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Green Values and Economic Growth: Macroeconomic Dynamics, Decoupling, And Sustainable Development

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Abstract: This article analyzes the macroeconomic relationship between green values and economic growth within three theoretical frameworks: the Environmental Kuznets Curve (EKC), the decoupling concept, and endogenous growth models with directed technical change. The study draws on the Global Carbon Budget 2024, IEA Global Energy Review 2025, IRENA, and the World Bank State and Trends of Carbon Pricing 2025. In 2024, energy-related CO_2 emissions reached 37.8 billion tonnes, cumulative green bond issuance totaled $3.4 trillion, and energy transition investments amounted to $2.4 trillion. Over 32 countries have achieved absolute decoupling, yet Vogel and Hickel (2023) demonstrate that these rates are ten times below what is needed for Paris Agreement targets. The experiences of the European Union (EU ETS, CBAM), Sweden, and British Columbia are analyzed, and an integrated policy package for Uzbekistan is recommended—comprising Pigouvian taxation, cap-and-trade, green bonds, and just transition mechanisms.

Keywords: Green economy, EKC, decoupling, endogenous growth, negative externalities, Pigouvian tax, cap-and-trade, green bonds, sustainable capital accumulation, resource efficiency, carbon tax, institutional determinism, circular economy.

Introduction: The central theoretical and practical challenge in economics during the second quarter of the twenty-first century is ensuring long-term economic growth within planetary ecological boundaries. The “planetary boundaries” concept advanced by Rockström et al. (2009) established that a safe operating space for economic activity exists and that exceeding these boundaries can lead to irreversible ecological consequences. According to Friedlingstein et al. (2025), fossil fuel CO_2 emissions reached 37.4 billion tonnes in 2024, while atmospheric CO_2 concentration hit a record 422.5 ppm—50 percent above pre-industrial levels (IEA, 2025). This indicator signals the rapid depletion of the remaining carbon budget for the 1.5°C global warming threshold identified by the IPCC (2022).

At the same time, the World Bank (2025) reports that 28 percent of global emissions are now covered by carbon pricing mechanisms, which generated over $100 billion in government revenue in 2024. This two-directional dynamic appears paradoxical: on one hand, emissions continue to grow; on the other, policy interventions and financial investments to curb them are expanding at an unprecedented scale. This paradox transforms the notion of green values from a purely normative category into a central variable in positive macroeconomic analysis.

Under the term “green values,” we understand a system of institutional, technological, and ethical principles that integrates ecological sustainability into the fabric of economic decision-making. Within the neoclassical framework, this concept encompasses the internalization of negative externalities (Pigou, 1920), investments directed toward green technological innovation, sustainable capital accumulation, and mechanisms for enhancing resource efficiency. In practice, policies rooted in green values manifest as carbon taxation, cap-and-trade systems, the green bond market, and circular economy principles. According to the Ellen MacArthur Foundation (2024), the circular economy means eliminating waste and pollution through design, keeping products and materials in circulation, and regenerating natural systems.

The article's objective is to analyze the macroeconomic relationship between green values and economic growth within three interrelated theoretical frameworks: the Environmental Kuznets Curve (EKC) hypothesis; the concept of absolute and relative decoupling; and the endogenous growth models with directed technical change developed by Acemoglu, Aghion, Bursztyn, and Hémous (2012). Drawing on these frameworks, the article conducts a comparative analysis of the experiences of the European Union, Sweden, British Columbia, and Uzbekistan, and develops policy recommendations for developing economies.

The novelty of this research is expressed in the following: first, a critical synthesis of empirical EKC literature published between 2018 and 2025; second, a synthetic analysis of the methodological debate on absolute decoupling based on IPCC AR6, OECD, and Vogel and Hickel (2023); third, a quantitative comparison of the effects of EU's Carbon Border Adjustment Mechanism (CBAM), which entered into force in 2026, and other carbon pricing instruments; and fourth, the development of integrated policy implications for resource-dependent, energy-intensive developing economies such as Uzbekistan. The article follows the IMRAD format: literature review and theoretical framework, materials and methods, results, discussion, and conclusions with policy recommendations.

The relevance of this study is particularly high in the Central Asian context. Countries in the region, including Uzbekistan, Kazakhstan, and Turkmenistan, continue pursuing resource-dependent models of economic growth. The global green transition creates both opportunities and threats for these nations: on one hand, access to green technologies and finance is expanding; on the other, border carbon mechanisms like CBAM may erode export competitiveness. Existing literature features a dearth of systematic analyses of the macroeconomic consequences of the green transition for Central Asian economies, and this article aims to fill that gap.

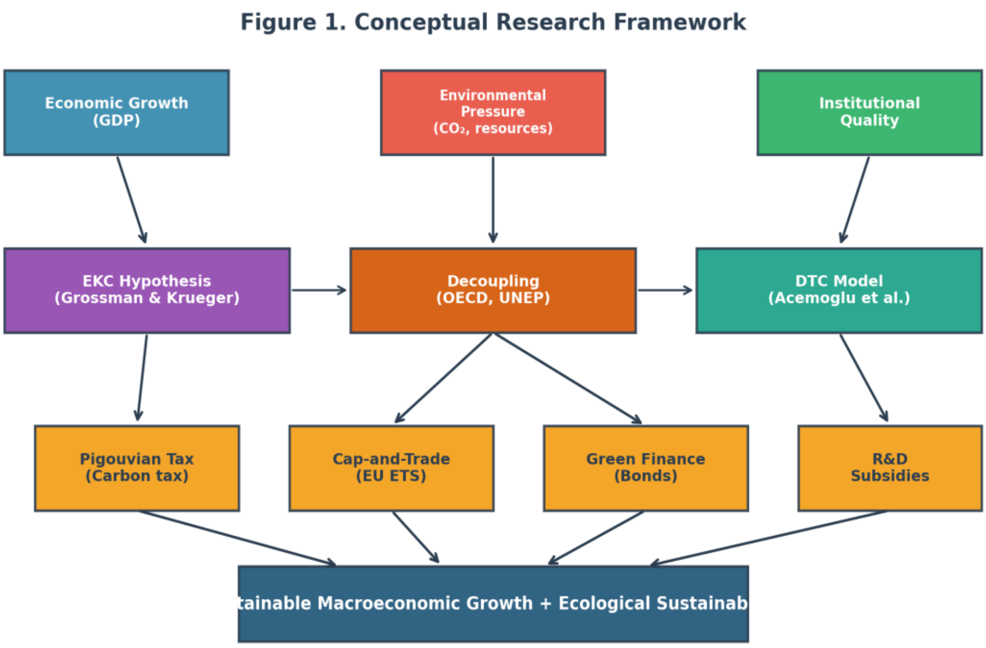

Figure 1. Conceptual research framework

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

1. The Environmental Kuznets Curve: Contemporary Empirical Evidence

The EKC hypothesis, originating from Grossman and Krueger's (1991) study of the environmental effects of the North American Free Trade Agreement, posits an inverted U-shaped relationship between ecological degradation and per capita income: beyond a certain turning point, economic growth leads to environmental improvement. Inspired by Kuznets's (1955) inverted-U idea linking income inequality to economic development, the hypothesis was initially proposed for local pollutants such as SO_2 and particulate matter, and later extended to carbon emissions. However, empirical studies from 2018–2025 clearly demonstrate its context-dependence.

Muratoğlu, Songur, Uğurlu, and Şanlı (2024), employing the Panel Nonlinear Autoregressive Distributed Lag

(PNARDL) method, tested the EKC at the sectoral level across OECD countries, confirming the classical inverted-U shape for the industrial and services sectors, but finding the relationship statistically insignificant for agriculture. This result reveals sectoral heterogeneity in the EKC and suggests that aggregate-level analyses may mask inter-sectoral differences. Gravina and Lanzafame (2025), using Bayesian Model Averaging (BMA) across 84 developed and developing economies, identified an inverted N-shaped EKC—meaning emissions may rise again at higher income levels after an initial decline. This finding is a serious warning for policy practitioners: economic growth alone does not guarantee environmental improvement.

A study of the Southern African Development Community (SADC) region using CS-ARDL and CCEMG estimators (Frontiers in Environmental Economics, 2025) finds partial support for the EKC: the squared GDP term is negative and statistically significant in some specifications, but this result is sensitive to model specification. As an alternative to the EKC, Stern (2017) emphasizes that environmental degradation declines not with income per se but with governance quality, effective regulation, and the diffusion of technological change. Anwar et al. (2024) empirically demonstrate that in fragile states, economic policy uncertainty and technological innovation have emission-increasing effects—pointing to the decisive role of institutional quality. Accordingly, the EKC hypothesis should be interpreted not as a universal law but as a conditional hypothesis valid only under specific institutional and technological conditions.

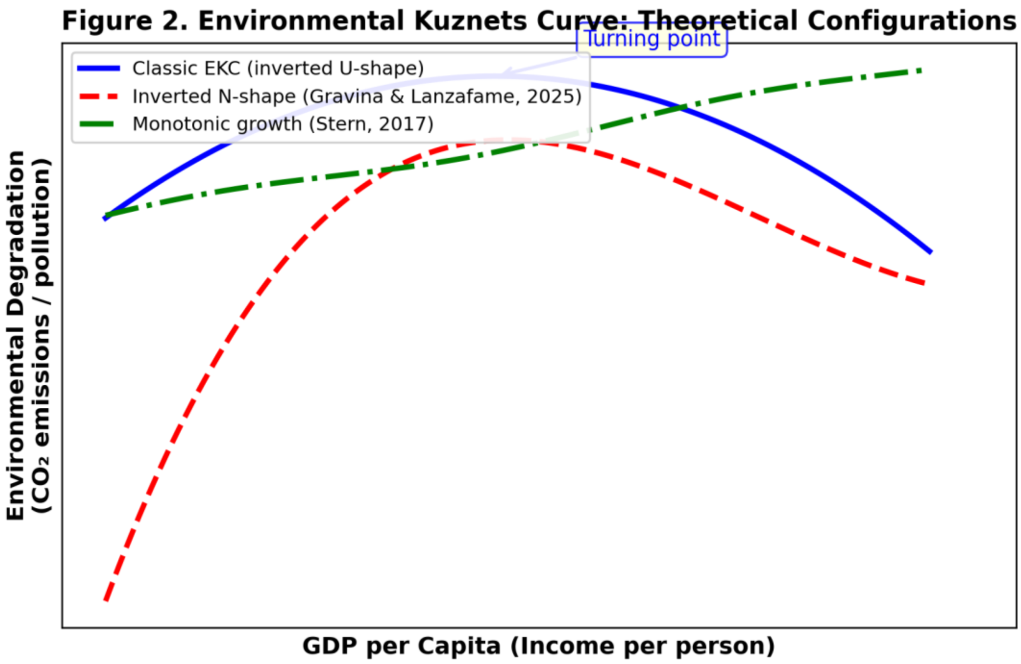

Figure 2. The Environmental Kuznets Curve: theoretical configurations

2. The Decoupling Concept: Absolute and Relative Dissociation

According to the OECD (2002), decoupling is understood as the rate of economic activity growth exceeding the rate of resource use or environmental pressure growth. Conceptually, two main forms are distinguished: relative decoupling involves GDP and emissions growing simultaneously but emissions at a slower rate; absolute decoupling means emissions declining in absolute terms while GDP continues to grow. IPCC AR6 WGIII (2022) analyzes decoupling through the Kaya identity: CO_2 = Population × (GDP/Population) × (Energy/GDP) × (CO_2/Energy). This decomposition reveals the dependence of emissions on four factors and helps identify which factors policy interventions should target.

Wiedmann et al. (2024), using segmented sample regressions for 164 countries over 1822–2018, found that 49 countries achieved absolute decoupling while 115 did not. Among OECD nations, 71 percent achieved decoupling, while 29 percent had not. According to the Breakthrough Institute's analysis (Hausfather, 2023), since 2005, at least 32 countries with populations exceeding one million have successfully decoupled both territorial and consumption-based CO_2 emissions from GDP growth in absolute terms—including the United States, Japan, Germany, the United Kingdom, France, Sweden, and Denmark.

However, Vogel and Hickel (2023) show that the rates of absolute decoupling achieved in 11 high-income countries are insufficient to meet the Paris Agreement's fair carbon budget: even the best-performing countries have reduced emissions at rates approximately ten times below what is required.

Haberl et al.'s (2020) systematic review of 179 articles concludes that there is no reliable evidence of absolute resource decoupling at the economy-wide scale and that the degree of decoupling necessary for ecological sustainability has not materialized. IPCC AR6 WGIII also warns that countries that have achieved absolute decoupling cannot serve as direct models for the rest of the world, as this decoupling occurred at very high baseline emission and GDP levels.

3. Endogenous Growth and Directed Technical Change

Romer (1990) and Aghion and Howitt (1992) developed endogenous growth theory, modeling technological progress as an internal product of R&D activity, enabling analysis of knowledge accumulation's impact on long-run growth. This theoretical framework extends to green technologies: green R&D investments expand the green technology base, which in turn generates more efficient green innovations, creating a virtuous cycle.

The directed technical change (DTC) model of Acemoglu, Aghion, Bursztyn, and Hémous (2012) yields four key results. First, if dirty and clean production inputs are sufficiently substitutable, temporary taxes and subsidies can ensure sustainable growth. Second, optimal policy must simultaneously employ both a carbon tax and clean energy R&D subsidies—this dual intervention avoids an excessively high carbon tax. Third, delayed intervention is costly: early action requires a short transition period, while delayed action leads to a longer transition with slower growth. Fourth, rising prices of exhaustible natural resources do encourage a market-driven shift toward clean innovation, but this process is slower than what optimal policy intervention could achieve.

Acemoglu, Aghion, Barrage, and Hémous (2023) empirically validate this theory using firm-level patent data. They demonstrate path dependence: firms that previously patented dirty technologies exhibit strong innovation inertia toward new dirty patents. This finding has critical policy implications: overcoming firms' technological inertia requires substantially stronger policy signals over a sustained period. Aghion, Dechezleprêtre, Hémous, Martin, and Van Reenen (2016) empirically demonstrate the causal effect of fuel prices on green innovation in the automotive industry. Zhou, Tian, Yang, and Wan (2024), incorporating green innovation as an endogenous factor in a Schumpeterian growth model, show that a declining green premium preserves the inverted-U relationship between pollution emissions and GDP.

4. Externalities Theory and the Pigouvian Tax

According to Pigou's (1920) classical doctrine, negative externalities are internalized by imposing a tax on market prices equal to their marginal social cost. In the climate change context, this is expressed through the social cost of carbon (SCC). Nordhaus (2017), using the DICE model, estimated the optimal carbon price at \$43/tCO_2. Van der Ploeg and Rezai (2021), accounting for uncertainty and climate tipping points, estimate the risk-adjusted SCC at no less than \$100. The famous debate between Stern (2007) and Nordhaus (2017) centered on the choice of social discount rate: Stern applied an ethically grounded low rate (1.4%) emphasizing current generations' obligations to future ones, while Nordhaus used a market-based higher rate (5–7%). This choice leads to differences of two or even three orders of magnitude in the SCC.

As an alternative to the Pigouvian approach, the Coase theorem (1960) posits that externalities can be internalized through free negotiation between parties when transaction costs are zero. However, in the climate change context, Coasean conditions are not met: affected parties number in the billions, transaction costs are astronomically high, and property rights are poorly defined. Therefore, two principal instruments are applied in practice: Pigouvian taxation (carbon tax) sets the price and leaves the emission volume to the market, while cap-and-trade sets the emission volume and lets the market determine the price. Weitzman's (1974) classical analysis demonstrated the superiority of price-based instruments (taxes) under uncertainty: when the slope of the marginal cost curve exceeds that of the marginal benefit curve, a price-based instrument reduces social losses. In climate policy, however, this choice is not purely theoretical: in practical implementation, a tax is simpler and generates budget revenue, while cap-and-trade guarantees a specific level of emission reduction. Hybrid approaches—ETS systems equipped with price floors and price ceilings—are increasingly employed to combine the advantages of both instruments.

METHODS

1. Research Design and Data Sources

The study employs a mixed methodology combining qualitative and quantitative approaches. The theoretical component involves deductive analysis synthesizing the EKC, decoupling, and endogenous growth models; the empirical component includes descriptive statistics and comparative analysis of global and country-level indicators. The data sources include: Global Carbon Project (Friedlingstein et al., 2025) CO_2 emission time series; IEA Global Energy Review 2025 energy indicators; IRENA Renewable Capacity Statistics 2025 for renewable energy investment and capacity data; World Bank State and Trends of Carbon Pricing 2025 for carbon pricing instrument data; Climate Bonds

Initiative 2025 for green bond market statistics; European Commission Carbon Market Report 2025 for EU ETS performance data; and OECD (2024) for analysis of Uzbekistan's investment climate.

The temporal scope covers 2015–2024, the most active phase of the global green transition following the Paris Climate Agreement. The geographic scope includes developed countries (Sweden and EU member states), transition economies (British Columbia), and developing countries (Uzbekistan). Country selection was based on three criteria: duration of carbon pricing experience, availability of empirical research, and relevance of lessons for developing economies.

2. Analytical Framework and Methodological Boundaries

The boundaries between descriptive and normative analysis are clearly delineated. The descriptive component involves testing the EKC and decoupling hypotheses against historical data and factually describing international experience. The normative component covers questions of optimal carbon pricing, social discount rate selection, and equity in distribution. Each normative statement in the article is explicitly identified and separated from descriptive evidence. The trade-off between short-term transformation costs (stranded assets, inter-sectoral labor reallocation, consumer price increases) and long-term macroeconomic dividends (increased resource efficiency, emergence of new markets, avoidance of climate damage) is analyzed.

Distributive impact analysis is conducted across three principal stakeholder groups. First, at the household level, the regressive effect of carbon taxation is examined: lower-income households spend a larger share of their income on energy, and therefore carbon pricing affects them disproportionately. Second, at the sectoral level, the impact on competitiveness of fossil fuel-dependent industries and job displacement is assessed. Third, inter-regional disparities are considered: the fiscal and social consequences differ between energy-producing and energy-consuming regions. This three-dimensional distributive analysis provides the essential foundation for the social acceptability and practical implementation of policy recommendations.

3. Comparative Analysis of Econometric Methods

The strengths and limitations of the principal econometric methods employed in the empirical literature on green growth are summarized in the following table. These methods are essential for evaluating the reliability and limitations of the empirical findings described in this article.

Table 1. Principal econometric methods used in green growth research

Method	Key Advantage	Applied by
STIRPAT	Estimating population, income, and technology elasticities	Khan et al. (2024)
PNARDL	Separating short- and long-term asymmetric effects	Muratoğlu et al. (2024)
GMM	Addressing endogeneity and dynamic bias	Acheampong & Opoku (2023)
CS-ARDL / CCEMG	Controlling for cross-sectional dependence	SADC study (2025)
SCM	Isolating causal effects from policy interventions	Andersson (2019)

RESULTS

1. Global Emissions and Decoupling Dynamics

Analysis of global data for 2015–2024 reveals two parallel trends. First, global energy-related CO_2 emissions reached a record 37.8 billion tonnes in 2024, growing 0.8 percent over 2023 (IEA, 2025). China (12.6 Gt), the United States (4.7 Gt), and India (2.9 Gt) remain the three largest emitters. Second, global GDP grew by 3.2 percent, meaning the emission growth rate (0.8%) was four times lower than GDP growth (3.2%)—indicating relative decoupling. However, absolute decoupling has not occurred at the global scale: total emissions continue to rise.

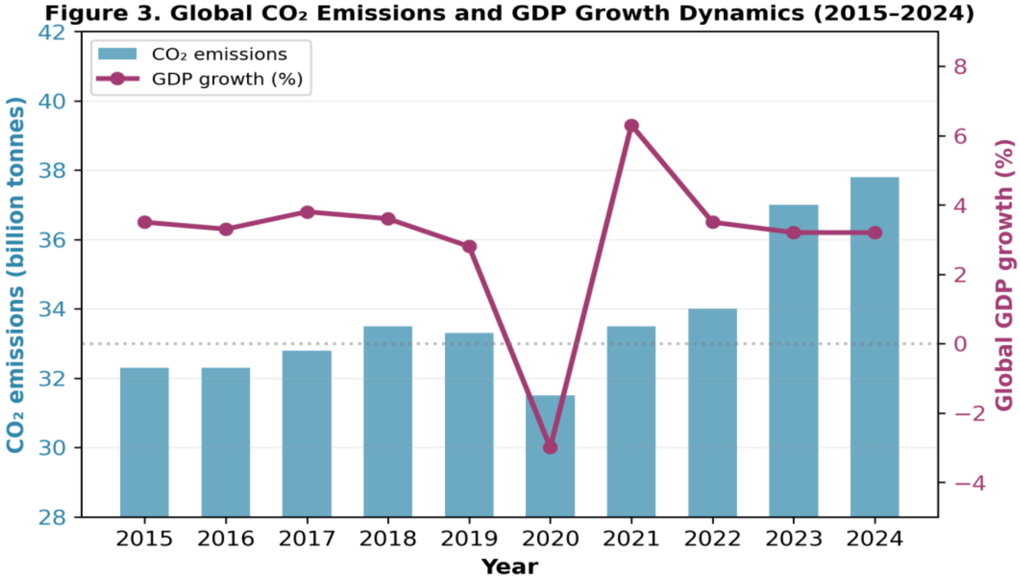

Figure 3. Global CO_2 emissions and GDP growth dynamics (2015–2024)

Country-level analysis reveals significant variation. Sweden has increased its real per capita GDP by 78 percent since 1990 while simultaneously reducing CO_2 emissions by 35 percent—one of the world's most striking examples of absolute decoupling. Denmark has cut emissions by 45 percent, the United Kingdom by 42 percent, and Germany by 38 percent. The United States has reduced emissions by 22 percent, but per capita emissions (14 t/person) remain substantially higher than those of European countries (5–7 t/person). In the majority of developing countries, including China and India, emissions continue to grow despite relative decoupling.

The structural causes of these cross-country variations can be traced to several factors. First, most countries that have achieved absolute decoupling possess high carbon pricing mechanisms: Sweden, Denmark, and the United Kingdom have employed various forms of carbon pricing for decades. Second, economic structure plays a crucial role: economies with a larger services sector are less carbon-intensive. Third, the energy intensity component of the Kaya identity matters: technological innovations and energy efficiency standards contribute to decoupling by reducing energy intensity. However, as York, Rosa, and Dietz (2003) demonstrate through the STIRPAT model, population growth and rising consumption levels can partially or fully offset the decoupling effect.

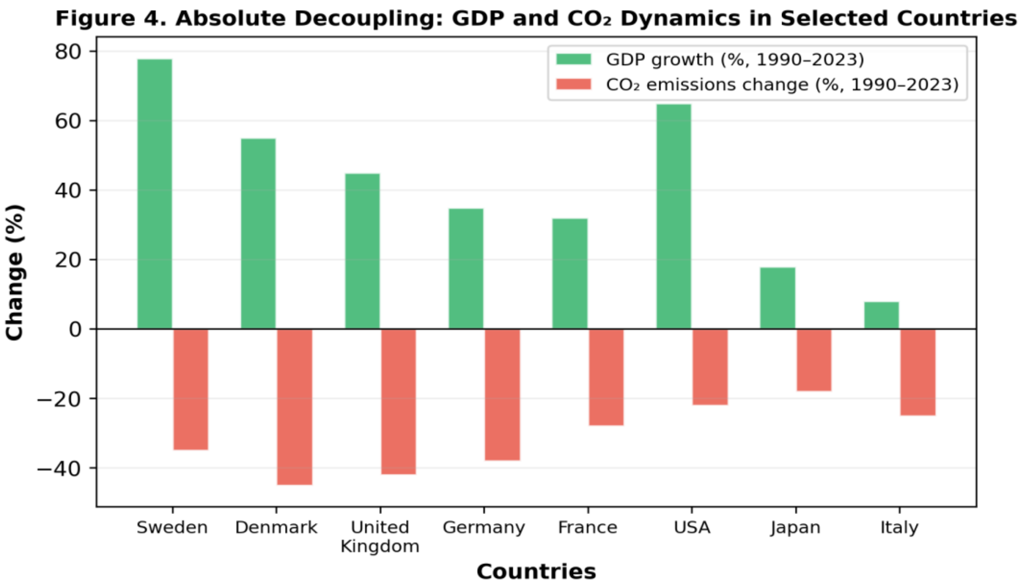

Figure 4. Absolute decoupling: GDP and CO_2 dynamics in selected countries (1990–2023)

2. Carbon Pricing Instruments: Comparative Effectiveness

According to the World Bank (2025), by 2024 there were 80 carbon pricing instruments in operation worldwide, including 39 emissions trading systems (ETS) and 41 carbon taxes. Global emissions coverage reached 28 percent, up from 22 percent in 2020. In 2024, carbon pricing instruments generated over $100 billion in government revenue. However, as the World Bank notes, less than one percent of global emissions is priced at levels consistent with Paris Agreement targets—that is, at the carbon price necessary for 1.5°C.

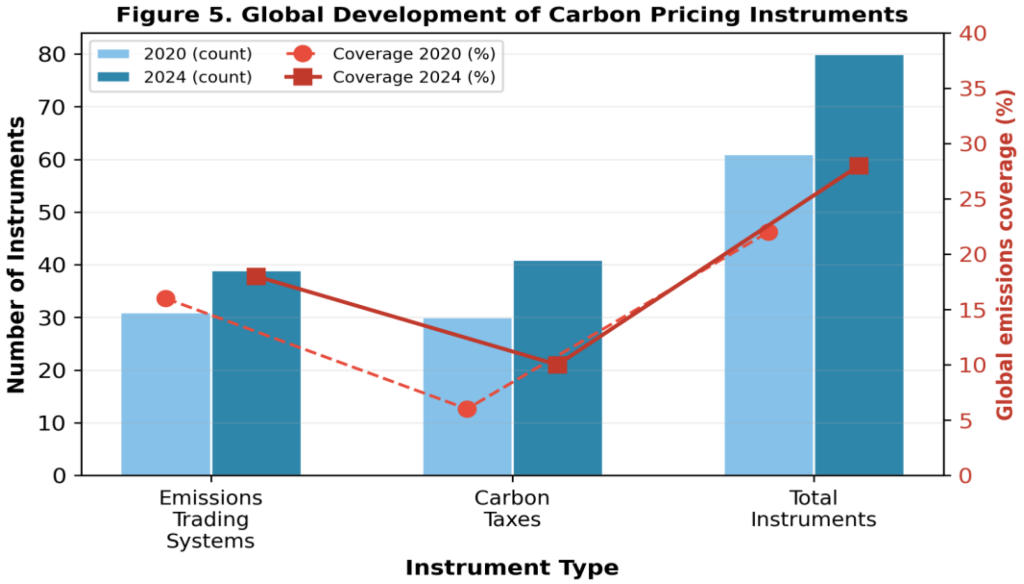

Figure 5. Global development of carbon pricing instruments (2020–2024)

Sweden's experience provides the most vivid illustration of carbon tax effectiveness. Sweden has maintained the world's highest carbon tax since 1991: according to the Tax Foundation (2024), as of April 1, 2024, the tax rate stands at €115.34 ($125.56) per tonne of CO_2. Andersson (2019), using the synthetic control method, demonstrated that approximately 11 percent of the reduction in transport-sector CO_2 emissions can be attributed as the direct causal effect of the tax. Notably, the elasticity of gasoline demand to the carbon tax is three times higher than the overall price elasticity, suggesting that consumers respond differently to ecological taxation. Thonipara et al. (2020) demonstrated reductions of 200–800 kilograms in per capita CO_2 emissions in the housing sector. As the Tax Foundation (2023) emphasizes, between 1990 and 2019, Sweden's real per capita GDP grew by over 50 percent while emissions declined in absolute terms—strong empirical evidence of the double dividend effect.

British Columbia (Canada) introduced North America's first revenue-neutral carbon tax in 2008, starting at C$10/t$CO_2$ and reaching C$80 by 2024. According to Murray and Rivers' (2015) analysis, the tax reduced emissions by 5–15 percent without a significant negative impact on GDP. Yamazaki (2017) empirically demonstrated annual employment growth of 0.74 percent between 2007 and 2013. However, on April 1, 2025, British Columbia Premier David Eby abolished the tax entirely for political reasons. This abolition represents a significant precedent highlighting the importance of institutional stability in green policy and the decisive influence of political economy factors.

Under the EU ETS framework, emissions from stationary installations fell 11 percent in 2024 compared to 2023 and 50 percent compared to 2005 (European Commission, 2025). A target of 62 percent reduction by 2030 has been set. From January 1, 2026, the Carbon Border Adjustment Mechanism (CBAM) entered into full force, requiring importers of cement, iron and steel, aluminum, fertilizers, hydrogen, and electricity to purchase certificates. CBAM is designed to eliminate the risk of carbon leakage and incentivizes third countries to establish their own domestic carbon pricing mechanisms.

3. Green Finance and Investment Trends

According to IRENA (2025), global investment in renewable energy reached $807 billion in 2024. A total of 585 GW of new renewable capacity was installed, bringing cumulative installed capacity to 4,448 GW. Investment in solar photovoltaic systems reached $554 billion, growing 49 percent in a single year. Total energy transition investment amounted to $2.4 trillion, a 20 percent increase. Per the Climate Bonds Initiative (2025), cumulative green bond issuance reached $3.4 trillion, while the broader GSS+ (green, social, sustainability, and sustainability-linked) bond market reached $5.7 trillion. Annual green bond issuance in 2024 totaled approximately $600 billion.

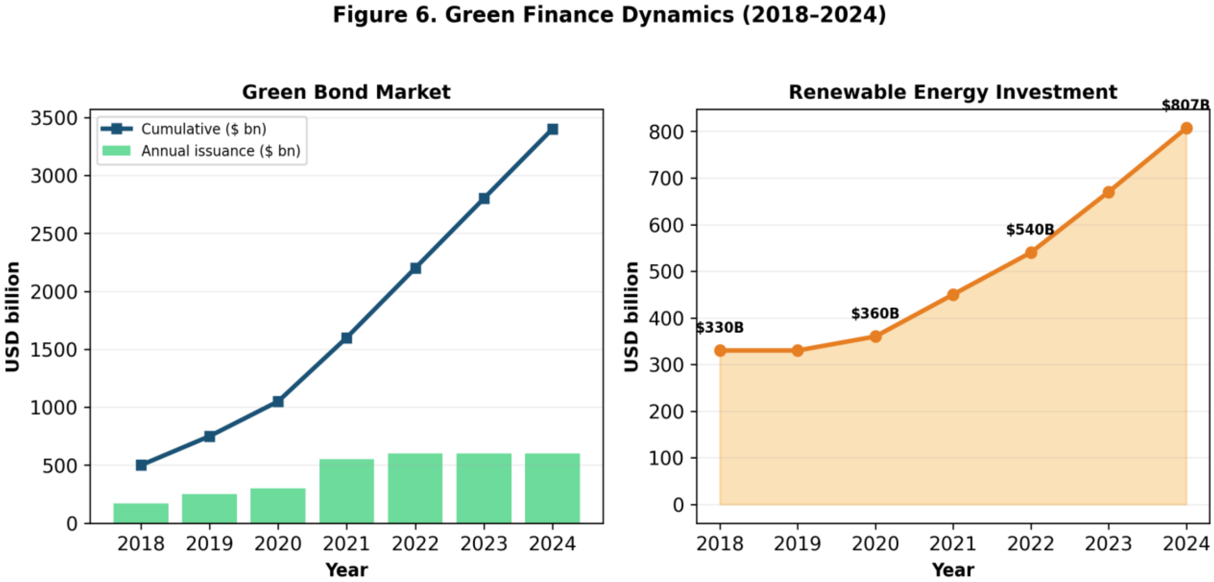

Figure 6. Green finance dynamics: bonds and renewable energy investment (2018–2024)

4. Uzbekistan: The Developing Economy Context

According to the World Bank (2023), Uzbekistan ranks fifth globally in greenhouse gas emissions per unit of GDP and is the most emission-intensive economy in the Europe and Central Asia region. IEA data show that Uzbekistan's energy intensity of GDP is four times the EU level and twice the global average. This high intensity is attributable to the fossil fuel-based energy mix, the energy-intensive nature of industry, and low energy efficiency. OECD (2024) analysis indicates that carbon intensity has declined by over 70 percent since 1990 and by nearly 50 percent over the last decade, yet natural gas still accounts for 86 percent of the energy supply.

Table 2. Uzbekistan's green transition indicators

Indicator	Value	Source
Energy intensity of GDP (EU ratio)	4:1	IEA, 2024
Carbon intensity decline (since 1990)	>70%	OECD, 2024
Renewable energy capacity (2024)	3,467 MW (16%)	OECD, 2024
2030 target: renewable share	40–54%	NDC; OECD
Required investment	~$60 billion	World Bank, 2023
First green Eurobond (2023)	UZS 4.25 trillion	UNDP, 2023
EBRD investment (2024)	€938 million	EBRD, 2025
ADB climate loan (2024)	$250 million	ADB, 2024

Uzbekistan is a leader in green finance among CIS countries. In 2021, with support from the United Nations Development Programme, a $235 million sovereign SDG bond was placed; in October 2023, the first CIS sovereign green Eurobond (UZS 4.25 trillion) was successfully listed on the London Stock Exchange. In 2024, the ADB allocated a $250 million policy-based loan to accelerate the climate transition—the first such program in Central Asia. The EBRD invested €938 million across 34 projects, 55 percent of which supported the green economy. According to OECD (2024), the government plans to install 21 GW of renewable energy capacity by 2030 and achieve a 54 percent share of renewables in electricity supply. However, World Bank CCDR (2023) estimates indicate that approximately $60 billion in investment is needed for the climate transition, signaling a substantial annual financing gap.

Institutionally, Uzbekistan must address several systemic barriers for the green transition. First, energy tariffs remain at economically unjustified low levels, encouraging energy waste and artificially undermining the competitiveness of renewables. OECD (2024) estimates that total energy subsidies exceed 3 percent of GDP. Second, domestic R&D capacity in green technologies is limited: patent statistics indicate a very low share of green innovations. This aligns with Acemoglu et al.'s (2023) path dependence theory: because the existing technology base is fossil fuel-oriented, overcoming innovation inertia requires strong and sustained policy signals. Third, the environmental governance system lacks transparency and monitoring capacity: emissions inventories and reporting do not fully comply with international standards, constituting a major technical barrier to implementing carbon pricing mechanisms.

DISCUSSION

The findings necessitate several important theoretical and practical conclusions. First, interpreting the EKC hypothesis as a universal law is empirically unfounded. The inverted N-shape identified by Gravina and Lanzafame (2025) implies that economic growth beyond a certain stage may lead to a renewed increase in emissions. The monotonic emission growth demonstrated by Anwar et al. (2024) in fragile states confirms the EKC's status as a context-dependent conditional hypothesis. For policy practice, this means that economic growth alone is no guarantee of environmental improvement: it must be accompanied by institutional quality, effective regulation, and structural technological change. This aligns with Stern's (2017) emphasis on institutional factors.

Second, analysis of decoupling results presents a complex picture. On one hand, the achievement of absolute decoupling by over 32 countries confirms the practical feasibility of green growth strategies: simultaneously achieving economic growth and emission reductions is both theoretically and practically possible. On the other hand, Vogel and Hickel's (2023) ten-fold gap indicator reveals that existing decoupling rates are insufficient for meeting the Paris Agreement's climate objectives. Haberl et al. (2020) also note the absence of absolute resource decoupling at a global scale. Crucially, when consumption-based emissions are taken into account, instances of absolute decoupling diminish significantly, as some developed countries have offshored emission-intensive production to developing nations. This offshoring effect calls into question the reality of true emission reductions at the global level.

Third, comparative analysis of carbon pricing instruments empirically confirms the theoretical predictions of the Pigouvian tax, albeit with important institutional caveats. Sweden's experience demonstrates that a high carbon tax can substantially reduce emissions without hindering GDP growth—confirming the double dividend hypothesis. However, British Columbia's 2025 abolition reveals the decisive role of political economy: revenue neutrality and distributive compensation proved insufficient to maintain political support. This aligns with Acemoglu et al.'s (2012) model: a carbon tax alone is not enough; it must be combined with R&D subsidies, industrial policy, and just transition mechanisms. The EU ETS's 50 percent emission reduction since 2005 and the entry into force of CBAM in 2026 demonstrate the long-term effectiveness of cap-and-trade, though the volatility of EU ETS prices (declining from €100 in 2023 to €65 in 2024) signals instability in investment signals.

Fourth, the results in the Uzbekistan context illustrate the distinctive challenges of the green transition for developing economies. While the 50 percent decline in carbon intensity over the last decade is a positive trend, the 86 percent share of natural gas in the energy mix underscores the need for structural change. The entry into force of EU CBAM creates new regulatory pressure on Uzbekistan's exporters: without a domestic carbon pricing mechanism, exporters will be required to pay the full CBAM certificate price. While achievements in green finance—green Eurobonds, ADB and EBRD investments—are positive signals, the annual financing gap relative to the $60 billion target remains very large. The IPCC AR6 WGIII (2022) warnings regarding distributive impacts are particularly relevant for Uzbekistan: energy price increases disproportionately affect lower-income groups, necessitating just transition mechanisms.

Fifth, the global growth of green finance instruments demonstrates the financial possibilities of this transition, though qualitative limitations exist. The green bond market reaching $3.4 trillion and renewable energy investments of $807 billion illustrate the power of capital mobilization. However, the geographic distribution of these flows is highly uneven: developed countries attract the vast majority of green investments, while developing countries lag behind despite being in greatest need. This financial inequality is directly connected to climate justice and constitutes one of the weakest points of the global climate architecture. Blended finance mechanisms—leveraging public finance and international development institution guarantees to attract private capital—may partially address this gap.

Sixth, from a theoretical perspective, the findings offer new insights into the problem of ecological externalities in neoclassical economics. While the Pigouvian tax mechanism is theoretically optimal, its practical application encounters political economy constraints, as British Columbia's experience demonstrates. From the standpoint of Buchanan and Tullock's (1962) public choice theory, a socially optimal policy is not always politically sustainable: concentrated costs and diffuse benefits generate political resistance. The long-term success of green policy requires not only economic efficiency but also strategies for political feasibility and social acceptability. In this regard, Ostrom's (2005) polycentric governance approaches, developed within institutional economics, may prove highly relevant.

CONCLUSIONS AND POLICY RECOMMENDATIONS

This study has demonstrated that the relationship between green values and economic growth is not automatic but rather the product of institutional, technological, and policy choices. The EKC hypothesis is not a universal law: economic growth alone does not guarantee environmental improvement. Relative decoupling is occurring at the global scale, but absolute decoupling has been recorded in only 32 countries, and these rates are ten times too slow for Paris Agreement targets (Vogel & Hickel, 2023). Acemoglu et al.'s (2012, 2023) directed technical change model provides both theoretical and empirical proof that delayed intervention is costly and that optimal policy must have a diversified composition.

Based on these findings, the following policy recommendations are formulated. First, a phased introduction of a carbon tax is necessary. Drawing on Sweden's experience, it is recommended that Uzbekistan begin at \$5–10/tCO_2 and escalate over 5–7 years. The tax should be enshrined in legislation and indexed to inflation—an institutional safeguard arising from the precedent of British Columbia's 2025 abolition. Second, a domestic carbon pricing mechanism is essential for CBAM compliance: domestic pricing reduces CBAM obligations, internalizes fiscal revenues, and preserves export competitiveness.

Third, in line with Acemoglu et al.'s (2012, 2023) models, the carbon tax must be combined with R&D subsidies and industrial policy. It is recommended to establish a clean energy technology center, introduce differentiated tax incentives for green patents, and develop blended finance mechanisms to fund the 21 GW renewable energy target. Fourth, expansion of the green bond market and creation of a just transition fund are warranted. As a CIS leader in green bonds, Uzbekistan should expand the corporate and municipal green bond market. A national just transition fund should be created, drawing on EU experience, to finance worker retraining programs in fossil fuel-dependent regions.

Fifth, integrating circular economy principles into industrial policy is essential. Strengthening material recycling chains in the cotton-textile, metallurgy, and construction sectors can significantly enhance resource efficiency and reduce emissions. The Ellen MacArthur Foundation (2024) indicates that full adoption of circular economy principles can achieve up to a 45 percent reduction in industrial emissions. This is particularly relevant for Uzbekistan, where substantial opportunities exist for converting waste into resources in cotton processing and the mining industry.

The study's limitations should be acknowledged. First, the descriptive-comparative methodology does not permit causal inference: differences across countries' experiences may be attributable to factors other than carbon policy. Second, the quality and completeness of Uzbekistan's emissions data do not fully meet international standards. Third, the article does not include a full analysis of consumption-based emissions (carbon footprint), which limits the coverage of emissions exported and imported through trade.

Future research should pursue the following directions. First, computable general equilibrium (CGE) modeling of CBAM's macroeconomic impact on Uzbekistan and Central Asian exports is a priority. Second, analyzing the impact of green technologies on total factor productivity using DEA and the Malmquist index is necessary. Third, evaluating the gender and regional distributive impacts of just transition policies through microsimulation is of significant importance. Fourth, modeling the economic and ecological effects of coordinated green transition policy at the Central Asian regional level represents a promising avenue for future research.

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