Effects of Forest Area, Environmental Patents And Financial Progress on Carbon Emissions in Azerbaijan

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Abstract. Decarbonization is at the top of the global agenda, with many countries setting net zero emissions sustainable development goals. Azerbaijan is a country that has managed to significantly reduce its carbon emissions in recent years, and analyzing the determinants of carbon emissions is important for Azerbaijan to continue this success. In this context, the study aims to examine the impact of forest area, financial development, environmental patents and economic growth on carbon emissions according to the Environmental Kuznets Curve (EKC) hypothesis for Azerbaijan over the period 1992-2021. To this end, the study tests the validity of the EKC using the ARDL approach. In addition, the study shows that financial development increases environmental problems, environmental patents have no effect on carbon emissions, and forest area is a critical factor for decarbonization. In light of these results, the government of Azerbaijan should expand its policies to promote afforestation in order to achieve a zero-carbon economy.

Keywords: Afforestation, Azerbaijan, Carbon emissions, Environmental Sustainability, Financial progress

1 Introduction

Global climate change and its environmental consequences are significant challenges currently confronting the world, posing a risk to humanity's sustainable progress. However, the actions undertaken by humans to meet their basic needs have a negative influence on the environment, resulting in significant environmental and socioeconomic difficulties worldwide. In this context, carbon dioxide (CO2) emissions are a crucial catalyst for the acceleration of climate change, originating largely from human activities. Hence, it is of

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utmost importance to determine the factors that contribute to environmental problems in order to minimize their negative consequences and effectively address the climate issue.

Forest cover is a potent component in ecological system preservation by absorbing atmospheric CO_2 emissions. Throughout history, human activities have resulted in the reduction of forest lands, with timber serving as a fundamental resource for economic growth. According to recent reports from the FAO [13], the world continues to face deforestation, albeit at a decreasing rate. Deforestation is the permanent transformation of forested areas into different types of land uses. Stern (2006) points out that the most cost-effective method to decrease CO2 emissions is to regulate or halt deforestation activities. Hence, the preservation of forest cover is a crucial matter, serving as a fundamental component in conserving biodiversity and attaining climate stability.

Innovation in green technologies refers to improving sustainable processes and products. It is regarded as a crucial approach for attaining a low-carbon economy and sustainable development. The International Energy Agency (IEA) [20] highlights green technology as a prominent element in contributing to emission reduction measures. Across all 450 possible scenarios, it has the potential to help achieve over 60% of the goals for reducing CO2 emissions. Green technology innovation has the potential to boost efficiency, increase competitiveness, and reduce environmental impact by facilitating resource conservation, waste recycling, and material and energy conservation [44].

Financial development (FD) is also another determinant of environmental conditions. A well-developed financial system is essential for economic progress because it facilitates the accumulation of capital through savings and investments and increases understanding of how to best use resources. While it accelerates economic operations, it also facilitates research and development (R&D) activities and channels foreign direct investment into renewable energy technology [3]. Advancements in R&D activities lead to improved energy efficiency and increased affordability of renewable energy, thus enhancing ecological sustainability. As a result, the financial sector promotes green innovation and finances clean energy supply to mitigate emissions and pollution from the fossil fuel-based energy sector [24]. The financial sector also contributes to adverse environmental outcomes. Providing funds to firms and industries can increase environmental pollution due to the broad use of fossil fuel-intensive technologies. In the absence of stringent environmental restrictions, the availability of financial resources leads enterprises to rely increasingly on conventional technologies, thereby causing significant environmental issues [49].

This study focuses on Azerbaijan, which is responsible for 10% of the global CO_2. Natural gas is the primary contributor to CO_2, representing 67% of the overall CO_2. in Azerbaijan. Fig. 1 illustrates the CO_2 trends between 1992 and 2021. Azerbaijan has effectively reduced its CO_2 emissions, from 7.34 tonnes per capita in 1991 to 3.63 tonnes per capita in 1997. In 2021, the country recorded 3.71 tonnes per capita of CO_2. emissions. Specifically, from 1997 to 2021, there has been a 1% decrease in total CO_2. per capita, while the trend of CO2 emissions remains flat. This shows that Azerbaijan has failed to successfully reduce CO_2 emissions during the past 20 years.

Accordingly, Azerbaijan pledged in its first Nationally Determined Contribution (NDC) to attain a specific target of reducing CO_2. by 35% by 2030, in comparison to the levels recorded in 1990. Azerbaijan subsequently declared a target of reducing GHG emissions by 40% by 2050 at COP 26. In addition, the country has established a goal of fostering the advancement of green technology and augmenting the proportion of renewable energy technologies in its energy system.

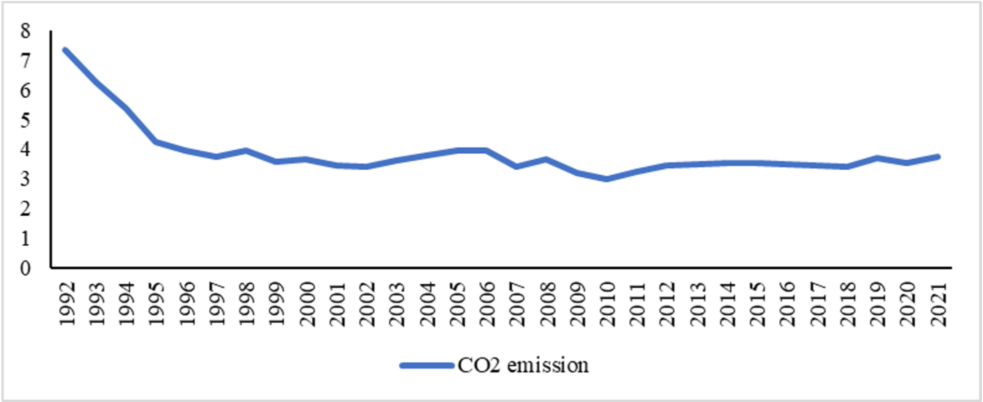

Fig.1. CO_2 emissions in Azerbaijan (tones per capita) [39].

Between 2001 and 2023, Azerbaijan lost 8.16 kha of tree cover, representing a 0.64% decline since 2000 [15]. Given that forest cover functions as carbon sinks, Azerbaijan has the potential to make its ambitions of reducing emissions by giving priority to the protection of forest cover. Fig. 2 shows the changes in forest area between 1992 and 2021. The forest cover has risen from 11.454 in 1992 to 13.832 in 2021, indicating a 20.7% increase. Notwithstanding the modest rate of growth, the country may successfully combat climate change by safeguarding its existing forest areas and engaging in afforestation efforts.

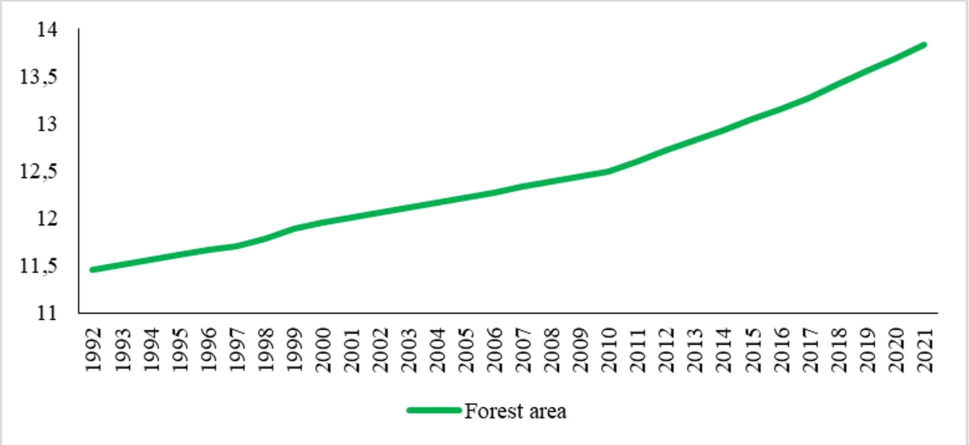

Fig. 2. Forest land area (% of land area) [61].

In light of the aforementioned context, this study examines the influence of forest area, green technology innovation, and FD on CO_2 emissions in the EKC framework in Azerbaijan. This study is the first to examine these factors in the context of Azerbaijan. The significance of using Azerbaijan as a study case stems from its hosting of COP29 in 2024. In this context, determining the factors that influence the country's CO_2 emissions is of utmost importance. Furthermore, the protection of the forest area and effective forest management are among the priorities of the Sustainable Development Agenda. Given the significant role that forestry plays in achieving emission abatement targets, it is crucial to determine how it contributes to the country's environmental goals. Finally, the results of the study can provide a valuable insight for Azerbaijan in reviewing and updating their commitment in line with COP29.

2 Literature Review

2.1 EKC related literature

In the environmental literature, Grossman and Krueger [16] proposed the EKC to investigate the correlation between income level and ecological deterioration. According to the EKC, while economic growth often results in ecological degradation during the early phases of the process, countries ultimately achieve a decent environment as they advance in their economic development. Numerous studies [11, 59, 60] explored the validity of the EKC in accordance with this.

Following the EKC hypothesis proposal, researchers have conducted empirical studies from various viewpoints, countries, and sectors. In line with this perspective, several studies have explored the EKC between forest resources and income. In China, Zhong and Wang [64] find an inverted U-shaped connection between the total factor productivity of the forest industry and emissions. The studies of Caravaggio [8] for 114 countries, Murshed [36] for Bangladesh, and Ajanaku and Collins [2] for 45 African countries confirm the deforestation-based EKC hypothesis. Furthermore, studies conducted by Benedek and Ferto [5, 6] for 72 countries, Minlah et al. [32] for Ghana, and Farooq and Dar [14] for India have also revealed an N-shaped EKC for deforestation. On the contrary, Tsiantikoudis et al. [56] provide evidence for an inverted N pattern in Bulgaria.

2.2 Forest and environment

The forest sector is widely recognized for its significant natural capital to humanity and its ability to withstand climatic risks. Forests are essential for several ecological functions, including CO2 and oxygen sequestration, biodiversity maintenance, and climate regulation. Accordingly, the loss of forests has recently garnered more attention, particularly because of the crucial role that forests play in the global carbon cycle. Recent climate change research findings have suggested that forests may contribute to climate change mitigation.

Magazzino et al. [29] reveal that forest density is a significant barrier to releasing CO2 emissions in 50 countries. Yang et al. [62] find that deforestation is a main driver of CO2 emissions in China. Yasin et al. [63] reach the same conclusion for BRICS economies. Kocoglu et al. [26] assert that the increasing forest area in 181 countries contributes to emission reduction efforts. Pata and Karlilar Pata [41] document that the forest load capacity factor inhibits emissions in India. By analyzing the same country, Rahman et al. [46] find the same results. Barak et al. [5] argue that efforts for extending forest area are a powerful strategy for ecological well-being in G20 countries. Qing et al. [45] find that forest areas improve the sustainability of ecological conditions in six South Asian countries. Interestingly, Chopra et al. [10] find that forest area increases the carbon footprint in five high-emitting countries. Lin and Ullah [57] point out that the depletion of forest area reduces the ecological quality in Pakistan.

2.3 Green innovation and environment

In recent years, many scholars have analyzed green technologies as a potential indicator of carbon reduction efforts. Fang [12] finds that green patents are a driver in carbon-abatement efforts in China. Karlilar et al. [23] show that innovation in green technologies improves the environmental conditions in 36 countries. Li et al. [27] prove the emission reduction impact of innovation activities in China. According to Liao et al. [27], patent activities in green technologies help to increase environmental improvements, and green innovation mitigates the environmental degradation impact of industrialization in OECD countries. Aneja et al. [4] find that technological progress is an essential element in achieving environmental quality in G20 countries. Javed et al. [21] assert that green technology developments in ten mineral-rich countries contribute to environmental protection. Jiang et al. [22] note that technological advancement in sustainable technologies mitigates environmental problems through increasing energy efficiency in China. Somoye et al. [51] uncover that technological patent activities help to mitigate emissions in Nigeria.

2.4 Financial development and environment

The association between financial system development and environment is ambiguous. For instance, Majeed and Mazhar [30] demonstrate that FD promotes environmental sustainability by providing financing for sustainable technology, R&D activities, and technical support to firms and industries. Ozturk et al. [40] demonstrate that the financial system plays a crucial role in assisting five South Asian economies in safeguarding their environment and prioritizing sustainable energy initiatives. In contrast, Ali et al. [3] discover that promoting FD results in improved industrial performance, thereby facilitating increased consumption of fossil fuels. Therefore, this leads to environmental issues in the E7 countries. Ullah et al. [57] find similar results for the financially developed top 14 countries. Wang et al. [59] find that FD in 36 countries exacerbates environmental problems. Saqib et al. [58] highlight that the developments in the financial sector limit the progress of ten countries with high ecological footprints in achieving green growth.

3 Data and methodology

3.1 Data

The study analyzes the effects of forest area on decarbonization within the scope of EKC hypothesis using 1992-2021 data for Azerbaijan. The study compiles data from four different data sources and information about the series is presented in Table 1.

Considering the data in Table 1, the study analyzes the validity of EKC using a forest-oriented approach. For the EKC test, the study uses equations 1 and 2.

$$lnCO_{2t} = \delta_0 + \vartheta_1 lnFORA_t + \vartheta_2 lnGDP_t + \vartheta_3 lnGDP_t^2 + \vartheta_4 lnFD_t + \vartheta_5 lnEPAT_t + \varepsilon_t \quad (1)$$

$$lnCO_{2t} = \delta_0 + \vartheta_1 lnFORL_t + \vartheta_2 lnGDP_t + \vartheta_3 lnGDP_t^2 + \vartheta_4 lnFD_t + \vartheta_5 lnEPAT_t + u_t \quad (2)$$

where δ_0 is the constant term, $\vartheta_{1,2,3,4,\text{and } 5}$ are the long term coefficients, and ε_t and u_t are the error terms. If ϑ_2 is positive, ϑ_3 is negative and both coefficients are statistically significant, the validity of EKC is established for analyzed country. EKC implies that a country gains the ability to reduce environmental degradation above a certain per capita income and is thus an eco-friendly component of GDP growth. The EKC turning point can be calculated as $GDP^* = -\vartheta_1/2\vartheta_2$, where exp(GDP*) denotes the monetary value of the turning point that enables a reduction in environmental degradation. Mikayilov et al. [31] and Mukhtarov et al. [35] state that EKC is not valid for Azerbaijan, in contrast, Gurbuz et al. [17] and Acar et al. [1] state that it is valid. In other words, the validity of EKC for Azerbaijan is still controversial.

Table 1. Data definition.

Symbol	Definition	Measurement	Source
CO_2	Carbon dioxide emissions	Per capita, tonnes	Our World in Data (2024)
GDP	Gross domestic product	Per capita, Constant 2015 USD	World Bank (2024)
FORA	Forest area	square kilometer	
FORL	Forest area	% of land area	
FD	Financial development index	Index	IMF (2024)
EPAT	Environmental patents	International collaboration in development of environmental technologies (% of total technologies)	OECD (2024)

Forests provide carbon absorption through photosynthesis and their CO_2 sequestering functions [47]. In addition, forest areas can reduce CO_2 by absorbing CO_2 and storing it in their biomass [48]. Therefore, the study expects the sign of ϑ_1 to be negative. Waheed et al. [58] for Pakistan, Raihan et al. [47] for Vietnam, Mo and Ke (2023) for China and Raihan et al. (2023) for Thailand found that forests mitigate CO2, whereas Sarwar et al. (2022) emphasized that the increase in forest area is insufficient for CO_2 mitigation and that forest investment should be increased for China. In addition, Chopra et al. [10] determined that increasing forest area upsurges the carbon footprint for the five carbon embittering countries. These results show that there is no consensus on the effect of forest area on CO_2 and this relationship can be investigated for Azerbaijan.

Financial development can theoretically influence the environment in two ways. A well-developed financial system can reduce environmental degradation by supporting the development of new and green technologies and helping to reduce the cost of environmental projects (Tamazian et al., 2010). In contrast, an increase in FD can promote CO_2 emissions by supporting fossil energy consumption and industrialization with GDP growth. Habiba et al. (2023) stated that FD enables CO_2 reduction by encouraging renewable energy for emerging seven countries. In contrast, Wang et al. (2023) emphasized that FD causes CO_2 increase. Similarly, Singh et al. (2023) showed that financial inclusion increases the pollution. Considering the theoretical foundations and previous studies, it can be concluded that ϑ_4 can have a positive or negative sign.

Table 2. Descriptive statistics

	lnCO_2	**lnGDP**	**lnFORA**	**lnFORY**	**lnFD**	**lnEPAT**
Mean	1.330	7.973	9.236	2.517	-1.579	2.655
Median	1.275	8.266	9.226	2.509	-1.536	2.644
Maximum	1.994	8.613	9.344	2.627	-1.307	3.765
Minimum	1.092	7.005	9.162	2.438	-1.931	0.732
Std. Dev.	0.189	0.631	0.053	0.054	0.184	0.563
Skewness	2.218	-0.311	0.488	0.399	-0.421	-0.920
Kurtosis	7.659	1.367	2.133	2.106	2.069	6.019
Jarque-Bera	51.758	3.816	2.132	1.796	1.968	15.632
Probability	0.000	0.148	0.344	0.407	0.373	0.000
Observations	30	30	30	30	30	30

Environmental patents theoretically have a reducing effect on environmental pollution. The technique effect proposed by Grossman and Krueger (1991) suggests that the development of technologies and green patents mitigate CO_2 by supporting renewable energy and eco-friendly consumption habits. Kirikkaleli et al. [25] and Pata et al. [42] showed that EPAT has no impact on the environment, while Cheng et al. [9] and Töbelmann and Wendler [55] reported that EPAT contributes to carbon reduction. The disagreement on the environmental impact of EPAT shows that research is needed for other countries. The sign of the coefficient of EPAT ϑ_5 is expected to be negative. Table 2 shows the descriptive characteristics of the series used in the study.

FORA is the variable with the highest mean value. FD has the lowest statistical value. The variables with the lowest standard deviation relate to the forest. This indicates that the change in forest area in Azerbaijan over time is not high. The study looks at forest area using two different units of measurement (i.e., square kilometers and % of land area) to test whether the results change depending on the forest variable. The Jarque-Bera test statistics and the probability values indicate that EPAT and CO_2 are normally distributed, while the other series are not normally distributed.

3.2 Methodology

The study uses the unit root test of Zivot and Andrews [65]) (ZA) and the ARDL approach of Pesaran et al. [43] for the empirical analysis. The ZA makes it possible to investigate the stochastic properties of series by taking an endogenous structural break into account. For the ARDL approach to be applicable, the dependent variable must be I(0) and must not be a series I(2). To check this prerequisite, the study applies the ZA unit root test in the first stage.

The study applies the ARDL approach in the second phase. The ARDL approach is favored by researchers because it allows the simultaneous estimation of short-run and long-run coefficients, permits the cointegration analysis of mixed-order series, and provides estimates that are robust to endogeneity problems. The ARDL modeling applied in the study is shown in Eq. (3):

$$\Delta \ln CO2_t=\beta_0+\sum_{i=1}^{m}\mu_1\Delta \ln CO2_{t-i}+\sum_{i=0}^{n}\mu_2\Delta \ln GDP_{t-i}+\sum_{i=0}^{o}\mu_3\Delta \ln GDP^2_{t-i}+\sum_{i=0}^{p}\mu_4\Delta \ln FD_{t-i}$$

$$+\textstyle\sum_{i=0}^{r}\mu_5\Delta \ln EPAT_{t-i}+\forall_1 \ln CO2_{t-1}+\forall_2 \ln GDP_{t-i}+\forall_3 \ln GDP^2_{t-i}+\forall_4 \ln FD_{t-i}+\forall_5 \ln EPAT_{t-i}+z_t \quad (3)$$

where β_0 is the constant term, and z_t is the error term. The null hypothesis of no-cointegration of the ARDL model is tested as Ho=β_0=$\forall_1$=$\forall_2$=$\forall_3$=$\forall_4$=$\forall_5$=0 for Case II (restricted constant and no trend).

4 Empirical results

The study first performs a unit root analysis and reports the results in Table 3. The ZA unit root test shows that GDP, FD and EPAT are stationary at their levels I(0), while the series CO_2, FORA and FORL are stationary at their first differences I(1). Since the series have a mixed order of integration, the use of the ARDL approach is appropriate.

Table 3. ZA Unit root results.

	Level	Time break	First difference	Time break
	-4.166	2011	-6.571*	1997
	-6.077*	2005	—	—
A	-0.491	2002	-8.525*	2011
FORL	-1.115	2000	-6.509*	2011
	-6.538*	1997	—	—
	-6.827*	2007	—	—

Note: * denotes 1% significance level.

The study applies bounds testing as the first stage of the ARDL and reports the results in Table 4. The test statistics for the FORA and FORL models are larger than the CVs, indicating a long-term correlation between CO2, GDP, forest area, FD and EPAT. The results of the diagnostic tests in panel (b) show that the ARDL models are free of autocorrelation, heteroscedasticity, non-normal distribution and model specification problems.

Table 4. Bounds test results and diagnostic check.

Panel (a): Bounds test						
			Pesaran et al. (2021)		Narayan (2005)	
ARDL Model	k	Test statistic	1% CV	5% CV	1% CV	5% CV
FORA (2,2,0,0,2,0)	5	9.149*	4.15	3.38	5.761	4.193
FORL (1,2,1,0,2,1)	5	10.262*				
Panel (b): Diagnostic check						
Models		FORA (2,2,0,0,2,0)		FORL (1,2,1,0,2,1)		
Test		Test statistic	p-value	Test statistic	p-value	
Jarque-Bera		0.890	0.640	0.300	0.860	
White		0.720	0.704	0.862	0.596	
Ramsey		0.397	0.679	0.542	0.596	
LM		2.095	0.159	0.275	0.763	

Note: * denotes 1% level of significance. CV: Critical value.

Table 5 presents the findings of the ARDL estimation. It was determined that EKC is valid for both models. The validity of EKC for Azerbaijan confirms the results of Gurbuz et al. [17] and Acar et al. [1]. The turning point is determined as 2588USD for FORA and 2553USD for FORL. Azerbaijan exceeded this per capita GDP income level (USD 2631) in 2005. In other words, income has been a tool for reducing environmental degradation since 2005.

The impact of EPAT on CO_2 is insignificant. This finding is consistent with Kirikkaleli et al. [25] and Pata et al. [42]. This situation implies that environmental patents are not used in Azerbaijan to the extent and with the efficiency that would enable decarbonization. FD has an increasing effect on CO_2 emissions. According to Model 1, a 1% augment in FD increases CO_2 emissions by 0.57%. The rise in FD provides people with more financial resources and more consumption opportunities. More consumption and the use of natural resources increase environmental destruction.

Table 5. ARDL estimations results.

Model	FORA		FORL	
Variables	**Test stat.**	**p-value**	**Test stat.**	**p-value**
lnFORA	-4.582*	0.009	—	—
lnFORL	—	—	*	
lnGDP			*	
$lnGDP^2$	*		*	
lnFD	**		*	
lnEPAT				
C			*	
ECT_{t-1}	-0.487*	0.000	-0.755*	0.000

The forest area is identified as the most important element in the analysis of CO_2 reduction. Increasing the forest area by 1% mitigates CO_2 by about 4-4.5%. In this case, it shows that the protection of forest areas and the acceleration of reforestation activities in Azerbaijan should be accelerated to achieve the net zero target. This finding is consistent with the outcomes of Raihan et al. [47] and Mo and Ke [34].

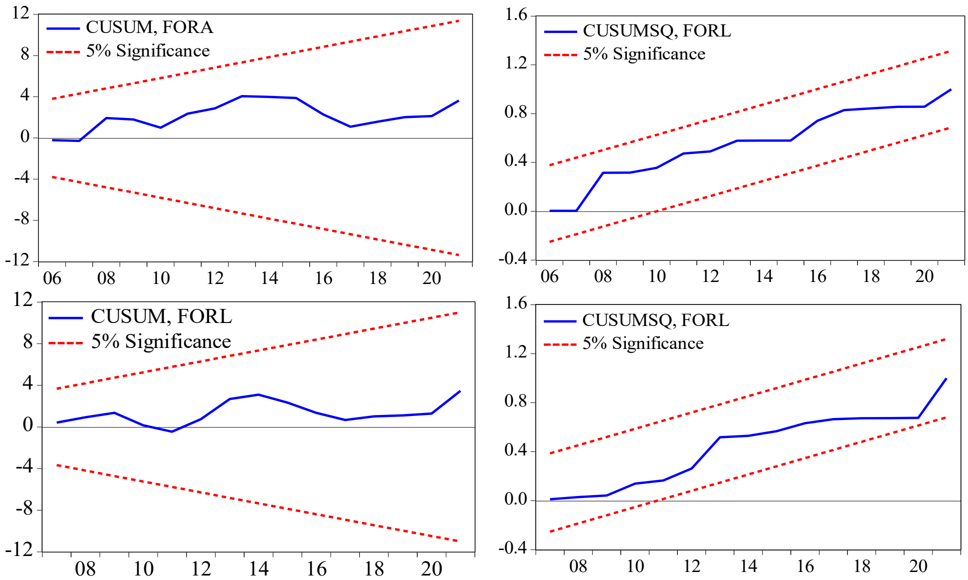

Fig. 3. Stability check for parameters.

A negative and significant ECT supports the cointegration relationship Fig. 3 presents the results of the CUSUM and CUSUMSQ tests by Brown et al. [7]. The findings of the stability test confirm that the coefficients obtained from the ARDL models are stable and the findings are reliable.

5 Conclusion

The objective of this study is to analyze the impact of forest area, GDP growth, FD and environmental patents on carbon emissions in Azerbaijan. For this purpose, the study uses the ARDL approach. EKC is active in Azerbaijan. FD increases carbon emissions, while EPAT has no impact on the environment. The growth of forest area is the most effective factor in reducing CO2 emissions in Azerbaijan. Based on these results, the study offers various recommendations for action in the context of carbon neutrality.

Azerbaijan is a developing country and, in this context, it is important to continue GDP growth. The analysis shows that the GDP growth of Azerbaijan since 2005 has contributed to the mitigation of CO_2 emissions. In this context, the government of Azerbaijan should direct the growing income level and state budget to environmental awareness programs and R&D, thereby supporting the decarbonization process.

Financial development is a detrimental factor for environmental quality in Azerbaijan. Therefore, Azerbaijan should implement reforms in the field of FD. It is important that all sectors of society benefit from financial services and that financial opportunities are transferred to green projects. To this end, investments in green finance should be encouraged and companies using green finance should be exempted from taxes.

EPAT is not a factor supporting green and carbon-neutral development in Azerbaijan. This may be due to the inadequate and ineffective use of EPAT. In light of this finding, the Azerbaijani government may choose an approach that specializes in developing green patents, expands the development of special patents that promote carbon neutrality, and encourages patents that improve energy efficiency in the energy sector. In particular, encouraging patents that improve the efficiency of natural gas could allow Azerbaijan to do more work with less energy, which would help reduce carbon emissions.

Forest areas play a key role in the decarbonization process for Azerbaijan. Taking this into account, the government of Azerbaijan should increase penalties for those who pollute and destroy forest areas, promote education about the environmental and economic benefits of forest areas, and increase funding for afforestation projects. Thus, increasing investment in forests can help reduce CO2 emissions and improve living standards. The study has some limitations. First of all, the determinants of environmental indicators such as ecological footprint could not be analyzed due to the limited data for Azerbaijan. Future studies may analyze the interaction of environmental indicators such as carbon footprint with forest area for Azerbaijan when more than 30 years of data are available. Another limitation of the study is related to the methodology. Future studies may assess the environmental impact of forest area in Azerbaijan using Fourier transform and wavelet transform methods when more data are available. Thus, the importance of forest investment for a sustainable ecosystem in Azerbaijan can be discussed from different perspectives.

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