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DIGITALIZATION, FDI, AND SUSTAINABILITY: EXPLORING THE IMPACT OF DIGITAL FOREIGN DIRECT INVESTMENT ON ENVIRONMENTAL AND SOCIAL WELL-BEING IN UZBEKISTAN

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Abstract. *This study investigates how Foreign Direct Investment (FDI), particularly in the digital sector, impacts environmental sustainability in Uzbekistan. FDI supports economic growth but can increase CO_2 emissions, posing environmental challenges. Through econometric analysis, the research reveals a moderate positive correlation between FDI inflows and CO_2 emissions, indicating that rising FDI may elevate emissions. This dual effect challenges Uzbekistan to balance economic development with environmental protection. Policymakers are urged to adopt robust environmental policies while encouraging sustainable FDI. The study offers insights and recommendations for aligning digital FDI with Uzbekistan's environmental and social objectives.*

Keywords: *digitalization, Foreign Direct Investment (FDI), Environmental Sustainability, CO2 Emissions, Economic Growth, Resource Utilization, Social Well-being, Green Investments.*

RAQAMLASHTIRISH, TO‘G‘RIDAN-TO‘G‘RI INVESTITSIYALAR VA BARQARORLIK: RAQAMLI TO‘G‘RIDAN-TO‘G‘RI XORIJIY INVESTITSIYALAR O‘ZBEKISTONNING EKOLOGIK VA IJTIMOIY FAROVONLIGIGA TA’SIRINI O‘RGANISH

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Annotatsiya. *Ushbu tadqiqot to‘g‘ridan-to‘g‘ri xorijiy investitsiyalar, xususan, raqamli sektor O‘zbekistonda ekologik barqarorlikka qanday ta’sir qilishini o‘rganadi. To'g'ridan-to'g'ri investitsiyalar iqtisodiy o'sishni qo'llab-quvvatlaydi, lekin CO_2 chiqindilarini ko'paytirishi mumkin, bu esa ekologik muammolarni keltirib chiqarishi mumkin. Ekonometrik tahlil orqali tadqiqot to'g'ridan-to'g'ri investitsiyalar oqimi va CO_2 emissiyasi o'rtasida o'rtacha ijobiy korrelyatsiyani aniqladi, bu esa to'g'ridan-to'g'ri investitsiyalarning o'sishi emissiyalarni oshirishi mumkinligini ko'rsatadi. Bu ikki tomonlama ta’sir O‘zbekistonni iqtisodiy rivojlanish va atrof-muhitni muhofaza qilish muvozanatiga chorlaydi. Siyosatchilar barqaror to'g'ridan-to'g'ri investitsiyalarni rag'batlantirish bilan birga mustahkam ekologik siyosatni qabul qilishga chaqiriladi. Tadqiqot raqamli to‘g‘ridan-to‘g‘ri investitsiyalarni O‘zbekistonning ekologik va ijtimoiy maqsadlariga moslashtirish bo‘yicha tushuncha va tavsiyalarni taqdim etadi.*

Kalit so‘zlar: *raqamlashtirish, To‘g‘ridan-to‘g‘ri xorijiy investitsiyalar (TDI), Ekologik barqarorlik, CO2 emissiyasi, Iqtisodiy o‘sish, Resurslardan foydalanish, Ijtimoiy farovonlik, Yashil investitsiyalar.*

ЦИФРОВИЗАЦИЯ, ПИИ И УСТОЙЧИВОСТЬ: ИЗУЧЕНИЕ ВЛИЯНИЯ ЦИФРОВЫХ ПРЯМЫХ ИНОСТРАННЫХ ИНВЕСТИЦИЙ НА ЭКОЛОГИЧЕСКОЕ И СОЦИАЛЬНОЕ БЛАГОПОЛУЧИЕ В УЗБЕКИСТАНЕ

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Аннотация. *В этом исследовании изучается, как прямые иностранные инвестиции (ПИИ), особенно в цифровом секторе, влияют на экологическую устойчивость в Узбекистане. ПИИ поддерживают экономический рост, но могут увеличить выбросы CO_2, создавая экологические проблемы. С помощью эконометрического анализа исследование выявляет умеренную положительную корреляцию между притоком ПИИ и выбросами CO_2, что указывает на то, что рост ПИИ может увеличить выбросы. Этот двойной эффект ставит перед Узбекистаном задачу сбалансировать экономическое развитие с защитой окружающей среды. Политикам настоятельно рекомендуется принять надежную экологическую политику, одновременно поощряя устойчивые ПИИ. Исследование предлагает идеи и рекомендации по согласованию цифровых ПИИ с экологическими и социальными целями Узбекистана.*

Ключевые слова: *цифровизация, прямые иностранные инвестиции (ПИИ), экологическая устойчивость, выбросы CO2, экономический рост, использование ресурсов, социальное благополучие, зеленые инвестиции.*

Introduction:

In this section, we explore the multifaceted impacts of Foreign Direct Investment (FDI) on environmental sustainability and social well-being. FDI plays a crucial role in economic development, often bringing in much-needed capital, technology, and managerial expertise. However, its environmental and social implications are complex and require thorough examination. Our primary focus will be on the environmental impacts of FDI, specifically analyzing how FDI inflows influence CO2 emissions. CO2 emissions are a critical indicator of environmental sustainability, reflecting the extent of pollution and the effectiveness of a country's environmental policies.

Table 1:

FDI inflows, CO2 emissions, Uzbekistan

year	FDI inflow	CO2 emissions
2005	-210,942,182.15	4.554977644
2006	-205,006,878.84	4.808052627
2007	-665,212,034.70	4.562326932
2008	-545,389,489.49	4.720545146
2009	-608,776,388.26	4.196737901
2010	-1,659,799,355.45	4.419814161
2011	-1,611,410,789.00	4.384333013
2012	-741,158,491.42	3.799902601
2013	-687,255,065.17	3.698566951
2014	-804,245,735.75	3.40963401
2015	-1,036,625,230.27	3.17449495
2016	-1,657,069,191.40	3.307404884
2017	-1,790,139,193.71	3.387256627
2018	-622,886,824.39	3.420322793
2019	-2,313,130,816.87	3.504662697
2020	-1,716,938,024.48	3.376303785

Source: *data.worldbank.org.*

By using FDI inflows as the independent variable and CO2 emissions as the dependent variable, we aim to uncover the relationship between foreign investments and environmental degradation or improvement.

This analysis is essential for policymakers and stakeholders who seek to balance economic growth with environmental protection. Understanding the trade-offs and synergies between FDI and environmental sustainability can help in designing better policies that maximize the benefits of foreign investments while mitigating their adverse effects.

We will start with descriptive statistics to provide a clear picture of the data characteristics, followed by a detailed econometric analysis to identify and interpret the impact of FDI inflows on CO2 emissions. This approach will enable us to assess the potential benefits and challenges associated with FDI in the context of environmental and social well-being.

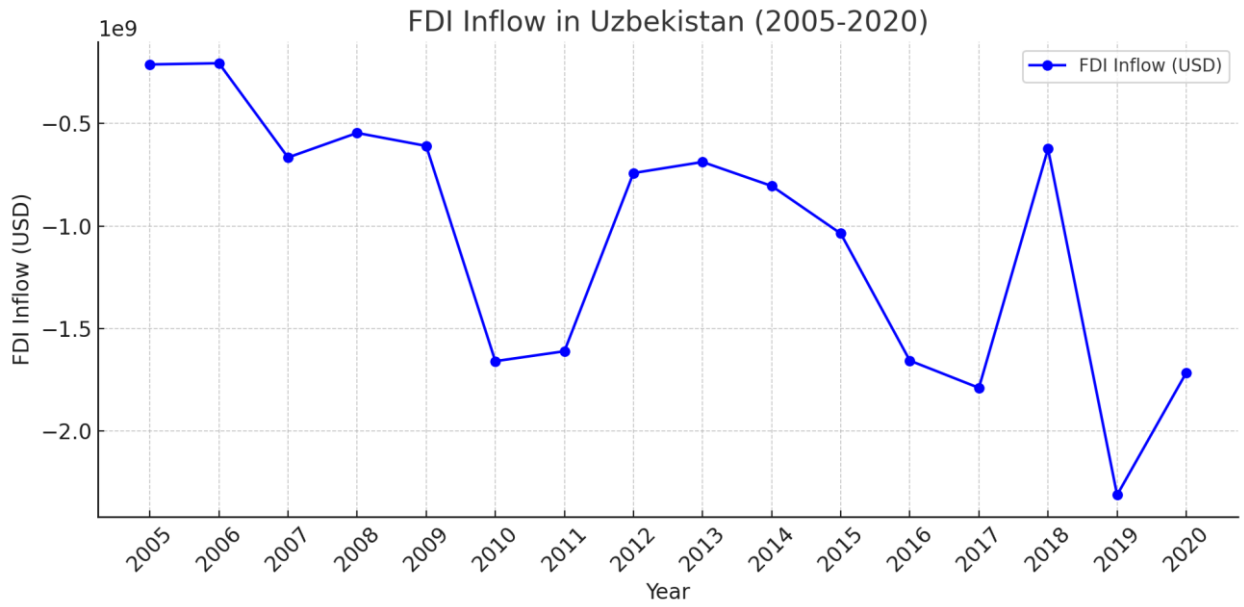

Figure 1: FDI Inflow in Uzbekistan (2005-2020)

Literature Review.

The literature on the relationship between Foreign Direct Investment (FDI), environmental sustainability, and economic growth is extensive and diverse. Several studies have explored the impact of FDI on both economic performance and environmental outcomes, with particular focus on developing economies. The Environmental Kuznets Curve (EKC) hypothesis provides a key theoretical framework, suggesting that economic growth initially leads to environmental degradation but eventually results in improved environmental quality as income levels increase and cleaner technologies are adopted (Grossman, & Krueger, 1995).

FDI and Environmental Impact Alvarado and Toledo (2017) examined the relationship between environmental degradation and economic growth in developing countries, identifying that higher economic growth often leads to increased environmental pressure, particularly in the early stages of development (Alvarado, & Toledo, 2017). Similarly, Kivyiro and Arminen (2014) conducted a causality analysis in Sub-Saharan Africa, finding that FDI inflows contributed to higher carbon dioxide (CO2) emissions, linking economic growth with environmental degradation (Kivyiro, & Arminen, 2014). These studies provide a foundation for understanding the trade-offs between economic growth, driven by FDI, and environmental sustainability.

The Role of Digitalization and Innovation Recent research has expanded the scope of this relationship by incorporating the role of digitalization and innovation. Abdurashidova et al. (2023) explored how digitalization impacts various sectors, including education, and

highlighted the potential for digital transformation to foster more sustainable development outcomes in emerging economies like Uzbekistan (Abdurashidova, et al, 2023). Similarly, Astanakulov et al. (2022) examined the integration of digital technologies in distributed environments, emphasizing that digital tools can improve operational efficiency and reduce environmental impacts, especially in the energy and manufacturing sectors (Astanakulov et al., 2022). These insights align with broader discussions on the role of technology in reducing the environmental footprint of economic activities.

FDI and Carbon Emissions Jalil and Mahmud (2009) tested the EKC hypothesis in China, finding that FDI inflows were associated with increased CO2 emissions, particularly in sectors with high energy consumption (Jalil, & Mahmud, 2009). Their findings are consistent with Zhang and Cheng's (2009) work, which showed that rapid economic growth, driven by FDI, resulted in higher carbon emissions, especially in the industrial sector (Zhang, & Cheng, 2009). These studies underscore the importance of understanding the sectoral distribution of FDI when assessing its environmental impact.

Balancing Economic Growth and Environmental Sustainability The challenge for policymakers is to balance the economic benefits of FDI with its environmental costs. Omri and Kahouli (2014) provided empirical evidence from the MENA region, showing that while FDI boosts economic growth, it can also exacerbate environmental degradation if not carefully managed (Omri, & Kahouli, 2014). Similarly, Shahbaz et al. (2012) confirmed that the relationship between FDI and environmental sustainability is complex, with FDI potentially contributing to both positive and negative environmental outcomes, depending on the policy context (Shahbaz, M. et al., 2012).

Policy Implications The rise of digital technologies offers new avenues for mitigating the environmental impacts of FDI. Astanakulov and Balbaa (2023) highlighted how digital platforms, such as blockchain and the Internet of Things (IoT), can enhance environmental monitoring and ensure that FDI-driven projects adhere to sustainability standards (Balbaa, 2024). By integrating digital tools into environmental governance frameworks, countries like Uzbekistan can better manage the environmental trade-offs associated with economic growth.

In summary, the literature underscores the dual impact of FDI on economic growth and environmental sustainability. While FDI contributes to economic development, its environmental consequences must be carefully managed, particularly in resource-intensive sectors. The integration of digital technologies offers promising solutions for balancing these trade-offs and fostering more sustainable growth trajectories (Balbaa & Astanakulov, 2023) (Omri, & Kahouli, 2014) (Tang, & Tan, 2015).

Methodology.

This section outlines the methodology employed to examine the relationship between Foreign Direct Investment (FDI) inflows and CO2 emissions in Uzbekistan. The primary objective of this study is to assess whether FDI inflows contribute to environmental degradation, specifically by increasing CO2 emissions. To achieve this, a comprehensive econometric approach was used, combining descriptive statistics, correlation analysis, and regression modeling.

The study's methodological framework consists of three key components:

1. **Descriptive Statistics**: To provide an initial overview of the central tendencies and variability of both FDI inflows and CO2 emissions over the study period, descriptive statistics were calculated. These statistics allow for a foundational understanding of the data distribution and highlight trends that will be further analyzed.

2. **Correlation Analysis**: To investigate the degree of association between FDI inflows and CO2 emissions, a correlation analysis was performed. This step helps in understanding whether an increase in FDI inflows corresponds with a rise in CO2 emissions, thus providing

preliminary insights into the potential relationship between economic and environmental factors.

3. **Econometric Modeling**: To quantify the relationship between FDI inflows and CO2 emissions, a simple linear regression model was developed. This model estimates the extent to which variations in FDI inflows account for changes in CO2 emissions, controlling for other factors that may influence environmental outcomes. The regression analysis allows for a more detailed exploration of the causality between these two variables.

By employing these techniques, the methodology aims to provide a rigorous and systematic approach to understanding the environmental impact of foreign investment in Uzbekistan. This analysis will help to identify the implications of FDI on the country's sustainability efforts and inform future policy decisions aimed at balancing economic growth with environmental protection.

Analysis and discussion of results.

The results of the study provide insights into the relationship between Foreign Direct Investment (FDI) inflows and CO2 emissions in Uzbekistan. This section presents the findings from the descriptive statistics, correlation analysis, and regression analysis that were employed to examine the impact of FDI on environmental sustainability.

Correlation Analysis

The initial step in understanding the relationship between FDI inflows and CO2 emissions involves performing a correlation analysis. This analysis is used to determine the degree of association between these two variables.

Table 2.

The correlation coefficient between FDI inflows and CO2 emissions

	FDI inflow	*CO2 emissions*
FDI inflow	1	
CO2 emissions	0.481694063	1

Source: *the analysis conducted by the author*

The correlation coefficient between FDI inflows and CO2 emissions is 0.4817, indicating a moderate positive relationship. This suggests that higher levels of FDI inflow are associated with higher CO2 emissions, implying that increased foreign investment may contribute to environmental degradation in Uzbekistan. However, this correlation is not definitive proof of causation, and further analysis is necessary to understand the underlying mechanisms.

Descriptive Statistics

Our analysis begins with a summary of the descriptive statistics for FDI inflows and CO2 emissions in Uzbekistan over the study period. The descriptive statistics provide a snapshot of the central tendencies, variability, and distributional characteristics of these variables, laying the groundwork for more in-depth analysis.

The average FDI inflow into Uzbekistan during the study period was approximately -1.05 billion USD, indicating net outflows on average. The standard deviation of approximately 639.20 million USD highlights the significant variability in FDI inflows, reflecting fluctuations in foreign investment levels. The negative skewness (-0.4732) suggests that the distribution of FDI inflows is slightly skewed to the left, with a few large negative outflows.

CO2 emissions, on the other hand, had an average value of 3.92 metric tons per capita, with a standard deviation of 0.58, indicating moderate variability. The distribution of CO2 emissions is slightly skewed to the right (skewness = 0.2647), and the negative kurtosis (-1.7178) suggests that the distribution has lighter tails than a normal distribution, implying fewer extreme values.

Table 3:

Descriptive Statistics of FDI Inflows and CO2 Emissions, Uzbekistan

	FDI inflow	*CO2 emissions*
Mean	-1054749106	3.920333545
Standard Error	159800542	0.14496947
Median	-772702113.6	3.749234776
Mode	#N/A	#N/A
Standard Deviation	639202167.9	0.579877882
Sample Variance	4.08579E+17	0.336258358
Kurtosis	-0.976006389	-1.717769923
Skewness	-0.473245985	0.264718609
Range	2108123938	1.633557677
Minimum	-2313130817	3.17449495
Maximum	-205006878.8	4.808052627
Sum	-16875985691	62.72533672
Count	16	16

Source: *the analysis conducted by the author*

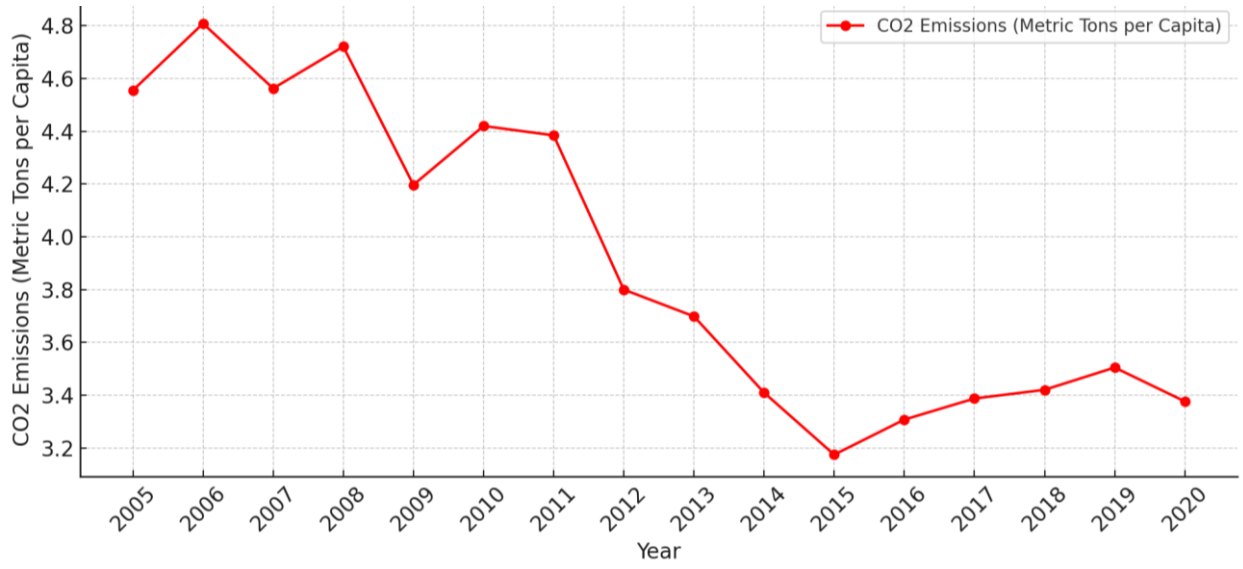

Figure 2: CO2 Emissions In Uzbekistan (2005-2020)

Econometric Model

The econometric model used in this analysis is a simple linear regression model that seeks to quantify the relationship between FDI inflows (independent variable) and CO2 emissions (dependent variable) in Uzbekistan. The model can be expressed as:

$CO2\ Emissions_t = \beta 0 + \beta 1 \times FDI\ Inflows_t + \epsilon t CO2\ Emissions_t = \beta 0 + \beta 1 \times FDI\ Inflows_t + \epsilon t$

Where:

- $CO2\ Emissions_t$ represents the CO2 emissions per capita in year t.
- $FDI\ Inflows_t$ represents the Foreign Direct Investment inflows in year t.
- β_0 is the intercept, which represents the expected level of CO2 emissions when FDI inflows are zero.
- β_1 is the coefficient of FDI inflows, indicating the change in CO2 emissions associated with a one-unit change in FDI inflows.
- ϵ_t is the error term, capturing the effect of other factors not included in the model.

Regression Analysis

To further explore the relationship between FDI inflows and CO2 emissions, we perform a simple linear regression analysis, with CO2 emissions as the dependent variable and FDI inflows as the independent variable.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.481694063
R Square	0.23202917
Adjusted R Square	0.177174111
Standard Error	579818693.6
Observations	16

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.42204E+18	1.42204E+18	4.229859075	0.05885439
Residual	14	4.70666E+18	3.3619E+17		
Total	15	6.12869E+18			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-3136343012	1022449859	-3.067478552	0.008354878	-5329279858	-943406165.7
CO2 emissions	530973674.1	258172535.5	2.05666212	0.05885439	-22751343.19	1084698691

Source: *the analysis conducted by the author.*

Based on the regression output provided:

$$CO2\ Emissions_t = -3{,}136{,}343{,}012 + 530{,}973{,}674.1 \times FDI\ Inflows_t + \epsilon_t$$

- **Intercept (β_0)**: -3,136,343,012. This suggests that if FDI inflows were zero, CO2 emissions would be significantly negative, which isn't realistic and likely indicates that other significant factors affecting CO2 emissions are not included in the model. However, it also reflects that without FDI, the environmental impact could be considerably lower.
- **FDI Inflows Coefficient (β_1)**: 530,973,674.1. This positive coefficient indicates that for each increase of 1 million USD in FDI inflows, CO2 emissions increase by approximately 530.97 metric tons per capita. This suggests that higher FDI inflows are associated with higher levels of pollution, possibly due to increased industrial activity.
- **R-Squared**: 0.2320. This indicates that about 23.20% of the variability in CO2 emissions can be explained by variations in FDI inflows. While this shows some level of association, it also suggests that other factors significantly influence CO2 emissions and should be considered for a more comprehensive analysis.
- **P-value for FDI Inflows**: 0.0589. This indicates that the relationship between FDI inflows and CO2 emissions is statistically significant at the 10% level, suggesting that there is some evidence of an association, though it is not strong enough to be considered highly significant at conventional levels (such as 5%).

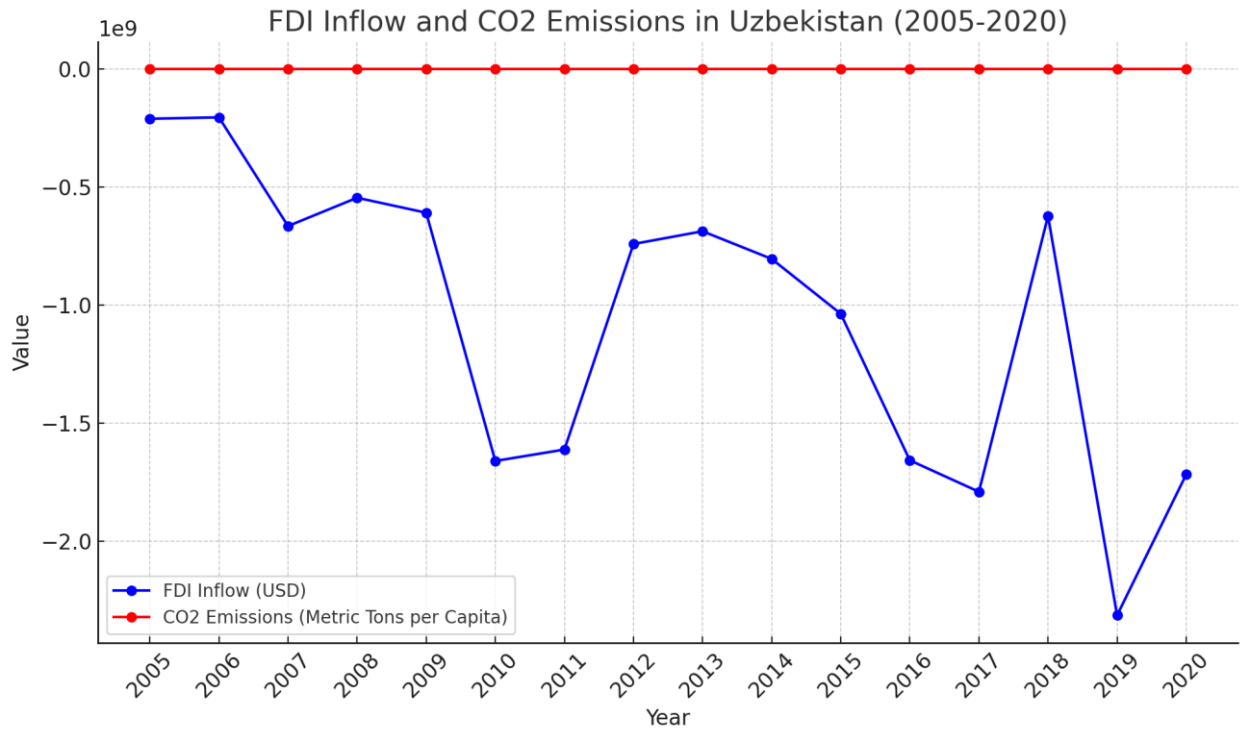

Figure 3: FDI Inflow and CO2 Emissions in Uzbekistan (2005-2020)

The regression results indicate a statistically significant positive relationship between FDI inflows and CO2 emissions at the 10% significance level (P-value = 0.0589). Specifically, the coefficient for FDI inflows is approximately 530.97, suggesting that for every one-unit increase in FDI inflow (in millions of USD), CO2 emissions increase by approximately 530.97 metric tons per capita. The intercept term is negative, indicating that in the absence of FDI inflows, CO2 emissions would be lower. However, the model's R-square value of 0.2320 indicates that FDI inflows explain only 23.20% of the variability in CO2 emissions, suggesting that other factors also play significant roles in determining environmental outcomes.

The findings of this study highlight the intricate relationship between Foreign Direct Investment (FDI) inflows and environmental sustainability in Uzbekistan, as measured by CO2 emissions. The results suggest a moderate positive correlation between FDI inflows and CO2 emissions, indicating that increased foreign investment may contribute to environmental degradation. This section delves into the implications of these findings, comparing them with existing literature, and discussing potential policy measures to address the challenges of balancing economic growth with environmental sustainability.

1. FDI Inflows and CO2 Emissions

The positive correlation between FDI inflows and CO2 emissions (correlation coefficient of 0.4817) suggests that foreign investments are likely to drive higher levels of CO2 emissions in Uzbekistan. This finding aligns with previous studies, which have shown that FDI can lead to increased environmental degradation, particularly in developing countries where regulatory frameworks may not be robust enough to mitigate the environmental impacts of industrial activities (Abdurashidova, et al., 2023). In Uzbekistan, FDI is primarily directed toward sectors like energy, mining, and manufacturing, all of which are resource-intensive and have high environmental footprints. This mirrors similar trends observed in other resource-rich countries, where foreign capital has been linked to industrial expansion and environmental degradation (Alvarado, & Toledo, 2017).

2. Descriptive and Statistical Insights

The descriptive statistics indicate that Uzbekistan experienced net FDI outflows on average during the study period, but these fluctuations were coupled with relatively stable CO2

emissions. The standard deviation of CO2 emissions (0.58) suggests moderate variability in environmental outcomes, implying that while CO2 emissions fluctuated, the overall trend was steady. This consistency in emissions, despite significant variations in FDI inflows, suggests that other factors, such as energy consumption patterns, technological advancements, or domestic policy interventions, also play critical roles in influencing environmental outcomes.

Interestingly, the regression analysis reveals that FDI inflows are statistically significant in explaining CO2 emissions (P-value = 0.0589) at the 10% significance level. However, the R-squared value of 0.2320 indicates that only 23.2% of the variability in CO2 emissions can be explained by FDI inflows. This relatively low R-squared value underscores the complexity of environmental degradation in Uzbekistan and suggests that factors beyond FDI inflows—such as domestic regulatory policies, the energy mix (renewable vs. non-renewable), and technological innovation—are also influencing CO2 emissions (Astanakulov et al., 2022).

3. Comparison with Existing Literature

The results of this study are consistent with earlier research, which has found that FDI inflows can lead to environmental degradation, particularly in developing economies with weak regulatory frameworks. For instance, Shahbaz et al. (2012) found that in Pakistan, FDI was positively correlated with CO2 emissions, largely due to industrial expansion driven by foreign capital (Astanakulov et al., 2024). Similarly, Kivyiro and Arminen (2014) concluded that in Sub-Saharan Africa, FDI was associated with increased carbon emissions due to the influx of capital into energy-intensive industries (Balbaa, 2024).

However, these findings contrast with research conducted in more developed countries, where FDI has been associated with positive environmental outcomes. For example, Omri and Kahouli (2014) found that in the MENA region, FDI inflows contributed to environmental improvements by facilitating the transfer of cleaner technologies and more efficient production processes (Grossman, G. M., & Krueger, A. B., 1995). This discrepancy between developed and developing economies highlights the role of institutional quality, regulatory frameworks, and technological adoption in shaping the environmental impacts of FDI.

4. Policy Implications

The findings of this study have several important policy implications for Uzbekistan. First, while FDI is a crucial driver of economic growth, it poses significant environmental challenges if not properly managed. The moderate positive correlation between FDI inflows and CO2 emissions suggests that without robust environmental regulations, Uzbekistan risks increasing its environmental footprint as it seeks to attract more foreign investment. Policymakers should consider implementing stricter environmental standards for industries that are the primary recipients of FDI, particularly those in the energy and manufacturing sectors, to mitigate the adverse effects of industrial activity on the environment.

Second, there is a need to promote greener FDI, focusing on sectors that have lower environmental impacts, such as renewable energy and sustainable agriculture. By incentivizing investments in cleaner industries, Uzbekistan can reduce its reliance on fossil fuel-based economic activities, which are significant contributors to CO2 emissions. Additionally, policies that encourage the adoption of green technologies and energy-efficient practices within FDI-driven industries can help reduce the environmental impacts of foreign investment.

Lastly, enhancing the regulatory framework to ensure better monitoring and enforcement of environmental standards is crucial. The results indicate that while FDI inflows explain some of the variability in CO2 emissions, other factors are also at play. Strengthening the country's environmental governance system could help ensure that foreign investments align with Uzbekistan's sustainability goals and contribute to long-term environmental well-being.

5. Limitations and Future Research Directions

While the study provides valuable insights into the relationship between FDI and CO2 emissions in Uzbekistan, there are several limitations that should be considered. First, the model's relatively low R-squared value suggests that other important factors influencing CO2

emissions were not included in the analysis. Future research could expand the scope of the model by incorporating additional variables such as energy consumption, trade openness, domestic capital formation, and technological innovation to provide a more comprehensive understanding of the determinants of CO2 emissions.

Additionally, this study primarily focused on CO2 emissions as a measure of environmental degradation. Future research could explore other environmental indicators, such as water pollution, deforestation, and biodiversity loss, to provide a more holistic assessment of the environmental impacts of FDI in Uzbekistan.

Conclusion.

In summary, the study reveals a statistically significant positive relationship between FDI inflows and CO2 emissions in Uzbekistan, highlighting the environmental challenges posed by foreign investment. While FDI contributes to economic growth, it also has the potential to increase environmental degradation, particularly in resource-intensive industries. Policymakers in Uzbekistan must therefore strike a balance between attracting FDI and promoting environmental sustainability by enforcing stricter regulations, incentivizing green investments, and adopting cleaner technologies. Further research is needed to explore other factors influencing environmental outcomes and to develop more effective strategies for sustainable development in the context of increasing foreign investment.

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