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Decarbonizing the U.S. Economy through Artificial Intelligence and Information Technology: An Empirical ARDL Analysis

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Abstract

Climate change has become one of the most paramount threats to a sustainable world, and therefore, this requires the development of sophisticated technological and financial strategies to become carbon neutral. This paper discusses how innovations in Artificial Intelligence (AI), stock market development, adoption of Information and Communication Technology (ICT), economic growth, and population dynamics have affected carbon emissions in the United States between 1990 and 2021. Using the Autoregressive Distributed Lag (ARDL) model and Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and Canonical Cointegrating Regression (CCR) estimators, the analysis establishes short-run and long-run associations between the variables chosen. The results indicate that economic growth, capitalization of stocks in the market, and population increase contribute greatly to carbon emissions, but the innovation of AI and diffusion of ICT decrease the emissions considerably in the long term. The diagnostics of robustness test or prove the reliability of the models, and there are no problems with serial correlation or heteroscedasticity. These results underscore the twofold nature of digitalization and financial development in building environmental sustainability. The paper emphasizes that policies that foster AI-based energy optimization, sustainable financial operations, and environmentally focused technological invention are needed to facilitate the American journey of achieving carbon neutrality.

Keywords: Artificial intelligence, Information and communication technology, Stock market development, Carbon neutrality, Using autoregressive distributed lag, United States.

1 | Introduction

The increased threat of climate change on the planet, greenhouse gas emissions, and ecological deterioration are becoming a growing challenge due to the accelerating rate of industrialization, reliance on fossil fuels, expansion of technologies, and Population Growth (POP) [1–3]. To counter this, major economies have been

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focusing more on strategic frameworks meant to contain carbon emissions and ensure environmental friendliness [4], [5]. The United States is one of them, being not only a leading economy but one of the largest emitters of carbon dioxide in the world, with an enormous impact on the final climate results on the planet [6]. The simultaneous economic growth and reduction of carbon dioxide emissions by the countries in 2021 (to 92.97 exajoules and over 4.7 billion tons, respectively) pose a serious policy challenge [7]. As a world economy, the United States. The economy is the engine of global production and consumption trends and, at the same time, experiences increasing sustainability pressures [8]. With the growing energy needs coupled with technological advances and population expansion, the need to disconnect development and environmental degradation is becoming an ever-growing necessity. As a result, there has been the emergence of the integration of AI, Information and Communication Technology (ICT), and the financial market mechanisms as a transformative method of realizing carbon neutrality in the United States.

The US is at a unique place in the crossroads between blistering economic growth and growing environmental problems [9]. Being the largest economy and the second-largest carbon emitter in the world, the developmental pathway is a powerful influence on the global climate agenda [6], [10]. Although the countries are advancing in terms of renewable energy utilization and technological modernization, the carbon intensity is kept at a high level by the countries that are dependent on fossil fuels and industrialized production [7]. This self-contradiction of stimulated economic and POP with promising innovation brings on a sense of urgency to find policy mechanisms that harmonize prosperity and sustainability. Over the past few years, interest has switched to digitalization, financial innovation, and AI as strategic means of reducing emissions [11], [12]. The use of AI and ICT investments is likely to streamline the use of resources, facilitate the transition to a cleaner energy system, and redesign production networks [13]. At the same time, the development of stock markets affects the financing of corporations, which makes it possible to invest in green investment and also to develop emission-intensive growth [14], [15]. Nevertheless, there have been few empirical studies conducted on the combined effect of these digital and financial drivers on the United States' carbon pathway. Filling this vacuum offers important insights into how the emerging technologies and market mechanisms will help the nations to commit to being carbon neutral fast.

The connection between economic activity, technological progress, and environmental decline has been under conceptual analysis since the IPAT and STIRPAT models that propose the environmental impact to be influenced by POP, wealth, and technology [16], [17]. Riding on these pillars, several studies have been conducted to understand the impacts of economic development, digitalization, and industrialization on environmental performance in different regions. It is always observed that fast economic growth will aggravate emissions; at the same time, technology advancement and digital innovation will reduce them [18–20]. Even with the increasing literature worldwide, the United States is the least studied in this context, especially when it comes to the duality of AI and financial markets. The past studies have concentrated on developing or regional economies, including China, the Nordic countries, and the G-7 [21], [22]. These articles support that AI and ICT might be promising to reduce emissions, but they do not often discuss how they interact with the growth of the stock market, which is another vital financial motivation for energy investments. Therefore, the consideration of both digital and financial aspects of the United States is required. The case and the development of one analytical model contribute to something new, combining both technological innovation and macroeconomic sustainability, and developing the discussion on the topic of carbon-neutral transitions.

This paper will be based on the above arguments and will be designed to give an empirical analysis of the role of AI, Stock Market Capitalization (SMC), ICT, economic growth, and population dynamics in contributing to carbon emissions in the United States over the period of 1990-2021. Based on the STIRPAT model and the Autoregressive Distributed Lag (ARDL) model, the study will examine the short-term and long-term dynamics of these relationships [16], [19]. The main research questions are as follows: 1) How do AI innovation and stock market development influence carbon intensity in the U. S? 2) How does ICT diffusion, economic growth, and population expansion either degrade or improve the environment? The research makes contributions to the literature in a number of ways. To begin with, it is one of the first efforts to combine the innovation of AI and financial market growth into a single econometric model of evaluating carbon neutrality in the United States. Second, it enhances the empirical coverage through the application of several robustness estimators (FMOLS, Dynamic Ordinary Least Squares (DOLS), and Canonical Cointegrating Regression (CCR)) to guarantee the statistical validity. Lastly, it offers practical information that can be used by policymakers to use digital transformation and sustainable financial processes with the aim of meeting the long-term targets of reducing emissions and supporting the countries' climate pledges.

The rest of this study is organized in the following way; Section 2 summarizes the existing literature regarding the nexus among AI, stock market development, and the use of ICT, economic growth, population dynamics, and environmental quality, Section 3 expounds on the sources of data, theories and econometric models, such as the ARDL, FMOLS, DOLS, and CCR models, Section 4 provides and discusses the empirical findings, and a set of diagnostic and robustness tests to guarantee the validity of the results. Lastly, Section 5 will end with key findings, policy implications, and strategic recommendations to further develop carbon neutrality in the United States.

2|Literature Review

The association between environmental degradation and economic growth is a topic that has attracted a lot of research, which shows intricate region-specific dynamics. The majority of studies show that the increase in the economic growth level tends to increase carbon emissions because of the increased industrial activities and higher energy use [20-24]. Experiments in Italy, Kenya, and China conclude that economic development plays a key role in putting pressure on the ecological context, and underlines the classic development-pollution trade-off [25], [26]. On the other hand, some of the analyses, especially in the context of the Environmental Kuznets Curve (EKC), indicate that economic growth may eventually help decrease emissions following technological and institutional breakthroughs [19], [27]. These results point to the fact that the nexus between economic growth and the environment is not linear, but it is influenced by the development, innovation capacity, and policy context. Nonetheless, even though the evidence of this across borders is vast, there has been a paucity of scholarship regarding the United States, whose economic size and technological depth make this a special case. Since it has two problems to overcome, growing sustainably and at the same time decarbonizing, it is essential to reevaluate the GDP-CO relationship through the new econometric models that will allow considering the impact of structural change, innovations, and policy implementation as a trinity of factors that will define the future path of emissions in a developed economy.

The concept of AI has become an innovation with transformative power towards sustainable development to improve energy efficiency, automate resource management, and create a cleaner production system. The experience of different regions indicates that AI innovation has a significant positive effect on ecological footprints and carbon emissions mitigation [22], [28]. Research in both the Nordic region and the United States shows that the private investment and innovation of AI enhance the environmental performance through the expansion of the load capacity and sustainable production [29], [30]. Likewise, empirical studies by means of advanced econometric methods, e.g., the ARDL and MMQR models, confirm the long-term environmental gain of AI-based technologies in developed markets [31], [32]. However, there are also opposing results, which indicate that the potential of AIs is not fully used or evenly distributed, particularly in developing situations with low returns on the environment [33]. Regardless of these conflicting results, the introduction of AI into environmental governance poses a strategic chance to countries such as the United States in meeting its emission reduction goals by decarbonization using innovation. However, an important gap in the research is that the empirical literature does not comprehensively understand AI/financial and macroeconomic interactions in the formation of carbon outcomes.

SMC has an impact on the quality of the environment by financing production and technology, as well as innovation. An effective and advanced stock market is capable of directing investment into cleaner technologies, but it might also spur industrial growth that will raise emissions [34]. The empirical evidence is thus inconclusive: in Asian and European economies, SMC has been found to improve the quality of the environment by facilitating green innovation and energy transition [35], [36], whereas other studies have found that financial growth actually adds to carbon emissions by promoting capital-intensive production [37], [38]. The data of BRICS-T and G-20 regions also suggest that the influence of stock market development depends on the level of economic development and the strictness of environmental regulations [39]. Even though SMC has the potential to find finances to invest in renewable initiatives, its hypothetical growth can also lead to the destruction of ecological stability. Therefore, the effects of stock market activity on the environment continue to be case-specific and policy-related. In the case of the United States, with one of the most developed financial markets in the world, it is necessary to evaluate the interaction between market capitalization, technological innovation, and economic growth to find the sustainable financial routes to carbon neutrality.

The ICT has a two-fold responsibility to influence the environmental outcome since it contributes to the creation of the model of digital efficiency and simultaneously leads to the creation of electronic waste and energy demands. Empirical findings indicate that carbon emissions can be mitigated through ICT development to enhance energy efficiency, promote remote work, and allow for cleaner production systems [40–42]. CO emissions have been linked to reduced ICT penetration in various economies, including those of the Belt and Road Initiative [43], [44]. But the opposite data points out that the growth of ICT can increase emissions in cases where the digital infrastructure is heavily reliant on non-renewable energy [45]. Such a back-and-forth trend highlights the environmental paradox of ICTs, namely, the digitalization process can expedite sustainability, but the advantages depend on energy efficiency and the use of green technologies. Although much of the research has been done internationally, there is little empirical data on the United States, where digital penetration and industrial integration is greater and therefore may have different environmental impact. In that way, the analysis of the ICTs net contribution to the decrease in carbon emissions in the United States background is critical in understanding whether digital transformation can help promote national sustainability aims or present new trade-offs of an ecological nature.

3 | Methodology

3.1 | Data and Variables

The paper uses annual time-series data on the United States of America between 1990 and 2021 to analyze the impact of technology, finance, and demographic variables on the quality of the environment. The dependent variable is carbon dioxide emissions (CO), which is granted in kilotons according to the World Development Indicators (WDI) and is taken as a surrogate of environmental degradation. As the key explanatory variables, it is possible to identify Gross Domestic Product (GDP), which is the measure in current United States dollars per capita, WDI; AI innovation, proxied by the number of patent applications in AI-related fields, our world in data; SMC, measured in Percentage of GDP, Global Financial Development Database; ICT, measured in ICT goods imports as a percentage of total goods imports, our world in data; and POP, measured in the total number of inhabitants All the variables were changed to natural logarithmic to stabilize variance and normalize distribution. The presence of these variables indicates the multidimensional factors of change of the environment: economic prosperity, technological progress, and population increase. These indicators together will give the study a grandiose empirical framework of the determinants of CO emissions in the United States, making results transparent and reproducible in terms of clearly defined sources and measures of units.

3.2 | Theoretical Framework

This study is grounded in the IPAT model, which conceptualizes environmental impact (I) as the multiplicative function of Population (P), Affluence (A), and Technology (T) [46]. The framework was later refined into the STIRPAT model by Dietz and Rosa [17] to allow for stochastic estimation and elasticity measurement. In this modified form, environmental degradation is expressed as:

$$I = aP^{b}A^{c}T^{d}e. \quad (1)$$

Where a is the constant term, b–d are the estimated elasticities, and e is the error component.

Now, the extended version of *Eq. (1)* can be written in *Eq. (2)*

$$CO_{2it} = \alpha_0 + \alpha_1 GDP_{it} + \alpha_2 AI_{it} + \alpha_3 SMC_{it} + \alpha_4 ICT_{it} + \alpha_5 POP_{it}. \quad (2)$$

The logarithmic forms of the variables are utilized in *Eq. (3)* to guarantee normal distribution.

$$LCO_{2it} = \alpha_0 + \alpha_1 LGDP_{it} + \alpha_2 LAI_{it} + \alpha_3 LSMC_{it} + \alpha_4 LICT_{it} + \alpha_5 LPOP_{it}. \quad (3)$$

In this research, CO_2 emissions serve as the environmental impact (I). POP represents the demographic component (P), economic growth, and SMC reflects economic affluence (A), while AI and ICT capture technological progress (T). By integrating these dimensions, the model enables the assessment of both economic and technological determinants of environmental sustainability. Applying the STIRPAT specification allows for flexible estimation of short- and long-run elasticities using the ARDL approach, facilitating a comprehensive understanding of how population dynamics, financial development, and innovation jointly influence carbon emissions in the United States.

3.3 | Empirical Strategy

To test the dynamic interrelationship among the chosen variables, this paper will use the ARDL model, which is an effective model of the small-sample data with mixed integration orders of either I(0) or I(1) [47]. This analysis commences with three unit root tests: The Augmented Dickey-Fuller (ADF), the Phillips-Perron (PP), and the DF-GLS tests to determine the stationarity of each of the series and to ensure that there are no I(2) variables. The ARDL bounds testing method is then used to determine relationships among CO emissions, economic growth, AI, SMC, ICT, and POP in the long run under the condition that the order of integration is established. Once cointegration has been determined, short-run and long-run elasticities are estimated using the ARDL model with an Error Correction Term (ECT) to include the rate of adjustment to equilibrium. In order to check the robustness, three complementary estimators are used, namely FMOLS, DOLS, and CCR, to guarantee the results' consistency and efficiency [48]. Lastly, the models are reliable as diagnostic tests, such as Jarque-Bera, Breusch-Pagan-Godfrey, and Lagrange Multiplier tests, have been used to determine that the models are free of normality, homoscedasticity, and serial correlation. This economic and technological approach gives a solid base to evaluate the impact of the environment in the United States, which is done by the collaboration of economic and technological factors.

4 | Results and Discussion

The summary statistics in *Table 1* indicate that all variables are approximately normally distributed, as reflected by the small difference between mean and median values and kurtosis values near three. CO_2 emissions (LCO_2) and population (LPOP) exhibit low variability, while AI innovation (LAI) shows higher dispersion, suggesting fluctuations in technological development over time. Negative skewness in most variables implies a concentration of observations at higher levels. Furthermore, Jarque–Bera probabilities above 0.05 confirm the normality assumption, validating the suitability of these variables for regression analysis and ensuring the robustness of the subsequent econometric estimations.

Table 1. Summary statistics.

Statistic	LCO_2	LGDP	LAI	LSMC	LICT	LPOP
Mean	15.5283	10.7145	7.6482	4.8627	2.6739	19.5431
Median	15.5231	10.7923	7.3268	4.9034	2.6681	19.5562
Maximum	15.6329	11.2104	9.8053	5.3536	2.9255	19.6627
Minimum	15.3017	10.1496	6.2351	3.9923	2.3049	19.3738
Std. Dev.	0.0865	0.3211	1.0943	0.3349	0.1378	0.0916
Skewness	-0.4178	-0.2835	1.0214	-0.7057	-0.2443	-0.2928
Kurtosis	2.7011	1.9615	3.0842	2.9837	3.6425	1.9329
Jarque–Bera	1.4823	2.1068	6.9324	2.9876	1.3542	2.0879
Probability	0.4775	0.3481	0.0312	0.2297	0.5086	0.3554

Table 2 presents the outcomes of the ADF, PP, and DF–GLS unit root tests. The findings reveal that LCO_2, LGDP, LAI, and LSMC are non-stationary at the level but become stationary after first differencing, confirming their integration at I(1). Conversely, LICT and LPOP are stationary at a level, implying I(0) processes. These mixed integration orders justify the application of the ARDL approach, which efficiently accommodates variables integrated at both I(0) and I(1) levels. Overall, the results ensure the suitability of the dataset for cointegration analysis and robust dynamic estimation.

Table 2. Unit root test.

Variables	ADF I(0)	ADF I(1)	P-P I(0)	P-P I(1)	DF-GLS I(0)	DF-GLS I(1)	Decision
LCO_2	-0.283	-5.038***	-0.337	-4.498***	-0.295	-3.944***	I(1)
LGDP	-0.812	-4.786***	-0.694	-4.165***	-0.742	-4.202***	I(1)
LAI	-0.372	-4.012***	-0.429	-4.091***	-0.388	-4.167***	I(1)
LSMC	-0.485	-5.106***	-0.421	-4.937***	-0.468	-4.862***	I(1)
LICT	-3.142**	-4.627***	-3.842***	-4.591***	-3.422**	-4.138***	I(0)
LPOP	-5.173***	-6.512***	-4.903***	-6.823***	-5.129***	-6.588***	I(0)

Table 3 presents the results of the ARDL bounds testing approach. The computed F-statistic value of 7.486 exceeds the upper critical bounds at the 1%, 5%, and 10% significance levels, thereby confirming the existence of a long-run cointegrating relationship among the selected variables. It implies that carbon emissions, economic growth, AI, SMC, ICT, and POP move together in the long term. Hence, the ARDL framework is appropriate for further analysis of both short-run and long-run elasticities, ensuring robust and reliable estimation of the dynamic relationships among the variables.

Table 3. ARDL bound test.

Test Statistic	Value	Significance Level	Lower Bound I(0)	Upper Bound I(1)	Decision
F-statistic	7.486	1%	3.41	4.68	Cointegration confirmed
k (Number of regressors)	5	5%	2.78	3.97	
Critical Values Pesaran et al. [47]	—	10%	2.45	3.52	

According to the ARDL estimates, AI innovation reduces CO emissions in both the horizontal with a long-run elasticity of -0.211 ($p<0.01$) and short-run impact of -0.107 ($p<0.05$), meaning that AI innovation has a significant impact on an immediate reduction in CO emissions and the increase in effects over the long run. Mechanistically, AI will be able to save energy, automate production, and make smarter resource distribution in various fields- cutting down waste and carbon intensity by automating processes, predictive maintenance, and making demands smarter. This meaning is consistent with the evidence provided in multi-country and regional settings, which suggests that the use of AI increases environmental performance or load capacity and facilitates sustainability transitions [28–31], [49], [50]. Simultaneously, the literature also mentions situations in which AIs' benefits are not stamped--particularly, in cases of shallow diffusion, in which energy systems are still fossil-intensive, or in which the implementation is cost-oriented rather than ecology-oriented, they produce minimal environmental benefits [33], [51]. Combined, our findings in the United States are also aligned with the major perspective that innovation-driven digitalization is a plausible route to decarbonization, whereas the inconsistent results in other countries highlight that policy design, sectoral preparedness, and other green investment enabling AIs to achieve an environmental payoff.

The ARDL outcomes indicate that in both the short run and long run, SMC has a positive and statistically significant impact on CO_2 emission, which implies that the growth of market capitalization is connected with higher degradation of the environment. A long-run coefficient (0.167) and short-run impact (0.102) of 0.167 show that financial deepening and increased capital flows can initially cause the stimulation of carbon-intensive industrial production and consumption by higher rates of investment and demand, which leads to the effect of scale that prevails over efficiency gains. This result confirms the findings that the rise in financial growth frequently increases emissions in highly industrialized economies [52–54]. On the other hand, research by Liang et al. [34], Musah [35], and Paramati et al. [36] points to the benefits of developing a stock market in terms of improving the environmental quality, i.e., investing in cleaner technologies, particularly in developed or political economies. The simultaneous presence of these opposing effects highlights the duality of SMC- although it gathers capital to drive innovation, the environmental result of the investments and the rigor of the green financial governance can only be so, which explains why the net effect of the trend in the United States case is still environmentally damaging.

The results of the ARDL show that CO emissions are positively and significantly influenced by GDP, both in the long run (0.543, $p<0.01$) and in the short run (0.328, $p<0.01$), which signifies that the growth in income levels and industrial production affects high levels of carbon emissions in the United States. Such an outcome confirms the scale effect of G economic growth DP whereby greater output, mobilization, and further energy consumption exacerbate environmental deterioration. The result aligns with the literature stating that fast economic growth is likely to increase fossil fuel reliance and intensity of emissions [25], [55], [56]. Raihan et al. [57] and Ridwan et al. [29] came to similar conclusions, as they observed that industrialized economies experience a challenge of balancing growth and output against environmental objectives. On the other hand, other studies support the existence of the EKC whereby, in the cases of higher income levels, both technological innovation and environmental regulation can counteract emissions [31], [58], [59]. Nevertheless, the positive correlation is maintained in the United States, which indicates that the growth of the economy is still carbon-intensive, and it needs to be transformed towards a green industrial structure, renewable energy, and new production strategies to separate the growth of the economy from the devastation of nature.

ICT is indicated to decrease CO emissions, and the estimates presented by the ARDL indicate its long-run coefficient of -0.186 ($p<0.05$), and its short-run effect of -0.091 ($p<0.10$). It shows that ICT diffusion enhances improvement of the environment in the short term and in the long term by increasing digital efficiency, improving energy management, and encouraging the innovation of a low-carbon economy across industries. ICT supports intelligent systems, distant operations, and automation that reduce energy wastage, which is in concert with previous findings that it has a positive impact on the environment [40–43], [60]. Based on these studies, it seems that digitalization promotes the resource-efficient processes that enhance energy productivity and minimize emissions. On the other hand, some of the results, specifically those of young economies, show that the ICT growth might increase emissions because of the energy-consuming nature of data infrastructure and electronic production [45]. However, the general practice, such as the current United States case, speaks in favor of the ICT decarbonization hypothesis, where digital technologies become drivers of sustainable change. Therefore, sustained ICT innovation, facilitated by the introduction of renewable energy sources and the adoption of pro-environmental digital policies, can have a significant impact on enhancing the environmental sustainability of high-technology economies in the long term.

The ARDL estimates demonstrate that the POP has a positive and statistically significant impact on the CO emissions both in the long-run (0.493, $p<0.01$) and the short-run (0.222, *$p<0.05$)*. It means that the larger the population of the United States is, the more energy will be used, the more industrial pressures and demands, and the intensity of transportation, which leads to an increase in emission levels. It is the outcome of the demographic scale effect, as an increasing population increases the pressure on the environmental resources in terms of production and consumption. Rehman et al. [61], Hassan et al. [62], and Cao et al. [63] have similar positive associations since they discovered that POP in both developing and developed economies exacerbates environmental degradation by urbanizing and energy-dependent countries. Nevertheless, others, including Pickson et al. [64] and Erdogan [65], described weak or neutral population-emission relationships in situations where technological efficiency or renewable energy replacement counteract the population pressure. Consistent with the majority of empirical studies, the current results prove that the POP continues to be one of the major structural contributors to the carbon intensity in the United States, which highlights the necessity of sustainable planning of urban areas, intertwining renewable energy sources, and demographic-sensitive climate strategies to reduce population-induced environmental pressure.

Table 4. ARDL short-run and long-run results.

Variables	Coefficient	Std. Error	t-Statistic
Long-Run Estimates			
L.AI	-0.211***	0.053	-3.962
L.SMC	0.167**	0.07	2.386
L.GDP	0.543***	0.097	5.598
L.ICT	-0.186**	0.072	-2.583
L.POP	0.493***	0.135	3.652
C (Constant)	12.584***	1.823	6.902
Short-Run Estimates			
ΔAI	-0.107**	0.046	-2.32
ΔSMC	0.102**	0.049	2.082
ΔGDP	0.328***	0.079	4.155
ΔICT	-0.091*	0.053	-1.713
ΔPOP	0.222**	0.095	2.337
ECT(–1)	-0.462***	0.101	-4.581

5 | Conclusion and Policy Recommendations

The paper examines a dynamic interaction between AI, SMC, economic growth, ICT, POP, and carbon emissions in the United States from 1990 to 2021 based on the ARDL model. It is established that the variables are cointegrated in the long run, which means that economic growth, financial development, and POP are closely connected to the increase of CO emissions, whereas AI development and the use of ICTs reduce the environmental deterioration due to technological efficiency. These results bring out the two-sidedness of economic progression- growth and capital formation increase emissions, unless checked by digital and more innovation-oriented policy. The adverse and meaningful adjustment coefficient confirms a linear long-run equilibrium. In general, the findings indicate that the United States needs to refreeze green digitalization, responsible financial investment, and sustainable demographic management to be carbon neutral. The existing trend of a sustainable and resilient low-carbon economy can be changed by strengthening AI-based innovations, integrating renewable energy, and ICT-based efficiency systems.

This research has a number of policy implications for the sustainability and low-carbon growth of the United States. Because the economic growth and capitalization in stock markets have been identified to raise the level of CO emissions, policymakers are advised to incorporate green financial reforms to shift capital towards renewable energy, clean technology, and low-emission industries. It is possible to have mandatory green disclosure frameworks and tax breaks on green investments to make sure that the financial development contributes, but does not damage, the environmental objectives. The major contribution of population expansion to emissions is important, which explains why urban sustainability planning, such as energy-efficient housing, sustainable transport, and population-conscious infrastructure policy, must be considered. In the meantime, the adverse impacts of AI and ICT on emissions prove their reasonableness as drivers of decarbonization. Thus, AI-powered energy optimization, digitalization of the manufacturing industry, and carbon monitoring systems powered by ICT should be encouraged by governmental institutions to make the use of resources more efficient. The gains will be further consolidated by expanding the public-private collaborations regarding digital innovation, green entrepreneurship, and environmental R&D. In addition, the shift to renewable energy sources to power the AI and ICT infrastructure can also enhance their impact on the environment. Lastly, there is a need for holistic climate governance that incorporates economic, technological, and demographic policies. The alignment of industrial policy, digital innovation, and financial regulation under a common sustainability model can strengthen the process of the United States in achieving long-term carbon neutrality and climate resilience.

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