000-2020 derived using the Eviews 11 software package.

Results and Discussion

Unit Root Tests of the Research Variables

The reliability of the research variables is checked using the panel unit root tests including the Levin-Lin-Chu (LLC) test, Im-Pesaran-Shin (IPS) test, and augmented Dickey-Fuller (ADF) test. We also used these three unit root tests, and the results were used to explain the variables used in the research.

As is observed in Table 4, the tests for the variables of all tested countries showed that all variables were stationary at the level and first level. So, the null hypothesis regarding the existence of a unit root is refuted for all variables at the level and first level. It can, therefore, be concluded that all research variables are stationary based on the unit root tests, so the estimation lacks false regression.

Table 4. The panel unit root tests.

Variable		Panel unit root tests	Statistic (Sig. level)	
			Statistic value	Statistic probability
Carbon dioxide	CO_2	Levin-Lin-Chu (LLC) test	-2.81990	0.0024
	D (CO_2)	Im-Pesaran-Shin (IPS) test	-6.65283	0.0000
	D (CO_2)	Augmented Dickey-Fuller (ADF) test	68.6017	0.0000
Economic complexity	ICE	Levin-Lin-Chu (LLC) test	-4.38631	0.0000
	ICE	Im-Pesaran-Shin (IPS) test	-2.11048	0.0174
	ICE	Augmented Dickey-Fuller (ADF) test	27.5161	0.0165
Industry	D (Indu)	Levin-Lin-Chu (LLC) test	-5.13425	0.0000
	D (Indu)	Im-Pesaran-Shin (IPS) test	-4.39513	0.0000
	D (Indu)	Augmented Dickey-Fuller (ADF) test	49.5760	0.0000
Human capital	Hum	Levin-Lin-Chu (LLC) test	-5.95307	0.0000
	Hum	Im-Pesaran-Shin (IPS) test	-1.83877	0.033
	Hum	Augmented Dickey-Fuller (ADF) test	22.1614	0.0754
Energy consumption	E	Levin-Lin-Chu (LLC) test	-5.23663	0.0000
	E	Im-Pesaran-Shin (IPS) test	-1.72805	0.0420
	E	Augmented Dickey-Fuller (ADF) test	23.2038	0.0570
Trade openness	Trade	Levin-Lin-Chu (LLC) test	-2.46314	0.0069
	Trade	Im-Pesaran-Shin (IPS) test	-2.51835	0.0059
	Trade	Augmented Dickey-Fuller (ADF) test	29.6351	0.0086
Actual growth rate	D (GDP)	Levin-Lin-Chu (LLC) test	-7.61477	0.0000
	D (GDP)	Im-Pesaran-Shin (IPS) test	-7.06563	0.0000
	D (GDP)	Augmented Dickey-Fuller (ADF) test	70.3761	0.0000
Population growth rate	Popg	Levin-Lin-Chu (LLC) test	-1.85430	0.0318
	D (Popg)	Im-Pesaran-Shin (IPS) test	-3.65815	0.0001
	D (Popg)	Augmented Dickey-Fuller (ADF) test	43.3247	0.0001

Source: Eviews 11 output.

There are several tests, e.g., the Kao test, the Pedroni test, and the Fisher test to check the cointegration of panel data. The present research used the Kao test. The Pedroni test could not be used due to the high number of model variables and the Fisher test could not be used due to data inadequacy. In this test, the hull hypothesis is the lack of cointegration.

The F Limer test is used to check the significance of the panel data method. The null hypothesis that was tested is the capability of model estimation as integrated data, whereas the opposite hypothesis, i.e., H1, is the capability of the model estimation by panel data.

The F Limer test is used to recognize panel and pooled data. The results favored the panel data.

Estimation of Research Model

The Sargan test is one of the tests of the GMM or augmented moment method. After the model is estimated, the Sargan test is used to judge the suitability of the instrumental variables. If the Sargan statistic is greater than the confidence level, the null hypothesis regarding the suitability of the instruments used in the model is supported; otherwise, it is rejected. Table 7 shows the results of the Sargan test.

Table 7 presents the results of the Sargan statistic for the GMM method. According to the results, the null hypothesis regarding the suitability of the instruments is supported and the opposite hypothesis regarding their unsuitability is refuted. So, the instruments used in the research were appropriate.

The homoscedasticity of the variance was checked by the adjusted Wald test. Given the χ^2 statistic, the hull hypothesis regarding the homoscedasticity of the variance is supported and the opposite hypothesis is refuted.

According to Table 8, the null hypothesis of variance homoscedasticity is supported and the opposite hypothesis is refuted.

The correlation in the model was checked by Wooldridge's test. The null hypothesis H0 is the lack of autocorrelation and the opposite hypothesis H1 is the presence of autocorrelation.

According to our results, Wooldridge's statistic value is 7.892 and its probability value is 0.0308. So, H0 is supported and H1 is rejected. There is no autocorrelation in the model's variables.

The results of estimating Equation (1), which investigates the effect of technology advancement on the reduction of CO_2 emission, in Table 10 were estimated by the GMM method. This table also shows the statistical value and the significance level of the studied variables.

The F Limer test was conducted to recognize panel and pooled data. The results were in favor of panel data. Then, the Hausman test was used to prove the model with constant and random effects. The results showed that the research model was a model with constant effects. So, the model related to the panel data was developed and the stationarity tests (unit root) were implemented. All variables studied in the research were significant at the level and difference, showing

Table 5. The results of Kao's cointegration test.

Integration Kao-ADF	p-value	t-statistic
	0.0397	-1.754631
Source: Research findings, Eviews 11		

Table 6. The F Limer test.

F Limer	p-value	t-statistic
	0.000	166.86

Source: Research findings, Strata 15

Table 7. The results of the Sargan test.

Test type	Statistic value	p-level
The Sargan test	163.6072	0.1653

Source: Strata15 output.

Table 8. The results of the variance heteroscedasticity test.

Variance heteroscedasticity	Statistic value	p-level
Adjusted Walt test	5837.23	0.0000
Source: Strata15 output.		

Table 9. The results of the lack of autocorrelation test.

Autocorrelation	Statistic value	p-level
Wooldridge's test	7.892	0.0308

Source: Strata15 output.

Table 10. The results of model estimation by the GMM method.

Variables	Symbol	Statistic value	Sig. level
Lagged CO_2 emission	CO_2	0.8818672	0.000
Economic complexity	ICE	-0.5498231	0.014
Industry	Indu	-0.0022264	0.080
Human capital	Hum	-1.810753	0.092
Energy consumption	E	0.0003289	0.038
Trade openness	Trade	-0.006375	0.544
Economic growth rate	Rgdp	-0.0098343	0.242
Population growth rate	Popg	-0.4511373	0.011

Source: Strata 15 output.

the lack of false regression. In the next step, the GMM method was used to test the research model regarding the effect of economic complexity on CO_2 emission. As was expressed in Table 10, the variables studied here, including economic complexity, industry, human capital, initial energy consumption, trade openness, economic growth rate, and population growth rate, had different impacts on the dependent variable (CO_2). The variables of economic complexity, industry, human capital, and population growth rate had negative and significant effects and the variable of energy consumption had a positive and significant effect on CO_2 emission, which is consistent with the theoretical foundation of the research. The effect of trade openness and economic growth rate on CO_2 emission was negative but insignificant. One unit of increase in the economic complexity of SCO countries would reduce CO_2 emission by 0.8818672 units. Although SCO member countries constitute about 44 percent of the world population, their population has an inverse relationship with CO_2 emission. On the other hand, human capital had a similar effect. It can, thus, be said that these countries have rich human capital. Regarding the variable of economic growth, most studies show that economic growth is accompanied by an increase in CO_2 emission at the early development stages. Economic growth increases energy consumption to meet the growing demand of companies, industries, and households for energy. Therefore, economic growth is expected to increase CO_2 emissions. Economic growth is harmful to the environment at early development stages, but then, it starts to improve environmental quality beyond a certain threshold of per capita income [41]. So, according to this hypothesis, the effect of economic growth on CO_2 emissions depends on the development stage of the countries. However, we cannot infer such a proposition because the effect of the variable of economic growth was not significant. The positive and significant effect of energy consumption in these countries reveals that most energy consumed in these countries is supplied from fossil fuels and it can depend in the industrial sector on how capital is used for production. When more advanced technologies are used, the effect is lower on CO_2 emission [42]. Given the negative effect of industry on CO_2 emission, it can be concluded that advanced technology is used in these countries. Regarding trade openness, after the industrial revolution, the world became growingly connected and the countries welcomed trade. The effect of exports and imports is not definite on carbon emission, but it mainly depends on whether exporting and importing commodities of a country are environmentally friendly. Oil and coal exporting countries are expected to experience more carbon emissions because these commodities are Compact carbon whereas countries that export cleaner energy or more environmentally-friendly products emit less carbon [42]. The results showed that the variable of trade openness had no impact on CO_2 emission. Therefore, our results corroborate previous studies.

Conclusions

Presently, the most important challenges of the modern world include environmental pollution, warming, and climate change caused by global warming [43]. According to NASA, the main cause of these pollutions is human activities. However, the results of the present study show that economic complexity significantly reduces CO_2 emissions in the long run. These findings are in agreement with Can and Gozgor (2017) who reported the negative and significant effect of economic complexity on CO_2 emissions in France in the long run. The results are also consistent with the reports of Yalta and Yalta (2021), and Boleti et al. (2021). Therefore, SCO member countries can contribute to reducing CO_2 emissions and subsequently improving environmental quality by moving towards a diverse and knowledge-based economy. Apparently, policymakers need to consider the structure of production and ensure that the economy is knowledge-based alongside other policies adopted for the alleviation of pollution. Based on the outcomes of this research, we recommend a number of specific policy actions:

– Many environmental researchers argue that technological innovation and the use of high-technology production can improve the productivity of production factors, thereby alleviating pollutant emissions. The results of the present study empirically confirmed that the transition of the countries to more complicated economies can help improving environmental quality. Therefore, these countries should focus on producing more sophisticated products.

– Authorities should place more importance on the improvement of energy efficiency for CO_2 emissions alleviation even in the early stage of development according to their advantages.

– According to our results, although SCO member countries constitute about 44 percent of the world population, their population and human capital have an inverse relationship with CO_2 emission. It can, thus, be said that these countries have rich human capital. To completely get advantages of this issue, the enhancement of human capital can be used to decrease the use of fossil fuel in the production procedure.

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Conflict of Interest

The authors declare no conflict of interest.

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