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FINANCIAL INCLUSION, CARBON FOOTPRINT AND HUMAN DEVELOPMENT NEXUS: THE CASE OF TÜRKİYE

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Abstract

In an era marked by increasing global challenges related to sustainability and human well-being, this research investigates the complex interrelationship between financial inclusion (FI), carbon footprint, and human development in the unique context of Türkiye. Leveraging a comprehensive dataset spanning three decades, we employ advanced econometric techniques, including the Fully Modified Ordinary Least Squares (FMOLS) and Canonical Cointegrating Regression (CCR), to shed light on this multifaceted nexus. The findings reveal that FI, as gauged by the Financial Institutions and Financial Markets, significantly contributes to Türkiye's Human Development. Improved financial access and stability are associated with positive advancements in human development indicators over the long term. Additionally, our analysis underscores the environmental dimension, as increased carbon dioxide emissions exhibit a detrimental impact on human development. These results emphasize the importance of aligning economic progress with ecological sustainability in Türkiye's development trajectory. By employing both FMOLS and CCR, our research enhances the comprehensiveness and robustness of the analysis. The combination of these methodologies not only elucidates the causal relationships within this intricate nexus but also offers insights into policy measures that can simultaneously foster FI, mitigate environmental degradation, and enhance human well-being in Türkiye. This study contributes to the broader discourse on sustainable development by providing empirical evidence on the interplay between FI, environmental concerns, and human development in Türkiye, ultimately advancing our understanding of the complex dynamics underpinning national development efforts in the twenty-first century.

Keywords: *Human development, financial inclusion, carbon footprint, cointegration regression.*

JEL codes: *G20, O15, Q01, C32.*

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1. INTRODUCTION

The concept of Financial Inclusion (FI), which means the spread of financial services to all segments of society, came to the fore with the increase in the internet and mobile applications in the early 21st century. The importance of the concept of FI has increased even more as organizations such as the World Bank, the United Nations and various international development organizations state that providing access to

financial services is essential for reducing poverty and inclusive economic growth. FI began to be accepted as one of the most important components of sustainable development after it was included among the goals set by the United Nations in 2015.

In an era marked by profound global challenges, the interplay between FI, environmental sustainability, and human development has emerged as a pivotal arena of inquiry. This nexus transcends national boundaries and resonates deeply with the intricate web of factors shaping the well-being of societies worldwide. The fact that many people, especially in developing countries, still do not have access to formal banking systems and other financial services is seen as one of the most important obstacles to savings, investment and new business establishments in these countries (Dluhopolskyi and Zhukovska 2023; Topić-Pavković, Kovačević, and Kurušić 2023). Within this multifaceted context, the focus of our study is Türkiye, a nation straddling Europe and Asia, where economic dynamism and cultural heritage converge. Against the backdrop of this unique geographic and historical tapestry, we delve into the intricate relationship between FI, carbon footprint, and human development, with a keen eye on its implications for Türkiye's socio-economic landscape.

In parallel with the developments in the world, initiatives to increase FI have yielded significant results in Türkiye, especially in the last 20 years. Over the past few decades, Türkiye has undergone a profound transformation, transitioning from an agricultural economy to a dynamic and rapidly industrializing economy. Another important transformation that has occurred in the Turkish economy since the 1990s has occurred in financial markets. Türkiye, which made its economy open to the outside world with the decisions of January 24, 1980, took important steps in the 1990s to bring its financial markets closer to world standards by keeping up with the globalization movements advancing all over the world (Erkişi and Boğa 2023). In this process, developments especially in the banking sector have facilitated access to the financial system for many more people. The most obvious effect of this transformation in Türkiye has been shown in economic growth rates. With its strategic geopolitical location and young population structure with a high tendency to consume, Türkiye has achieved average growth rate of 5 percent in the last 20 years. However, for countries that have not yet completed their development, such as Türkiye, an approach focused only on economic growth is not sustainable in the long term. Establishing human development simultaneously with economic growth and not harming the environment are of great importance in terms of increasing and sustaining the welfare level of the society.

Although Türkiye is not in the developed country category, it stands out among the developing countries with the momentum it has achieved in the field of human development. According to the human development index obtained longevity at birth, education level and income per capita indicators, Türkiye has made significant progress in human development since 1990. While it was among the countries with low human development in 1990 with an index value of 0.579, according to the latest ranking, it managed to become one of the countries with a very high human development class with a score of 0.838. However, when we look at environmental factors, we see that these high growth rates come with a significant environmental cost. So much so that carbon dioxide emissions, which were 150 metric tons in 1990, increased to 450 metric tons in 2021, and with this increase, Türkiye emerged as one of the world's top 10 carbon-emitting nations, as indicated by the latest report from the European Commission (Crippa et al. 2022). It is seen that Türkiye's high performance in the field of human development is not reflected in environmental sustainability. Considering Türkiye's remarkable performance in the field of human development, revealing the factors that increase human development is important both in terms of developing future policies for Türkiye and in guiding other developing countries. The aim of this study is to reveal how carbon footprint and FI affect human development in Türkiye. Understanding this complex relationship between variables is essential to promote sustainable, inclusive and resilient development pathways that address the complex challenges of our time, including climate change and inequality. It provides a holistic framework for decision-makers to navigate the complex interplay between economic, environmental and social factors in the pursuit of a better future for all.

The focus of this study is to explore how FI and carbon footprint influence human development in Türkiye. Using advanced econometric techniques, including the Fully Modified Ordinary Least Squares (FMOLS) and Canonical Cointegrating Regression (CCR), this paper examines the relationships among these variables to identify ways to foster sustainable, inclusive, and resilient development. This paper contributes to the literature by addressing a critical gap in understanding the interconnectedness of FI, human development, and environmental sustainability. By shedding light on these dynamics, the study offers practical insights for policymakers aiming to design integrated strategies that balance economic growth, environmental preservation, and social well-being.

The remainder of this paper is structured as

follows: Section 1 reviews the existing literature on FI, environmental sustainability, and human development. Section 2 describes the methodology and presents the empirical findings. Finally, the study concludes with policy recommendations and suggestions for future research.

1. LITERATURE REVIEW

When the empirical literature on the determinants of human development in Türkiye was examined, it was seen that there were a limited number of studies in this field. Existing studies have shown that human development is associated with internal migration, renewable energy and economic liberalization (İçduygu 2009; Satrovic 2018; Gulaliyev et al. 2016). A few studies in the literature focused on India and Sub-Saharan African countries (Kuri and Laha 2011; Matekenya, Moyo, and Jeke 2021).

Sarma and Pais (2011), who analyzed 49 countries with high, medium and low human development levels, revealed that human development and financial participation levels in a country move parallel to each other. The researchers examined the correlation between FI and development, with the objective of identifying country-specific characteristics that are linked to the degree of financial inclusion. A strong positive association was found between the levels of human development and financial inclusion within a nation. Income, inequality, literacy, urbanization, and infrastructure were identified as significant socio-economic and infrastructure-related elements. The research also emphasized the adverse association between non-performing assets (NPAs) and FI, refuting the belief that NPAs are a consequence of extending credit to low-income demographics. Furthermore, they underscored the need of initiatives aimed at diminishing income disparity, elevating literacy rates, enhancing infrastructure, and increasing reliance on domestic financial institutions to attain greater levels of financial inclusion. Matekenya, Moyo, and Jeke (2021) investigated the relationship between food insecurity FI and human development in Sub-Saharan African nations. Despite experiencing significant economic expansion in the area throughout the 1990s, there has been a persistent presence of elevated levels of inequality, poverty, and unemployment. As a result, officials have placed a heavy emphasis on attaining socio-economic objectives. The study utilized Generalised Method of Moments (GMM) method to analyze the impact of FI on human development. FI was seen as potentially encouraging business start-ups, enabling investments in health and education, managing risk, and alleviating financial shocks, all of which could positively influence human development. The findings affirmed that FI had a positive effect on human development.

Ofosu-Mensah Ababio's study (2021) delved into the reciprocal relationship between FI and human development within the unique context of frontier markets. Employing the dynamic panel Generalized Method of Moments (System-GMM) methodology and analyzing data from 2005 to 2014 for 20 frontier markets, the study uncovered that human development acted as a catalyst for amplifying FI within the banking industry, consequently bolstering the overall development process. Notably, income level, financial literacy, and health were identified as pivotal factors driving the scale-up of FI within the banking sector. The research presented novel evidence attributing low FI to insufficient human development, underscoring the critical role of promoting FI through the banking sector in propelling human development in frontier markets. Chowdhury and Chowdhury (2023) examined how FI impacted human development in Bangladesh, India, and Pakistan. Employing the GMM method, the study identified a positive association between FI and various dimensions of human development, including income level, life expectancy, and educational attainment.

The study by Unnikrishnan and Jagannathan (2015) sought to assess the contemporary state of Global FI and its relationship with economic growth measured through GDP and human development, evaluated using the United Nations Human Development Index. The levels of FI were measured using the Index for FI. FI levels were gauged using the Index for FI. Their research employed multiple regressions to validate the relationship between GDP and HDI with FI as a mediator, analyzing data from 162 countries in the year 2011 on a global scale. The study presented substantiating evidence that FI acts as a mediating factor. Notably, the research shed light on income inequality on a global scale, emphasizing that robust GDP performance does not guarantee equity in economic growth across developed, developing, and underdeveloped countries at that time. Raichoudhury's study (2016) delved into the critical concern of FI, highlighting that despite its policy priority in numerous countries, a substantial portion of the global population, approximately 2.5 billion people, lacked access to formal financial services. The research endeavored to measure FI using cross-country data from the Financial Access Survey (FAS) and Sarma's (2012) Index of FI (IFI). Subsequently, the paper conducted an empirical analysis to explore the relationship between FI and human development on a global scale. The findings affirmed a close correlation

between levels of human development and FI within a country. The calculated correlation coefficients between IFI and HDI values, as well as ranks, indicated a significant positive correlation, further emphasizing the strong linkage between the two indices. Additionally, the study highlighted a close association between income levels and FI in a country, showcasing that high-income nations tended to also exhibit higher levels of FI.

Abdelghaffar, Emam, and Samak (2023) conducted a study exploring the relationship between FI and human development across countries of various income groups from 2009 to 2019. The goal was to analyze potential variations in this relationship across different income levels. Employing dynamic panel data models and estimating them through the generalized method of moments (GMM), the study devised an index of FI (IFI) for countries across different income groups. Notably, the study found that FI exerted a more substantial effect on human development in low and lower-middle-income countries compared to high and upper-middle-income nations. Kuri and Laha (2011) highlighted the potential of FI as a mechanism to enhance people's choices in critical aspects of human development, such as health, education, and standard of living. The study explored the relationship between FI and human development across various states in India. The empirical evidence suggested that a comprehensive financial system could address fundamental disparities in human development within the Indian economy. The study's conclusion reinforced the view that FI could create an environment conducive to mitigating distortions in a country's human development. The analysis categorized states in India based on an index of FI, revealing a correlation between the levels of FI and human development. States with higher levels of human development also tended to exhibit higher levels of FI, underscoring the positive association between the two.

A study conducted by Zaidi, Hussain, and Zaman (2021) delved into how FI, energy consumption, and carbon emissions were interconnected in OECD countries from 2004 to 2017. The analysis also factored in corruption, infrastructure, and economic growth as control factors. Utilizing innovative methodologies like Principal Component Analysis and CS-ARDL, the research identified strong correlations between FI, energy utilization, and carbon emissions, emphasizing the need for aligning FI goals with environmental policies to achieve sustainable development objectives. The study underscored the importance of government efforts in integrating FI targets with energy behavior for effective pollution control and sustainable development. Hussain et al. (2023) addressed the growing significance of examining the relationship between FI and carbon emissions due to the increasing awareness of climate change's adverse effects. Analyzing data from 102 countries over 2004-2020 using the STIRPAT framework, the study established a non-linear (N-shaped) relationship between FI and carbon emissions. Particularly, the study highlighted the need for a comprehensive environmental strategy promoting FI, especially in developing countries, emphasizing tailored financial policies that consider governance, regulations, and income disparities across nations.

Sadiq et al. (2022) highlighted nuclear energy's potential in driving energy transition and addressing global climate challenges. Their focus was on BRICS countries, analyzing data from 1990 to 2019. Employing advanced estimation methods, the study found that nuclear energy and financial globalization had positive effects on human development and environmental sustainability, while external debt posed a hindrance to human development. Notably, bidirectional causal relationships were observed among human development, carbon emissions, and nuclear energy consumption. These findings offer crucial policy insights for promoting sustainable and inclusive development in the BRICS nations.

Liu et al. (2023) investigated the intricate relationship between natural resource management, human capital, FI, and sustainability in the G7 developed economies from 1992 to 2018. Employing advanced panel cointegration techniques and updated methodologies, the study revealed cross-sectional dependence, cointegration, and stationarity properties among the variables. The findings emphasized the positive impact of natural resources and human development in reducing ecological footprints in the G7 countries. However, FI was linked to environmental pollution, underscoring the need to align financial services with sustainability goals. Regulatory quality was identified as a factor that diminished ecological footprints over time. The study highlighted the importance of community awareness and government regulatory measures in achieving environmentally responsible outcomes. Additionally, the paper identified limitations and suggested future research directions.

Drawing from the review of existing literature, it is clear that the existing literature extensively explores the relationship between FI and its impact on human development across various countries. Additionally, some studies analyze FI in relation to other factors such as environmental sustainability, particularly carbon emissions. However, a specific focus on investigating the nexus of FI, carbon footprint, and human development in the context of Türkiye appears to be a gap in the existing literature.

2. Empirical Analysis

This section examines the relationships between human development, financial inclusion, and carbon emissions in the context of Türkiye, using annual data from 1990 to 2020. The empirical analysis begins with an explanation of the variables used in the model and the rationale behind the selection of their respective indicators. This is followed by an analysis of descriptive statistics, where the relationships among the model variables are evaluated using three-dimensional graphs. Subsequently, the methods used for parameter estimation in the empirical model, along with the rationale for their selection, are explained, and the parameter estimation results are interpreted. Finally, the analysis concludes with tests assessing the validity of the model.

2.1. Data Description, Key Insights and Model Specification

The variables used in this study were carefully selected to comprehensively analyze the relationships among human development, financial inclusion, and carbon emissions in Türkiye from 1990 to 2020. Each variable represents a critical dimension of the study's framework. Table 1 provides an overview of these variables, including their abbreviations, proxies used for measurement, and the respective data sources.

In Table 1, each variable reflects a critical aspect of the framework, drawing upon theoretical underpinnings and supported by empirical evidence. Below, we provide a detailed discussion of the justification for selecting these variables, exploring their significance in the context of the study and their alignment with the existing literature.

Human Development Index (*HDI*) is a composite indicator measuring human development in three key dimensions: health, education, and income. In theoretical literature, human development is regarded as both a result and a driver of sustainable development. Empirical studies have demonstrated that the level of human development is closely related to financial inclusion and environmental sustainability (Sarma and Pais 2011; Kuri and Laha 2011). HDI was selected as the dependent variable in this study because it encapsulates both social and economic development and provides an appropriate framework for understanding the relationship between financial inclusion (FI) and the carbon footprint.

Life Expectancy at Birth (*LET*) is a critical indicator of health and an essential component of human development. Theoretical literature posits that health enhances individuals' participation in economic activities, thereby supporting long-term economic growth and welfare. Empirical studies have shown that LET increases through improved access to healthcare facilitated by financial inclusion, which positively contributes to human development (Matekenya, Moyo, and Jeke 2021; Ofosu-Mensah Ababio 2021). Therefore, LET was included in the model as a significant variable affecting human development.

Expected Years of Schooling (*EYS*) is a quantitative indicator of education and is directly linked to the development of human capital. Theoretically, education enables individuals to become more productive in the labor market, thereby fostering economic growth. Empirical literature highlights that financial inclusion enhances access to education, which in turn has a positive effect on human development (Chowdhury and Chowdhury 2023; Unnikrishnan and Jagannathan 2015). Thus, EYS was included in the model to assess educational progress in the context of human development.

GDP per Capita (*GDP*) serves as an indicator of economic growth and welfare. Theoretical literature frequently emphasizes the linkages among economic growth, financial inclusion, and human development

Table 1. Variables

Variables	Abbr.	Proxy	Database
Human Development	HDI	Human Development Index (value)	UNDP
Health	LET	Life Expectancy at Birth (years)	UNDP
Education	EYS	Expected Years of Schooling (years)	UNDP
Production	GDP	GDP Per Capita (Constant 2015 US$)	UNDP
Financial Inclusion	FIN	Financial Institutions Index	IMF
Financial Inclusion	FM	Financial Markets Index	IMF
Carbon Footprint	CEM	Carbon dioxide emissions per capita (tonnes)	UNDP

Source: IMF- Financial Development - Story - IMF Data; United Nations- Human Development Index | Human Development Reports (undp.org)

(Raichoudhury 2016). Empirically, economic growth has been shown to contribute to human development through access to financial services and social expenditures (Sarma and Pais 2011; Zaidi, Hussain, and Zaman 2021). GDP was employed as a key control variable in this study to evaluate the economic dimension.

Financial Institutions Index (*FIN*) and *Financial Markets Index* (*FM*) represent two distinct dimensions of financial inclusion: access to financial institutions and activities within financial markets. Theoretically, financial inclusion enhances individuals' ability to save, invest, and build resilience to economic shocks. Empirical studies demonstrate that financial inclusion has positive impacts on both economic growth and human development (Matekenya, Moyo, and Jeke 2021; Chowdhury and Chowdhury 2023). These indices capture different aspects of FI, thereby broadening the scope of the study.

Carbon Emissions per Capita (*CEM*) is a critical indicator of environmental sustainability. In theoretical literature, the relationship between economic growth and environmental degradation is often discussed within the framework of the Environmental Kuznets Curve (EKC). Empirical studies have documented the adverse effects of carbon emissions on human development, particularly in the context of environmental degradation and health costs (Hussain et al. 2023; Liu et al 2023). Therefore, CEM was included in the study to evaluate the impact of environmental costs on human development.

The selection of variables is consistent with the theoretical foundations and empirical literature, ensuring an approach to understanding the nexus between financial inclusion, human development, and carbon emissions. In the context of our analysis, we have formulated a functional model expressed as in Equation 1.

$$HDI = f(\text{LET},\ \text{EYS},\ \text{GDP},\ \text{FIN},\ \text{FM},\ \text{CEM}) \quad \textit{Eq.}\ (1)$$

This equation serves as the foundational framework for exploring the relationships and dynamics among key variables. Through this model, we aim to gain insights into how financial inclusion, carbon footprint, production, education and health collectively contribute to shaping human development. Equation 1 is the functional representation of the model. We can express our model in the form of cointegration regression as in Equation 2.

$$\begin{aligned}&\ln(HDI_t) = a + \beta_1 \ln(\text{LET}_t) + \beta_2 \ln(\text{EYS}_t) \\ &+\beta_3 \ln(\text{GDP}_t) + \beta_4 \ln(\text{FIN}_t) + \beta_5 (ln\text{FM}_t) \\ &+\beta_6 \ln(CEM_t) + \varepsilon_t\end{aligned} \quad \textit{Eq.}\ (2)$$

Equation 2 is the cointegration regression model that explores how the natural logarithms of each of variables selected. $\ln(HDI_t)$ represents the natural logarithm of the human development index at time "t" (*t*:1990…2020). "*a*" is the intercept term, representing the constant in the regression equation. $\beta_1 \ldots \beta_6$ are the coefficients associated with the independent variables. Each β represents the effect or impact of the respective independent variable on $\ln(HDI_t)$. ε_t represents the error or residual at time "t", which captures the unexplained variability in $\ln(HDI_t)$.

To better understand the characteristics of the variables included in the empirical model, Table 2 presents their descriptive statistics, summarizing the key metrics such as mean, standard deviation, minimum, and maximum values. As shown in Table 2, the HDI has an average value of 0.717, with a standard deviation of 0.082. These values indicate that Türkiye generally maintained a high level of human development during the analyzed period. The HDI ranges from a minimum of 0.6 to a maximum of 0.842, showing an upward trend over time and reflecting progress in human development. LET has an average value of 73.27 years, with a standard deviation of 3.05. This indicates that the health variable, represented by life

Table 2. Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
HDI	32	.717	.082	.6	.842
LET	32	73.266	3.05	67.71	77.83
EYS	32	13.141	3.258	9.056	18.338
GDP	32	8156.386	2438.825	5256.942	13341.598
FIN	32	.313	.132	.1	.483
FM	32	.492	.104	.2	.611
CEM	32	3.983	.758	2.81	5.243

expectancy at birth, exhibits relatively stable variations over the years. The minimum value of 67.71 years and a maximum of 77.83 years highlight significant progress in health outcomes in Türkiye. Similarly, EYS has an average value of 13.14 years, with a standard deviation of 3.26. The values range from a minimum of 9.056 years to a maximum of 18.338 years, suggesting improvements in educational attainment over the period.

In Table 2, GDP, as an indicator of economic performance, has an average value of 8,156.39 USD, with a standard deviation of 2,438.83 USD. The values range from a minimum of 5,256.94 USD to a maximum of 13,341.60 USD, reflecting both periods of lower economic activity and substantial growth phases. The financial inclusion indicators reveal positive trends. The Financial Institutions Index (FIN) has an average value of 0.313, with a standard deviation of 0.132, ranging from a minimum of 0.1 to a maximum of 0.483. These figures suggest considerable progress in financial access. Similarly, the Financial Markets Index (FM) has an average value of 0.492, with a standard deviation of 0.104, and ranges from 0.2 to 0.611, reflecting gradual improvements in financial market development. Lastly, CEM has an average value of 3.983 tons of carbon dioxide emissions, with a standard deviation of 0.758. The values range from a minimum of 2.81 tons to a maximum of 5.243 tons, underscoring the environmental costs associated with Türkiye's economic growth.

2.2. Methodological Approach and Estimation Techniques

This study employs robust cointegration regression models, namely Fully Modified Ordinary Least Squares (FMOLS) and Canonical Cointegrating Regression (CCR), to address key econometric challenges and enhance the reliability of the analysis. These techniques are particularly suited for estimating long-term relationships in the presence of non-stationary data, endogeneity, and serial correlation, which are common issues in time series analysis.

FMOLS, introduced by Phillips and Hansen (1990), is an instrumental variable estimate with non-stationary regressors. It addresses endogeneity by utilizing kernel estimators and the covariance matrix of the error term, rectifying inadequacies in OLS estimation. The FMOLS estimator can be expressed as in Equation 3

$$\widehat{\theta_{FMOLS}} = \left(\sum_{t=1}^{T} X_t . X_t'\right)^{-1} \left(\sum_{t=1}^{T} X_t' Y_t^*\right) \qquad Eq. (3)$$

In Equation 3, X_t represents the independent variables, and Y^*_t is the adjusted dependent variable accounting for endogeneity and serial correlation. This adjustment ensures that FMOLS provides efficient and unbiased estimates of long-term relationships. This makes it particularly suitable for exploring the factors driving human development in this study.

The CCR method, introduced by Park (1992), transforms both the dependent and independent variables to eliminate endogeneity and serial correlation while preserving the cointegrating relationship. This transformation ensures consistency and efficiency in parameter estimation. The CCR estimator is defined as:

$$\widehat{\theta_{CCR}} = \left(\sum_{t=1}^{T} Z_t^* Z_t^{*\prime}\right)^{-1} \left(\sum_{t=1}^{T} Z_t^* Y_t^*\right) \qquad Eq. (4)$$

In Equation 4, Z_t^* and Y_t^* are the transformed independent and dependent variables, respectively, adjusted to remove endogeneity and serial correlation. CCR produces robust estimates of cointegration relationships, aligning with the study's objective of analyzing the interplay between human development, financial inclusion, and carbon emissions.

Both FMOLS and CCR estimators are ideal for time series data as they are robust to small sample sizes and effectively address issues arising from non-stationary regressors. These methods are instrumental in capturing long-term dynamics and provide reliable inferences for understanding the relationships among human development, financial inclusion, and environmental factors.

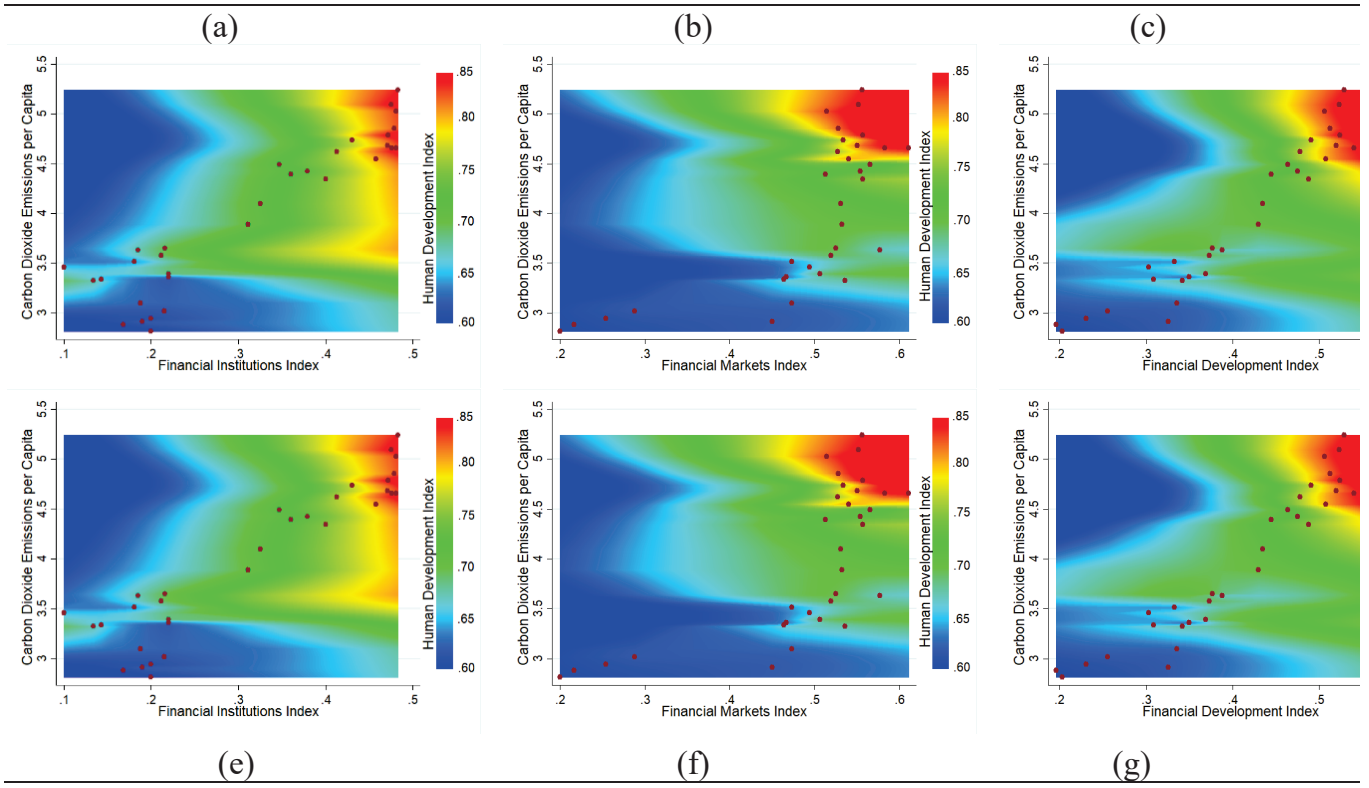
By utilizing these advanced techniques, this study ensures the validity and robustness of its findings, contributing to a deeper understanding of the key drivers of human development in Türkiye.

2.3. Connections between Variables

Figure 1 displays a contour graph illustrating the primary variable of the model. The "twoway contour graph" is a very effective visualization technique that presents data interactions inside a two-dimensional framework. The analysis of three variables, namely "x", "y" and "z" is very advantageous. The graph displays two independent variables, denoted as "x" and "y", typically drawn on the X and Y axes. Additionally, a third variable, represented by "z", is shown using filled contours.

Every individual contour line shown on the graph corresponds to a distinct value of "z" or a range of values, so generating a visual portrayal of the interdependence between "x" and "y" while considering the influence of "z". In Figure 1 "human development"

Figure 1: Pattern among the key variables



serves as the third variable "z" that adds depth to the visualization, allowing us to explore how it varies across different combinations of the two independent variables. This enable us to uncover relationships and patterns that may exist within our data.

Figure 1(a) depicts the potential relationship between income inequality, income, and emissions. When examining the relationship between per capita income and emissions, an Environmental Kuznets Curve (EKC) pattern is observed. In this context, it appears that increasing per capita income may lead to increased carbon emissions, suggesting a positive relationship between both variables and human development.

Figure 1(b) illustrates the relationships between per capita income, FI, and human development. It reveals a positive association between economic growth and FI, as well as a parallel increase in FI and per capita income, contributing to human development.

Figure 1(c) depicts the relationship between FI and human development, considering institutional and market dimensions separately. It suggests that FI is positively correlated with both institutional and market dimensions, and an increase in these dimensions could enhance human development.

Figures 1(e) and (f) separately demonstrate the relationship between FI's institutional and market dimensions and carbon emissions. Both institutional and market dimensions show a positive association with carbon emissions, indicating that an increase in both variables may parallel an increase in human development.

Figure 1(g) highlights a positive relationship between FI and carbon emissions, with an increase in FI paralleling an increase in human development.

2.4. Empirical Findings and Interpretations

Unit root tests are essential in time series analysis as they serve a crucial purpose in evaluating the stationarity of data. The purpose of these tests is to ascertain whether a variable demonstrates the presence of a unit root, which suggests non-stationarity, or if it remains stationary in its original form. The differentiation between various modeling techniques and the extraction of significant insights from time series data heavily rely on this distinction. As a result, unit root tests play a crucial role as a fundamental tool within the realm of time series analysis. Table 2 presents the outcomes of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. These tests are widely employed to evaluate the stationarity of time series data.

Table 3 presents a concise overview of the test results for each variable, both in their level and first differences. Considering the probability values for all

Table 3. ADF and PP Unit Root Test Results

	ADF - Level		ADF -1st diff.		PP -Level		PP -1st diff.		Decision
Variable	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	I(1)
HDI	-0.293	0.9265	-4.674*	0.0001	-0.142	0.9450	-4.729*	0.0001	I(1)
LET	-1.995	0.2887	-5.482*	0.0000	-2.240	0.1919	-5.492*	0.0000	I(1)
EYS	0.453	0.9834	-4.594*	0.0001	0.290	0.9769	-4.652*	0.0001	I(1)
GDP	1.399	0.9971	-4.653*	0.0001	-0.837	0.8080	-4.910*	0.0000	I(1)
FIN	-0.390	0.9118	-6.519*	0.0000	-0.299	0.9257	-6.480*	0.0000	I(1)
FM	-2.793	0.1997	-6.247*	0.0000	0.025	0.9945	-6.268*	0.0000	I(1)
CEM	-1.296	0.6311	-5.036*	0.0000	-1.297	0.6304	-5.018*	0.0000	I(1)

Note: * p<.01, ** p<.05

variables in Table 3, it is evident that the null hypothesis, which proposes the existence of a unit root, cannot be rejected. Therefore, it can be inferred that the series demonstrates non-stationarity at the level. Based on the available evidence, it can be observed that, after taking the first differences in the series, they exhibit stationarity. Consequently, it can be inferred that the series exhibits an integration order of I(1).

Considering the presence of structural breaks in time series analysis, it holds significant importance in ensuring reliable outcomes. Structural breaks are abrupt alterations in the fundamental process of generating data, leading to notable impacts on the stationarity and characteristics of time series data. In order to assess the impact of these modifications and their associated outcomes, it is crucial to employ unit root tests that account for structural breaks, such as the Zivot-Andrews (ZA) test. The results of the ZA unit root test, which considers a structural break in time series data, are presented in Table 4.

Table 4. ZA - Structural Brake Unit Test

Variable	Stat. (Level)	Stat. (1st diff.)	Decision
HDI	-3.534	-5.719 *	I(1)
LET	-1.451	-6.568*	I(1)
EYS	-2.030	-5.679*	I(1)
GDP	-2.819	-6.291*	I(1)
FIN	-3.888	-6.066*	I(1)
FM	-3.126	-8.107*	I(1)
CO2	-2.640	-5.772*	I(1)

Note: *p<.01: (-5.34), ** p<.05: (-4.80)

Table 4 shows the test statistics for each variable at both the level and first difference stages, along with the corresponding decisions. At the level, all variables exhibit non-stationarity (non-rejection of the null hypothesis) with high test statistics. At the first difference level, all variables show statistically significant results with p-values less than 0.01 or 0.05, indicating that differencing the variables once makes them stationary (I(1)).The ZA unit root test results confirm that all variables are integrated of order 1 (I(1)), meaning they become stationary after being differenced once.

Table 5 provides the result of a model selection procedure, specifically the VAR order selection. This procedure helps determine the optimal lag order for the VAR model based on various criteria. The model selection procedure considers lag orders from 0 to 4. At each lag order, It is seen the LL, LR statistic, df, p-value, FPE, AIC, HQIC, and SBIC. The LR statistic compares each higher-order lag model to the previous lower-order lag model. For example, when moving from lag 1 to lag 2, the LR statistic compares the fit of a VAR(2) model to a VAR(1) model. The asterisks (*) next to certain values indicate that these are the selected optimal lag orders based on the specific criterion. It appears that the selected optimal lag order is lag 4 based on the LR statistic, FPE, AIC, HQIC, and SBIC. This

Table 5. Optimal lag-length selection

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	353.51				6.70E-19	-24.8224	-24.7351	-24.5369
1	494.39	281.75	36	0.000	4.00E-22	-32.3133	-31.7024	-30.315
2	540.38	91.989	36	0.000	2.90E-22	-33.0272	-31.8926	-29.316
3	600.70	120.64	36	0.000	1.90E-22	-34.7641	-33.106	-29.3402
4	2130.91	3060.4*	36	0.000	9.7e-67*	-141.493*	-139.312*	-134.356*

means that the VAR(4) model is suggested as the best-fitting model according to these criteria.

As seen in Table 6, the analysis encompassed a range of rank values, spanning from 0 to 5. For each specific rank, the corresponding eigenvalue, trace statistic, and critical value were observed and examined. By comparing the trace statistic to the critical value, we discern the number of cointegrating relationships within the data. Notably, for Rank 4, the trace statistic (13.11) was found to be lower than the critical value (15.41), and this observation is marked with an asterisk (*) denoting statistical significance. Consequently, this indicates the presence of four significant cointegrating relationships among the variables. In essence, the Johansen tests provide compelling evidence for the existence of at least four long-term relationships among the variables, signifying their joint movement over an extended period, with each of these four relationships attaining statistical significance.

Table 7, we examine the cointegration regression estimations employing FMOLS and CCR techniques. The table encapsulates coefficients and their corresponding z-statistics for the variables of the model. Notably, the analysis considers the logarithmic transformations of "Human Development Index (LnHDI), Life Expectancy at Birth (LnLET), Years of Education (LnEYS), GDP per Capita (LnGDP), Financial Inclusion – Institutions Dimension (LnFIN), Financial Inclusion – Markets Dimension (LnFM), and Carbon Dioxide Emissions (LnCO2)". The coefficients and their associated z-statistics unveil the strength and directionality of these relationships.

The FMOLS estimation highlights the significant role of life expectancy (LET) in shaping human development (HDI), with a coefficient of 0.892. This implies that a 1% increase in life expectancy corresponds to

Table 6. Johansen tests for cointegration

Number of obs = 30; Lags = 4

No. of CE(s)	parms	LL	Eigenvalue	Trace Statistic	%5 Critical Value
0	42	502.99	.	136.40	94.15
1	53	526.41	0.790	89.58	68.52
2	62	543.96	0.689	54.47	47.21
3	69	556.02	0.552	30.35	29.68
4	74	564.64	0.437	13.11*	15.41
5	77	569.76	0.288	2.89	3.76

Table 7. Cointegration Regression Estimations

	FMOLS			CCR		
LnHDI	Coef. (z)	Coef. (z)	Coef. (z)	Coef. (z)	Coef. (z)	Coef. (z)
LnLET	0.663***	0.603***	0.892***	0.709***	0.659***	0.875***
	(56.01)	(83.27)	(129.7)	(63.62)	(85.12)	(174.8)
LnEYS	0.280***	0.283***	0.247***	0.267***	0.272***	0.239***
	(95.04)	(207.2)	(232.9)	(98.14)	(223.0)	(279.4)
LnGDP	0.0711***	0.0631***	0.0869***	0.0748***	0.0667***	0.113***
	(34.26)	(63.24)	(106.6)	(36.23)	(68.64)	(113.3)
LnFIN		0.00684***	0.00581***		0.00626***	0.00537***
		(21.90)	(30.03)		(20.12)	(48.49)
LnFM		0.00775***	0.00120***		0.00427***	-0.000240*
		(17.50)	(4.465)		(9.216)	(-1.757)
LnCO2			-0.0406***			-0.0580***
			(-35.08)			(-44.28)
con	-4.599***	-4.259***	-5.593***	-4.802***	-4.509***	-5.734***
	(-96.69)	(-136.0)	(-178.9)	(-112.7)	(-137.8)	(-242.1)

Note: "* p<0.10, ** p<0.05, *** p<0.01 - z statistics in parentheses"

a 0.892% increase in HDI, holding other factors constant. Similarly, expected years of schooling (EYS) exhibit a positive impact, with a coefficient of 0.247, indicating that a 1% increase in educational attainment contributes to a 0.247% increase in HDI. GDP per capita (GDP), with a coefficient of 0.087, suggests that a 1% increase in GDP leads to a 0.087% increase in HDI.

For financial inclusion indicators, the Financial Institutions Index (FIN) has a coefficient of 0.0058, showing that a 1% increase in FIN results in a 0.0058% rise in HDI. Similarly, the Financial Markets Index (FM) has a smaller coefficient of 0.0012, indicating a modest 0.0012% increase in HDI for every 1% increase in FM. On the environmental dimension, carbon dioxide emissions (CO2) exhibit a negative relationship with HDI, with a coefficient of -0.0406. This means that a 1% increase in CO2 emissions leads to a 0.0406% decrease in HDI. This result underscores the environmental costs of economic growth.

The CCR results verify the findings from FMOLS, reinforcing the significant role of life expectancy (LET) and expected years of schooling (EYS) in driving human development. LET has a coefficient of 0.875, suggesting that a 1% increase in life expectancy increases HDI by 0.875%. Similarly, EYS has a coefficient of 0.239. That is, a 1% increase in expected years of schooling contributes to a 0.239% rise in HDI. GDP per capita (GDP) exhibits a stronger relationship in CCR, with a coefficient of 0.113, which implies that a 1% increase in GDP results in a 0.113% increase in HDI.

For financial inclusion, the Financial Institutions Index (FIN) shows a coefficient of 0.0054. This means that a 1% increase in FIN contributes to a 0.0054% rise in HDI. However, the Financial Markets Index (FM), with a near-zero coefficient of -0.0002, suggests a negligible long-term effect on HDI. Regarding environmental sustainability, carbon dioxide emissions (CO2) continue to have a negative impact, with a coefficient of -0.058. This implies that a 1% increase in CO2 emissions decreases HDI by 0.058%, further emphasizing the importance of sustainable development policies.

The results obtained through FMOLS and CCR exhibit a remarkable degree of concurrence in their parameter estimates, demonstrating near-identical values in many cases. Additionally, the signs of these parameter estimates consistently align between both methods. Consequently, the insights gleaned from the CCR analysis appear to corroborate the conclusions drawn from the FMOLS analysis. A summary of these findings, as obtained from both estimators, is presented in Table 8 for reference.

The results from both FMOLS and CCR provide robust evidence of the critical role played by life expectancy, education, and financial inclusion in driving human development in Türkiye. Policies that enhance access to healthcare, improve educational opportunities, and foster financial inclusion can significantly contribute to sustainable human development. Additionally, the findings highlight the importance of addressing environmental challenges, as increased CO2 emissions are consistently associated with declines in HDI. These results underscore the necessity of integrating sustainable environmental policies with economic growth initiatives to achieve long-term development goals.

2.5. Model Validity and Diagnostics

In order to assess the validity of our regression model, a set of diagnostic tests were performed. Table 8 presents a detailed summary of the diagnostic tests and their corresponding results. The tests evaluate many facets of the model, including homoscedasticity, autocorrelation, normality of residuals, potential omission of essential variables, and the existence of multicollinearity. The outcomes of these examinations are of utmost importance in validating the adherence of our model to the requisite assumptions and provide robust estimates.

Table 8. Summary of Estimations

		FMOLS		CCR		Impact on HDI
Human Development	HDI	Sign	Significance	Sign	Significance	
Health	LET	+	√	+	√	Improve
Education	EYS	+	√	+	√	Improve
Production	GDP	+	√	+	√	Improve
Financial Institutions	FIN	+	√	+	√	Improve
Financial Markets	FM	+	√	+	~	Improve
Carbon Footprint	CO2	-	√	-	√	Distort

Table 9. Diagnostics for Model Validity

Test	Hypothesis	Statistics	Prob.
Breusch-Pagan/Cook-Weisberg	"H_0: constant variance"	$\chi2 = 2.69$	0.101
Breusch-Godfrey LM test	"H_0: no serial correlation"	$\chi2 = 2.22$	0.136
Jarque-Bera test	"H_0: res. norm. distributed (all)"	$\chi2 = 3.48$	0.176
Ramsey test	"H_0: model has no omitted variables"	$F = 1.50$	0.239
Mean VIF	"multicollinearity"	3.44	-

Table 9 presents the findings of the analysis pertaining to homoscedasticity, autocorrelation, normality of residuals, potential omission of key variables, and the existence of multicollinearity. The outcomes of these tests, as presented in Table 9, hold significant significance in validating the conformity of our model with the requisite assumptions, selecting the suitable estimation technique, and attaining dependable outcomes.

The Breusch-Pagan/Cook-Weisberg test determines whether the variance of the model's errors is constant. Since the p-value (0.101) is greater than the significance threshold of 0.05, the test does not provide convincing evidence against the assumption of constant variance. Therefore, the null hypothesis cannot be rejected, suggesting constant variance assumption holds.

The Breusch-Godfrey (LM) test is used to determine whether model residuals exhibit serial correlation. Since the p-value (0.136) is greater than the significance threshold of 0.05, the test does not provide strong evidence of serial correlation. Consequently, the null hypothesis of no serial correlation is not rejected. We may interfer that the residuals of the model do not demonstrate significant autocorrelation.

The Jarque-Bera test evaluates the model's residuals' normality. Since the p-value (0.176) is greater than the significance level of 0.05. Therefore, the null hypothesis of normality cannot be rejected, indicating that a normal distribution approximates the residuals reasonably well

The Ramsey test evaluates whether the model has omitted relevant variables. In this case, the test does not provide strong evidence that important variables have been omitted since the p-value (0.239) exceeds the significance level of 0.05. Consequently, the null hypothesis of no omitted variables is not rejected, implying that the model is adequately specified.

The Mean VIF assesses the presence of multicollinearity among predictor variables. A Mean VIF value of 3.44 suggests that multicollinearity may be present, but it does not necessarily indicate a severe issue. Typically, VIF values above 10 are a cause for concern.

In summary, the model validity and diagnostics tests collectively suggest that the regression model's assumptions are reasonably met

Conclusion

In this comprehensive study, we delved into the intricate nexus between financial inclusion, carbon footprint, and human development, with a specific focus on the unique context of Türkiye. We leveraged the benefits of FMOLS and CCR in our time series analysis. FMOLS is an estimator that is robust to common time series challenges such as endogeneity, heteroscedasticity, and serial correlation. It was preferred due to its competence in capturing long-term relationships and its ability to understand the permanent effects of variables over time. On the other hand, CCR was successful in cointegration analysis and provided insights into the equilibrium relationships between variables in the long run. Its robustness in detecting cointegration relationships and the interpretability of coefficients have increased our understanding of economic results. In this context, FMOLS and CCR methods have created a solid econometric framework that also contributes to the reliability and depth of our findings.

The results from FMOLS indicate that financial inclusion has a positive effect on human development within the framework of financial institutions and markets. It underscores the significance of including financial inclusion in defining Türkiye's human development. It implies that implementing measures that promote financial accessibility and stability might provide favorable outcomes in the long run. Furthermore, the model incorporates other factors such as life expectancy, health indicators, education levels, and per capita output, which seem to positively influence long-term human growth. Furthermore, the study emphasizes the significant impact of the environmental aspect. The FMOLS analysis uncovers a negative association between carbon dioxide emissions and human development. This finding underscores the significance of implementing sustainable environmental

policies in Türkiye's human development.

The FMOLS findings are corroborated by the CCR estimate results. Consequently, it demonstrates that health, education, per capita productivity, financial institutions, and markets have an impact on human development. Conversely, the findings of the CCR analysis demonstrate a substantial inverse association between carbon emissions and human development, underscoring the crucial role of environmental policy in fostering human resource development. Comprehensive, sustainable development strategies that prioritize ecological considerations alongside economic growth are crucial in Türkiye, as indicated by the negative coefficient.

These findings, consistent with existing literature, bear profound significance for policymakers, economists, environmentalists, and development practitioners. They emphasize the need for holistic policy frameworks that champion financial inclusion, human development, and environmental sustainability. The implications ripple beyond Türkiye's borders, resonating with global efforts to achieve the Sustainable Development Goals (SDGs) and combat climate change. In this regards, our study invites further research and discourse in this multifaceted field. The issues addressed in this research, from FI and carbon emissions to human development, are global in scope. As we navigate the complex challenges of the 21st century, our findings call for innovative policy solutions, sustainable development initiatives, and environmental conservation efforts. They underscore the importance of pursuing economic growth and human development within the framework of environmental responsibility.

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