

GREEN FINANCE AND THE DECOUPLING OF ECONOMIC GROWTH FROM CARBON EMISSIONS: EMPIRICAL EVIDENCE FROM UZBEKISTAN

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Abstract

The article examined the relationship between economic growth and carbon dioxide emissions amid Uzbekistan's green finance development. World Bank data for 2000-2023 supported carbon intensity analysis, Tapio elasticity calculations and structural break regressions. Robustness was assessed using alternative period boundaries and excluding the pandemic year. Carbon intensity declined over time, while changes in the relationship after 2019 were not statistically significant. Findings were interpreted considering limited observations and financing implementation lags. Recommendations addressed recording green financial flows, monitoring energy indicators and extending data coverage. Additional observations were considered necessary to assess the direct causal contribution of green finance to emissions decoupling.

Keywords: green finance, economic growth, carbon dioxide emissions, carbon intensity, decoupling, Tapio elasticity, renewable energy, Uzbekistan.

Annotatsiya

Maqolada O'zbekistonda yashil moliyalashtirish rivoji sharoitida iqtisodiy o'sish va karbonat angidrid chiqindilari o'rtasidagi bog'liqlik o'rganildi. Jahon bankining 2000-2023-yillardagi ma'lumotlari asosida uglerod intensivligi, Tapio elastikligi va tarkibiy o'zgarishlar regressiyasi tahlil qilindi. Natijalarning barqarorligi muqobil davrlashtirish va pandemiya yilini chiqarib tashlash orqali tekshirildi. Uglerod intensivligining uzoq muddatli pasayishi qayd etildi, biroq 2019-yildan keyingi bog'liqlik o'zgarishi statistik jihatdan tasdiqlanmadi. Natijalar qisqa kuzatuv davri hamda moliyalashtirish bilan loyihalarning ishga tushishi o'rtasidagi vaqt farqi doirasida talqin qilindi. Yashil moliyaviy oqimlarni hisobga olish, energetik ko'rsatkichlarni izchil kuzatish va ma'lumotlar qamrovini kengaytirish bo'yicha takliflar ishlab chiqildi. Yashil moliyalashtirishning bevosita sababiy ta'sirini baholash uchun qo'shimcha ma'lumotlar zarurligi ta'kidlandi.

Kalit so'zlar: yashil moliyalashtirish, iqtisodiy o'sish, karbonat angidrid chiqindilari, uglerod intensivligi, dekapling, Tapio elastikligi, qayta tiklanuvchi energiya, O'zbekiston.

Аннотация

В статье была исследована взаимосвязь экономического роста и выбросов углекислого газа в условиях развития зелёного финансирования в Узбекистане. На данных Всемирного банка за 2000-2023 годы были проанализированы углеродная интенсивность, эластичность Тапио и регрессионные оценки

структурных изменений. Устойчивость результатов проверялась изменением границы периодов и исключением пандемийного года. Было установлено долгосрочное снижение углеродной интенсивности, однако изменение рассматриваемой взаимосвязи после 2019 года статистически не подтвердилось. Результаты интерпретировались с учётом короткого периода наблюдений и временного разрыва между финансированием и вводом объектов. Были предложены совершенствование учёта зелёных финансовых потоков, последовательный мониторинг энергетических показателей и расширение данных. Была подчеркнута необходимость дополнительных наблюдений для оценки непосредственного причинного влияния зелёного финансирования.

Ключевые слова: зелёное финансирование, экономический рост, выбросы углекислого газа, углеродная интенсивность, декарбонизация, эластичность Тапио, возобновляемая энергия, Узбекистан.

INTRODUCTION

Uzbekistan's economy remains structurally dependent on energy-intensive sectors - natural gas, cotton, and metallurgy - with the energy sector alone responsible for approximately 75 percent of national greenhouse-gas emissions [19]. The World Bank estimates that achieving carbon neutrality by 2060 will require roughly \$340 billion in investment to replace energy infrastructure and support decarbonisation, and that, absent such investment, GDP by 2050 could be as much as 10 percent lower than under a no-climate-impact scenario [19]. It was against this backdrop that, on October 4, 2019, Presidential Resolution PP-4477 adopted the "Strategy for the Republic of Uzbekistan's Transition to a Green Economy for 2019-2030," which set targets of a 10-percent reduction in greenhouse-gas intensity relative to 2010, a doubling of energy efficiency, and an increase in the renewable share of electricity generation to above 25 percent by 2030 [20].

Over the following four years, this strategic framework began to take the form of concrete financial instruments. The national green taxonomy was adopted in December 2023 [18]. In October 2023, Uzbekistan became the first country in the CIS to issue a sovereign green Eurobond, raising 660 million USD (4.25 trillion soums) on the London Stock Exchange, with proceeds allocated to water-conservation technologies, expansion of the railway and metro network, and afforestation [16]; Agrobank subsequently issued its own green Eurobonds worth 400 million USD and 700 billion soums [6]. International financial institutions likewise stepped up their engagement: in 2023 the EBRD arranged 205 million USD in financing for three solar power plants (a combined capacity of roughly 900 MW) in the Jizzakh, Samarkand, and Surkhandarya regions [4], while the Asian Development Bank, in partnership with ACWA Power, signed a 116 million USD financing agreement to expand wind-energy capacity [1]. Between 2019 and 2023, in other words, Uzbekistan's green-economy agenda moved from a strategic document to measurable flows of capital.

This study poses a deliberately narrow and falsifiable research question: has the green-economy policy adopted in 2019, together with the green-finance instruments that followed, changed the relationship between economic growth and carbon

emissions in Uzbekistan to a statistically detectable degree? To address this question, the analysis constructs a fully reproducible, open-data panel for 2000-2023, computes the annual Tapio decoupling elasticity, and tests both 2019 and, as a robustness check, 2021 as candidate structural-break dates.

The study's contribution is threefold. First, it constructs, from open World Bank WDI indicators, the first fully reproducible decoupling-elasticity series for Uzbekistan. Second, it formally tests the policy-linked structural break using heteroskedasticity-robust (HC3) standard errors, while being explicit about the constraints imposed by the small sample. Third, it identifies and explains what might be termed a “renewable-energy paradox” - a falling renewable share coinciding with declining carbon intensity - through a financing-to-outcome lag hypothesis, and it flags the absence of an official annual green-finance statistical series for Uzbekistan as a substantial data gap.

LITERATURE REVIEW

The relationship between green finance and carbon emissions is most commonly examined in the international literature through ARDL-ECM specifications or Granger-causality tests applied to long national or panel time series. Using an ARDL-ECM framework that controls for trade openness and the level of economic development, Li and Shao [10] find that green finance reduces CO₂ emissions over the long run. Bughio et al. [3] similarly report both short- and long-run causal linkages among green finance, renewable-energy consumption, and economic growth. Such methods, however, generally presuppose a consistent financial-flow series - for instance, the share of green credit within total credit - spanning at least two to three decades; no official series of this kind currently exists for Uzbekistan.

Decoupling analysis rests methodologically on the eight-state typology introduced by Tapio [15], originally developed to characterise the relationship between CO₂ emissions and GDP in Finland's road-transport sector, and since applied widely at the national and regional level, including extended variants that incorporate the energy mix - for example, studies combining the Tapio framework with the Logarithmic Mean Divisia Index (LMDI) for China's Xinjiang region [14]. A direct decoupling analysis for Uzbekistan covering 1990-2023 has recently appeared in Eurasian Geography and Economics [8], though its focus is the general CO₂-GDP relationship rather than green-finance instruments specifically.

Bakhtiyorov [2] compares Uzbekistan and Azerbaijan for 2010-2023 using multivariate regression and an Environmental Kuznets Curve (EKC) specification, finding the relationship among GDP growth, the share of foreign direct investment, and per-capita CO₂ to be statistically unreliable - a result the author attributes to limited institutional capacity and the short interval since reform. As the only other quantitative study of Uzbekistan's green transition known to the present author, this finding offers an important point of external consistency with the statistically insignificant results obtained here.

World Bank and OECD reports [11]; [12]; [18]; [19] offer detailed qualitative accounts of Uzbekistan's green-finance ecosystem - its taxonomy, its still-underdeveloped capital market, and the dominant role of the state within the banking

sector - but none subjects the growth-emissions relationship to quantitative testing. The resulting gap in the literature is therefore clear: no existing study has tested a structural break dated to the introduction of Uzbekistan's green-economy policy and green-finance architecture using a fully open, reproducible official data panel. The present study is designed to fill precisely this gap.

METHODOLOGY

Data and sources

All data are drawn from the World Bank's open World Development Indicators (WDI) API [17] and cross-checked against the most recent figures in the Our World in Data country profile [13]. The core variables are listed in Table 1. The resulting panel is a balanced annual series ($N = 24$) spanning 2000-2023; the WDI series for the renewable share of electricity generation is currently available only through 2021 ($N = 22$), a limitation discussed further below.

Table 1

Variables, definitions, and sources¹

Variable	Definition	Source (WDI code)
GDP growth rate (%)	Annual real GDP growth, %	World Bank WDI, NY.GDP.MKTP.KD.ZG
GDP (billion USD)	At constant 2015 prices	World Bank WDI, NY.GDP.MKTP.KD
CO ₂ emissions (Mt)	Excluding LULUCF, AR5 inventory	World Bank WDI, EN.GHG.CO2.MT.CE.AR5
CO ₂ per capita (t)	Same inventory, divided by population	World Bank WDI, EN.GHG.CO2.PC.CE.AR5
Renewable electricity share (%)	Share of total electricity generation	World Bank WDI, EG.ELC.RNEW.ZS
Energy efficiency	GDP / unit of energy use, 2021 PPP US\$	World Bank WDI, EG.GDP.PUSE.KO.PP.KD

Table 1 shows that all six variables are taken from a single official source, the World Bank WDI [17], which keeps the series methodologically consistent. Economic output is measured both as an annual growth rate and as a level in constant 2015 prices, emissions are measured both in total and per capita, and the energy transition is captured through the renewable share of electricity generation and the energy efficiency of GDP. Because each indicator is identified by its standard WDI code, every step of the analysis can be reproduced from open data.

Research methods

Carbon intensity is computed for each year as CO₂ emissions (kt) divided by GDP (billions of constant 2015 US dollars).

$$CI_t = \frac{CO_{2t} \text{ (kt)}}{GDP_t \text{ (billion constant 2015 USD)}} \quad (1)$$

where CI_t is the carbon intensity of GDP in year t , CO_{2t} is total CO₂ emissions excluding LULUCF and GDP_t is real GDP. A falling CI_t means that each unit of output

¹ Source: World Bank, World Development Indicators [17].

is produced with fewer emissions, that is, the economy is moving towards at least relative decoupling of growth from emissions.

The Tapio decoupling elasticity [15] is calculated for each year t as follows:

$$e_t = \frac{\% \Delta CO_{2t}}{\% \Delta GDP_t} \quad (2)$$

where GDP growth is taken directly from the officially reported annual growth rate rather than derived from levels. For the states actually observed in the Uzbekistan sample, the original eight-category Tapio typology is collapsed into three: decoupling ($e < 0.8$, including cases of “strong decoupling” in which CO_2 falls as GDP rises), expansive coupling ($0.8 \leq e \leq 1.2$), and expansive negative coupling ($e > 1.2$). Thus a negative e_t in a year of positive growth signals strong decoupling, whereas e_t above one means that emissions grow faster than output.

To test for a structural break, the CO_2 growth rate is regressed on centred GDP growth, a policy indicator ($POLICY = 1$ for years ≥ 2019), and their interaction, using heteroskedasticity-robust (HC3) standard errors, appropriate for a short ($N = 23$) series. The estimated equation is:

$$gCO_{2,t} = \beta_0 + \beta_1(gGDP_t - \bar{g}GDP) + \beta_2 POLICY_t + \beta_3 POLICY_t(gGDP_t - \bar{g}GDP) + \varepsilon_t \quad (3)$$

where $gCO_{2,t}$ is the annual growth rate of CO_2 emissions, $gGDP_t - \bar{g}GDP$ is real GDP growth centred on its sample mean, $POLICY_t$ is the policy indicator and ε_t is the error term. The coefficient β_2 measures a shift in emissions growth after the policy date at average GDP growth, while β_3 measures a change in the sensitivity of emissions to growth; a negative and significant β_3 would indicate stronger decoupling after the policy date. Two robustness checks are performed: (i) substituting 2021 - identified by the OECD [12] as the year the green-bond market became active - as an alternative break date; and (ii) excluding the pandemic year 2020, whose GDP growth of only 1.62 percent destabilises the elasticity's denominator.

The association between carbon intensity and the renewable share is examined both in levels and in first differences, since two independently trending series can otherwise produce a spurious correlation in levels.

The principal limitation is stated explicitly: with $N = 22$ -24 annual national observations, the design has limited statistical power - a constraint shared with the only comparable Uzbekistan study [2], which likewise reports statistically insignificant coefficients over a similar window. The results should accordingly be read not as a definitive causal test but as a preliminary screening exercise, to be revisited as longer post-policy series become available.

ANALYSIS AND RESULTS

Long-run dynamics of carbon intensity

The long-run trajectory of the carbon intensity of GDP in Uzbekistan is shown in Figure 1.

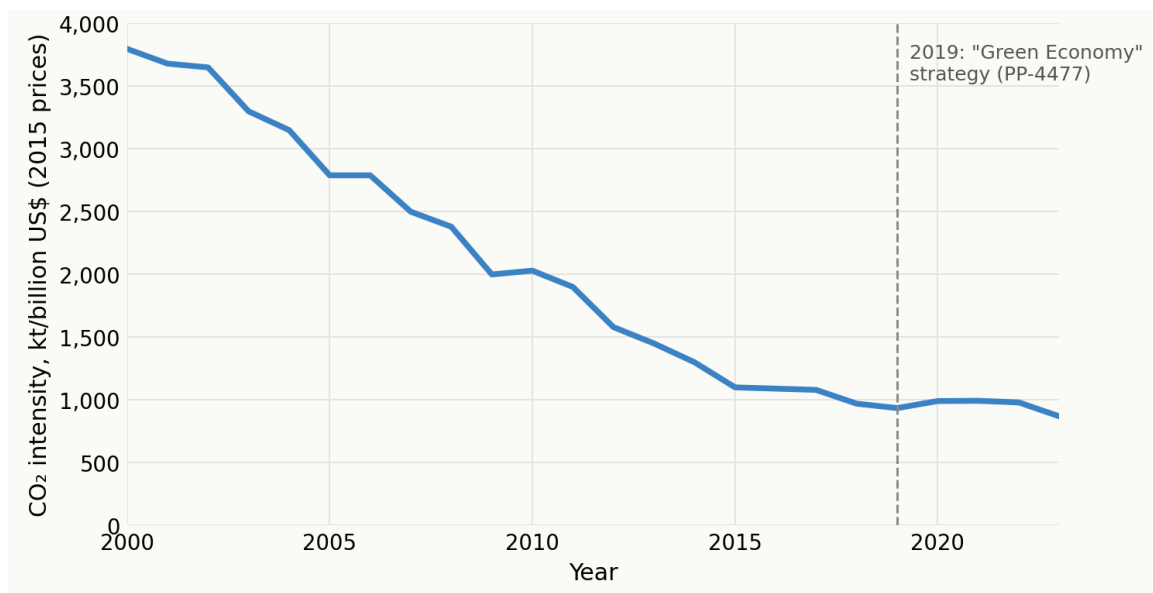


Figure 1. CO₂ intensity of GDP in Uzbekistan, 2000-2023¹

Carbon intensity declined from 3,798 kt per billion dollars of GDP in 2000 to 935 kt per billion dollars in 2019 - a reduction of 75.4 percent (Figure 1; Table 2). This downward trend paused, and even reversed slightly (rising to 991-993 kt per billion dollars), during the pandemic years 2020-2021, as GDP growth collapsed to 1.62 percent in 2020 while emissions did not fall proportionately. The decline resumed thereafter, and by 2023 intensity had reached a historic low of 869 kt per billion dollars - a further 7.1-percent reduction from 2019 and a cumulative decline of 77.1 percent since 2000.

Table 2

Descriptive statistics, 2000-2023 (2000-2021 for renewable share)²

Variable	Mean	Std. Dev.	Min	Max	N
GDP growth, % (2000-2023)	6.56	1.92	1.62	9.47	24
CO ₂ , Mt (2000-2023)	126.46	9.04	107.55	138.68	24
CO ₂ per capita, t (2000-2023)	4.36	0.68	3.48	5.39	24
CO ₂ intensity, kt/billion USD (2000-2023)	1,966.4	1,012.6	868.9	3,798.1	24
Renewable share, % (2000-2021)	14.24	3.73	7.08	22.62	22

Table 2 shows that the variables differ sharply in their variability. Annual GDP growth averaged 6.56 percent, ranging from 1.62 percent in the pandemic year to 9.47 percent. Total CO₂ emissions were comparatively stable, averaging 126.46 Mt with a standard deviation of only 9.04 Mt, whereas carbon intensity varied widely, from 3,798.1 to 868.9 kt per billion dollars. The renewable share averaged 14.24 percent over 2000-2021, within a range of 7.08 to 22.62 percent. The combination of fast-growing output, nearly stable emissions and sharply falling intensity is the statistical signature of relative decoupling.

¹ Source: author's calculations based on World Bank WDI data [17].

² Source: author's calculations based on World Bank WDI data [17].

The renewable-energy paradox

Figure 2 presents the share of renewable sources in electricity generation according to the official WDI series [17].

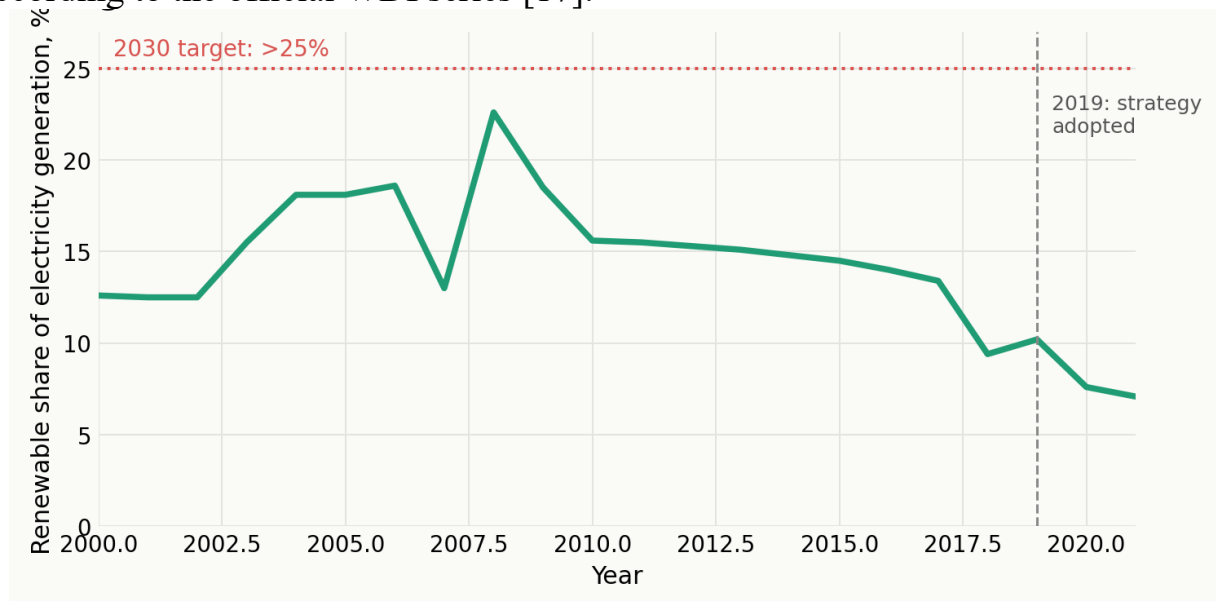


Figure 2. Share of renewable sources in electricity generation, 2000-2021¹

Over the same period, the renewable share of electricity generation follows an unexpected trajectory (Figure 2). Having risen from 12.6 percent in 2000 to a peak of 22.6 percent in 2008, the share then declined almost continuously, falling to just 7.08 percent by 2021 - two years after the green-economy strategy's adoption, and far below the strategy's target of exceeding 25 percent by 2030 [20]. This apparent paradox is best explained by a denominator effect: Uzbekistan's renewable base rests largely on Soviet-era hydropower capacity, whose output has remained essentially flat, while total electricity generation has nearly doubled to meet rising demand, with most of that additional generation supplied by gas turbines. The absolute volume of renewable generation has therefore not fallen; only its share of a rapidly expanding total has.

It should be noted that the 2000-2021 series discussed above is the WDI's validated, methodologically consistent series. Outside this panel, press and official sources report a renewable share of approximately 18 percent by May 2024 [5] and a record renewable-generation year in 2025 [9] - coinciding closely with the commissioning of the large-scale solar and wind projects financed by the EBRD and ADB in 2022-2023 [1; 4]. This suggests that the customary two-to-three-year lag between financing and generation has not yet been fully captured in the official, methodologically consistent WDI series.

Tapio decoupling elasticity

The annual Tapio elasticities are plotted in Figure 3, and their distribution across decoupling states before and after the policy date is summarised in Table 3.

¹ Source: author's calculations based on World Bank WDI data [17].

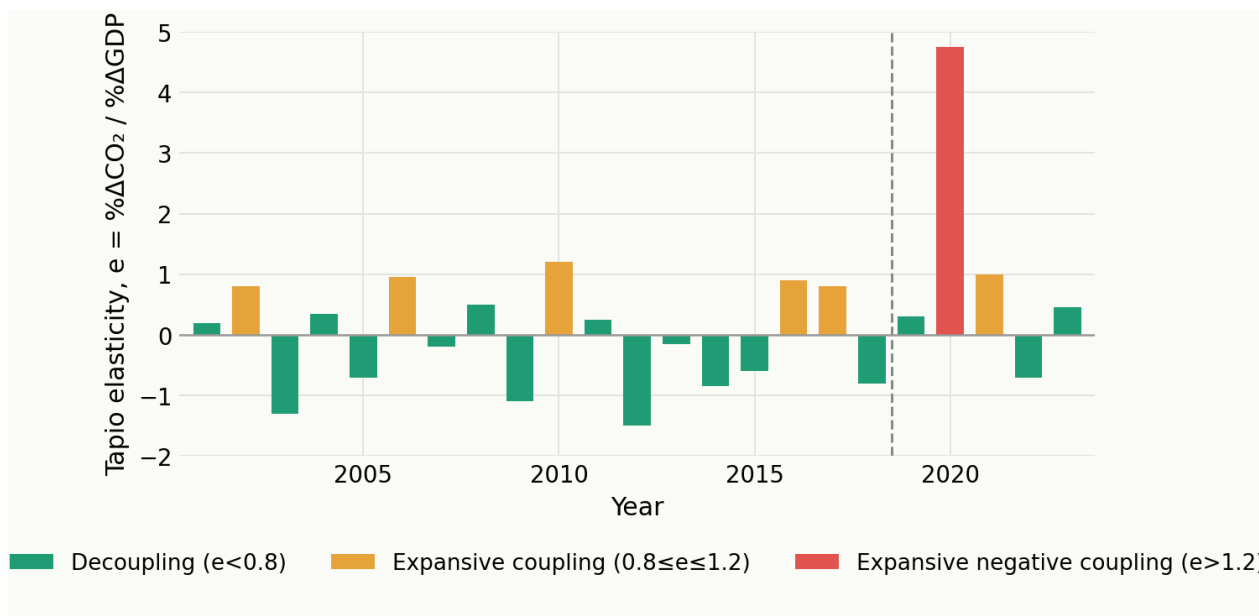


Figure 3. Tapio decoupling elasticity between GDP growth and CO₂ emissions, 2001-2023¹

Figure 3 shows that most annual elasticities before 2019 lie below the 0.8 threshold, and several of them are negative, which corresponds to strong decoupling. After 2019 the picture is dominated by a single spike in 2020, when the elasticity exceeded 4 because GDP growth in the pandemic year was very low; in the other post-policy years the values return to the decoupling or expansive-coupling range.

Table 3

Tapio decoupling states, pre- and post-policy periods²

Period	Decoupling ($e < 0.8$)	Expansive coupling ($0.8 \leq e \leq 1.2$)	Expansive negative coupling ($e > 1.2$)	Total years
2001-2018 (pre-policy)	14	4	0	18
2019-2023 (post-policy)	3	1	1	5

For the pre-policy period 2001-2018, the mean Tapio elasticity is -0.09, with 14 of 18 years classified as decoupling - close, on average, to strong decoupling. For the post-policy period 2019-2023 ($N = 5$), the mean elasticity rises to +1.17 (+0.28 excluding the pandemic-affected year 2020), indicating a shift away from strong decoupling, even though three of the five years remain in the decoupling state. Neither Welch's t-test ($t = -1.32$, $p = 0.25$ for the full sample; $t = -0.90$, $p = 0.41$ excluding 2020) nor the Mann-Whitney U test ($p = 0.17$) confirms this shift as statistically reliable.

Structural-break regression

Table 4 reports the structural-break regression estimates for the main specification and the two robustness checks.

¹ Source: author's calculations based on World Bank WDI data [17].

² Source: author's calculations based on World Bank WDI data [17].

Table 4
Structural break regression results for CO₂ growth rate (HC3 robust standard errors)¹

Model	Variable	Coefficient	Std. Error (HC3)	p-value
(1) Main: break=2019, N=23	const	-0.633	1.453	0.663
	GDP growth (centered)	-0.214	0.715	0.765
	Policy (≥ 2019)	3.685	4.160	0.376
	Policy $\times$ GDP growth	-0.177	5.297	0.973
(2) Excluding 2020, N=22	const	-0.633	1.453	0.663
	GDP growth (centered)	-0.214	0.715	0.765
	Policy (≥ 2019)	2.134	2.640	0.419
	Policy $\times$ GDP growth	4.970	3.082	0.107
(3) Alternative break=2021, N=23	const	-0.150	1.372	0.913
	GDP growth (centered)	-0.698	0.677	0.302
	Policy (≥ 2021)	1.641	12.659	0.897
	Policy $\times$ GDP growth	5.455	25.526	0.831

Across all three specifications, neither the policy indicator nor its interaction with GDP growth is statistically significant ($p > 0.3$ throughout), and the models' explanatory power remains low ($R^2 = 0.10$ - 0.15). This is an expected consequence of having only four to five post-2019 observations, but it also means that the official data as yet reveal no clear trace of a structural break.

Finally, the relationship between carbon intensity and the renewable share, weakly positive in levels ($r = 0.38$), falls to near zero in first differences ($r = 0.05$) - a standard diagnostic, also employed in prior studies, confirming that the level correlation is an artefact of two independently trending series rather than evidence that declining carbon intensity is genuinely related to a rising renewable share.

Taken together, the findings present an unspectacular but coherent picture. Uzbekistan's long-run decline in carbon intensity is real and substantial, but it predates the expansion of renewable electricity and is not statistically associated with it; it is better explained by structural change - a shift away from heavy industry toward services and light manufacturing - and by gains in energy efficiency, visible in the steady rise of GDP per unit of energy consumed. This interpretation is consistent with the OECD's qualitative assessment that Uzbekistan's energy system, while still gas-dependent, is becoming progressively more efficient [11]; [12].

The absence of a statistically detectable acceleration in decoupling after 2019 should not be read as evidence that the Green Economy strategy or green finance more broadly has failed. Nearly every green-financed generation asset identifiable by name in this study - the Nur Jizzakh, Nur Samarkand, and Nur Sherabad solar complexes (approximately 900 MW) [4], the ADB-ACWA wind project [1], and the projects financed through the 2023 sovereign green bond [16] - was contracted in 2022-2023 and commissioned in 2023-2025, that is, after both the most recent confirmed

¹ Source: author's calculations based on World Bank WDI data [17].

renewable-share observation in this panel (2021) and the end of the CO₂ series (2023). Should future WDI releases confirm the approximately 18-percent share reported for 2024 [5], that year may prove to be the first in which the financing-to-generation lag closes - precisely the test this study's design anticipates but cannot yet perform.

The elevated elasticity observed in 2020-2021 is more plausibly an artefact of the near-zero GDP-growth denominator under pandemic conditions (1.62 percent in 2020) than genuine 're-coupling' - a recognised weakness of the Tapio method, whereby elasticities derived from short annual differences are sensitive to denominator noise. This limitation is acknowledged rather than concealed.

These results are broadly consistent with those of Bakhtiyorov [2], the only other Uzbekistan-specific quantitative study of the green transition, which employs a different design - multivariate regression and an EKC specification over 2010-2023, benchmarked against Azerbaijan - and likewise reports statistically unreliable coefficients, attributing the result to limited institutional capacity and the short interval since reform.

Several limitations warrant emphasis. First, with N = 22-24 national annual observations - a constraint shared with the only comparable Uzbekistan study - any single year, particularly 2020, can materially influence the results. Second, the WDI renewable-electricity-share series for Uzbekistan currently extends only to 2021, so the years of greatest policy relevance (2022-2025, precisely when green-bond-financed capacity came online) cannot yet be tested against official, comparable data. Third, the CO₂ indicators used here are calculated on a territorial/production basis and are silent on emissions embedded in trade. Fourth, and most importantly, no Uzbek government body currently publishes an official, machine-readable annual series of green credit or green bond volumes; the 'green finance' variable in this study therefore remains a policy-date proxy (the 2019 strategy adoption, with 2021 as an alternative) rather than a direct measure of financial flows - arguably the single largest obstacle to causal identification in this strand of the Uzbekistan literature.

CONCLUSION AND SUGGESTIONS

This study set out to determine whether the green-economy policy adopted in Uzbekistan in 2019, together with the green-finance instruments subsequently developed, has statistically altered the relationship between economic growth and carbon emissions. Drawing on the official national panel for 2000-2023, four findings emerge: first, carbon intensity fell by 75.4 percent between 2000 and 2019, a decline attributable to structural change and efficiency gains rather than to renewable energy; second, the renewable share itself fell, from 22.6 percent to 7.1 percent between 2008 and 2021, owing to a denominator effect; third, although the direction of the post-2019 decoupling elasticity moved away from strong decoupling, the shift is not statistically reliable; and fourth, the results are better explained by the ordinary lag between financing and realised outcomes than by any shortcoming in green-finance policy.

On this basis, five recommendations follow.

1. The Ministry of Economy and Finance, the Central Bank, and the State Statistics Committee should jointly establish and publish an annual, machine-readable

registry of green credit and green bond issuance aligned with the 2023 green taxonomy - the most significant data gap this study identifies.

2. Because the renewable-share paradox is fundamentally a denominator problem, policy monitoring should track not only the percentage share but also the growth of renewable generation volume relative to total generation, so that genuine capacity gains are not obscured by a rapidly expanding denominator.

3. WDI-comparable reporting of the renewable electricity share should be extended through 2022-2025, or, failing that, IRENA's more current capacity statistics [7] should be adopted as a standardised supplement, enabling a proper assessment of the 2022-2025 commissioning wave against the pre-2019 baseline.

4. This analysis should be repeated in 2027-2028, once three to five further years of post-2021 data have accumulated, at which point ARDL/cointegration methods - which require longer series than are currently available - could be applied to conduct a genuine long-run causal test.

5. Since intensity gains to date have originated mainly in structural and efficiency channels, policy attention should be directed at least as much toward non-electricity decarbonisation - industrial energy efficiency and gas-distribution efficiency in particular - as toward the renewable-capacity build-out that currently dominates the green-finance narrative.

In sum, Uzbekistan has made real and meaningful progress in reducing carbon intensity, but most of that progress predates the recent wave of green finance. A genuine test of green finance's contribution will only become possible once the 2024-2026 statistics - reflecting the full commissioning of capacity financed in 2022-2023 - enter the official data panel.

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