Female Labor Force Participation and Sustainable Development: A Global Study

Chulan Lasantha Kukule Nawarathna

Department of Social Statistics, University of Sri Jayewardenepura, Sri Lanka.

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ABSTRACT

Low female labor force participation is a critical global issue, and the global agenda is achieving sustainable development. This study explores the impact of female labor force participation on economic, social, and environmental development, which are the three main pillars of sustainable development. To measure these pillars, the study uses indicators such as per capita Gross Domestic Product (GDP), the United Nations' Human Development Index (HDI), and carbon dioxide (CO2) emissions per capita. The primary variable of interest is the female labor force participation rate (FLFPR), with additional variables including total population (POP), per capita energy consumption (ENG), and the male labor force participation rate (MLFPR), which serve as both study and control variables. The research is conducted using data from a global panel of 118 countries spanning from 1990 to 2019. To effectively handle cross-sectional dependence and heterogeneity, second-generation panel data methods are employed. The Driscoll-Kraay robust standard error regression is utilized to estimate both the linear and nonlinear effects of female labor force participation on economic, social, and environmental development. Furthermore, the Dumitrescu–Hurlin causality test is applied to identify short-run causal relationships among the study variables. Empirical findings indicate that an increase in female labor force participation leads to enhancements in per capita GDP and HDI while contributing to a reduction in CO2 emissions globally. The relationship between female labor force participation and per capita GDP is found to be U-shaped, whereas its relationship with HDI and CO2 emissions is inverse U-shaped. These results underscore that higher female labor force participation significantly boosts economic, social, and environmental development worldwide, highlighting the importance for policymakers to foster sustainable development by maximizing the advantages of female labor force participation on a global scale.

Keywords: Female Labor Force Participation, Sustainable Development, Panel Data Analysis, per capita GDP, HDI, per capita CO2 emissions.

BACKGROUND OF THE STUDY

Sustainability represents a progressive mindset that harmonizes environmental, social, and economic dimensions to enhance the quality of life (UNESCO, n.d) It is built on three primary pillars: economic sustainability, which aims to alleviate extreme poverty and ensure fair, equitable job opportunities for all; environmental sustainability, which seeks to preserve the planet's natural balance while minimizing the ecological impact of human actions; and social sustainability, which emphasizes the importance of providing equal access to essential resources and services for every individual.

Sustainable development emphasizes economic efficiency, ecological sustainability, and social equity, aiming to meet present needs without compromising future generations' ability to do the same. In 2015, the United Nations (U.N.), the largest global intergovernmental organization, adopted the 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs) (Turra & Fernandes, 2020). This ambitious agenda provides a universal framework to eliminate extreme poverty, protect the planet, and promote peace and prosperity worldwide by 2030 for all 193 U.N. member states. Building on the pivotal Millennium Development Goals, the 17 SDGs and their 169 interconnected targets adopt a people-centered, rights-based perspective, presenting a holistic development vision that effectively integrates sustainability's economic, social, and environmental dimensions. (Turra & Fernandes, 2020).

We are facing unprecedented population growth, potentially reaching 11 billion by 2100 (United Nations Department of Economic and Social Affairs [UN DESA], 2019), challenging the Sustainable Development Goals (SDGs). Demographic shifts influence economic cycles through changes in the working-age population. Initially, a growing labor force boosts economic opportunities and income, known as the first demographic dividend. Later, an ageing population benefits from past investments, maintaining advantages as the second demographic dividend. Robust labor force participation is essential to maximize these benefits. Asset accumulation by ageing populations contributes to national income. The transition from the first to the second dividend can be prolonged, highlighting the working-age population's role in economic resources. The impact depends on resource utilization—addressing immediate needs, investing in education and healthcare, or saving for future ventures. The demographic dividend also offers social benefits, emphasizing the working-age population's role in shaping future outcomes. As high-fertility generations enter the workforce, the labor supply grows. Having fewer children, women are more active in the workforce, often with better education, enhancing productivity. Effective government policies are crucial to harness this shift by creating jobs; otherwise, unemployment and social unrest may result. A larger working-age population boosts personal and national savings, essential for industrial investment and economic growth. Individuals from high-fertility periods increase savings potential, fostering economic expansion. Fewer children improve women's health and workforce participation, enhancing social status and family contributions. Strategic management of labor supply, savings, and human capital can help nations leverage the demographic dividend for sustainable growth, a priority for policymakers and researchers. The demographic dividend offers economic growth opportunities but relies heavily on strong labor force participation, including working-age individuals employed or seeking work. A high participation rate is vital for economic development and realizing demographic dividends. Despite expectations for gender balance, female participation remains low globally. Increasing female labor force participation is crucial for leveraging the demographic dividend and achieving sustainable development goals (UN, 2015; UN DESA, 2019; Turra & Fernandes, 2020). Policies should include young adults, women, and capable older individuals in the workforce. Measures might involve raising the retirement age, adjusting pension benefits, allowing more part-time work to attract women and older workers, addressing gaps in knowledge, and supporting sustainable development.

Global Trends of Labor Force Participation

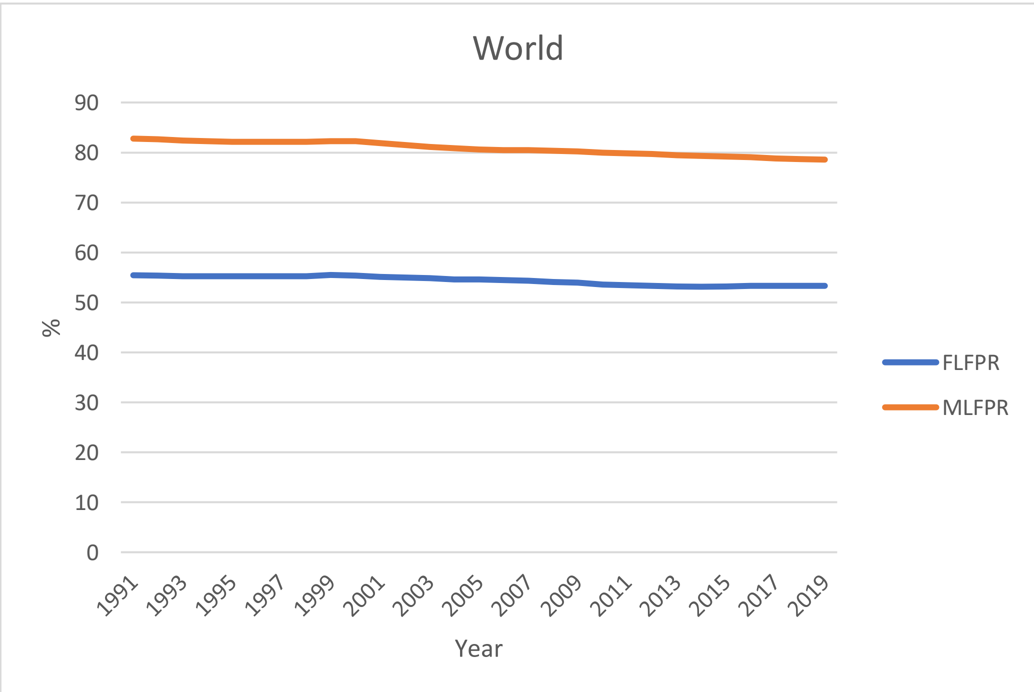

Figure 01: Male Labor Force Participation Rate (MLFPR) and Female Labor Force Participation Rate (FLFPR) at the Global

Source: Created by the author based on World Bank data.

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Figure 01 presents the worldwide distribution of the Female Labor Force Participation Rate (FLFPR) and the Male Labor Force Participation Rate (MLFPR) from 1991 to 2019. Ongoing trends in labor force participation underscore the enduring gender gap, illustrating the persistent differences between female and male participation rates globally. Participation in the labor force is vital for economic development, social progress, and demographic changes. Examining global labor force participation trends uncovers notable disparities related to gender, economic development stages, and global economic changes.

Labor Force Participation

Global labor force trends indicate ongoing gender disparities and shifts in demographics. Economic growth by itself cannot create gender equality or sustainable workforce development. To tackle these issues, we need targeted policies, societal reforms, and inclusive strategies that promote fair participation (International Labor Organization [ILO], 2022; World Bank, 2019). The intricacies of these trends cover demographic changes, economic structures, and policy frameworks. While some advances have been made, notable gender gaps and decreasing participation rates remain. A comprehensive approach incorporating gender-sensitive policies, education, skills development, and economic reforms is essential (OECD, 2021; United Nations [UN], 2023). Without proactive initiatives, labor markets will persist in reflecting deep-rooted inequalities and will overlook economic opportunities. (McKinsey Global Institute, 2020).

Female Labor Force Participation and Economic Development

Economic development aims to enhance living standards by increasing national income or GDP. Achieving sustainable growth presents a global challenge, necessitating policies that promote various forms of economic expansion. A significant working-age population can drive growth, whereas a higher ratio of children may impede it (Bloom & Canning, 2001). Therefore, policies must focus on creating job opportunities, especially for women (Lee & Mason, 2019). Despite progress in gender equality, global female labor force participation (FLFP) remains low, exhibiting a U-shaped relationship with GDP (Lechman, 2014; Roy, 2018). Raising FLFP can stimulate economic growth (Na-Chiengmai, 2018; Baerlocher et al., 2021), but it could also slow development in regions such as Pakistan (Khaliq et al., 2017). FLFP influences the UN's Sustainable Development Goals by facilitating economic, social, and environmental sustainability (Foster, 2016; Balakrishnan & Dharmaraj, 2018). Policymakers frequently emphasize socio-economic aspects over age structures to enhance FLFP.

Female Labor Force Participation and Social Development

Human development is crucial in evaluating a nation's social progress, as measured by the Human Development Index (HDI). This index assesses life expectancy, education, and income, established by the UNDP in 1990 (United Nations Development Program [UNDP], 1990). HDI is based on Amartya Sen's "capabilities approach." Despite criticism for not adequately addressing gender inequality and environmental concerns, HDI continues to serve as a significant socioeconomic indicator (Sen, 1999). The growth of the global population and changes in fertility and mortality rates influence labor growth and economic development. Countries experiencing advanced demographic dividend phases typically demonstrate higher HDI levels, shaped by the size of their working-age population. However, female labor force participation (FLFP) remains disproportionately low worldwide. Implementing effective policies is essential to maximizing demographic dividends and enhancing FLFP, which can contribute to economic growth, reduce gender inequality, and improve overall societal welfare. Promoting gender equality is vital in fostering economic growth in countries with higher HDI (OECD, 2019; UNDP, 2020). Furthermore, HDI illustrates sustainable development by encompassing health, human capital, and economic factors, while increasing FLFP can further advance the UN's Sustainable Development Goals, which focus on economic, social, and environmental considerations (World Bank, 2012; International Labor Organization [ILO], 2017).

Female Labor Force Participation and Environmental Development

Climate change presents a significant global challenge, primarily driven by human-generated CO2 and various greenhouse gases. Reducing CO2 emissions is crucial, as they accounted for 75% of total emissions in 2016 (Intergovernmental Panel on Climate Change [IPCC], 2022). Key factors influencing CO2 levels include technology, wealth, energy consumption, economics, and demographics (York et al., 2003). Research indicates that population growth has a more substantial impact on CO2 emissions than wealth alone. Increasing female labor force participation (FLFP) is essential for economic growth and gender equality. It boosts productivity and aligns with the UN Sustainable Development Goals, including poverty alleviation and quality education (United Nations [UN], 2015; World Bank, 2020). This study examines the global implications of FLFP on CO2 emissions, employing the expanded STIRPAT model to assess the environmental effects of gender-specific labor participation while considering links to population, wealth, energy, and gender-related labor rates (Dietz & Rosa, 1997; Shi, 2003).

Research Problem

Despite having equal numbers of working-age men and women, global female labor force participation (FLFP) remains notably low. Enhancing FLFP is vital for unlocking socio-economic and environmental benefits from demographic dividends and achieving Sustainable Development Goals such as eradicating poverty and hunger, advancing health and well-being, promoting education and gender equality, reducing inequality, ensuring sustainable consumption, driving climate action, and fostering peace. Sustainable development requires the integration of economic, social, and environmental progress. Although many studies link FLFP to economic growth, fewer explore its social and environmental impacts. This study examines these aspects simultaneously to gain deeper insights into global sustainable development. Understanding the connection between FLFP, social growth, economic development, and environmental progress is crucial for formulating effective policies. While several factors influencing FLFP have been explored, its overall impact on sustainable development is less understood. Assessing FLFP's effects on the pillars of sustainability will provide valuable insights for policies designed to maintain optimal FLFP levels to foster sustainable development.

Research Question

How does female labor force participation influence sustainable development globally?

Research Objectives

Main Objective

Identify the link between female labor force participation and global sustainable development.

Specific Objectives

To identify the connection between female labor force participation and global economic development.

To identify the link between female labor force participation and global social development.

To identify the connection between female labor force participation and environmental development on a global scale.

Significance of the Study

The United Nations underscores the importance of women's active involvement in achieving the 2030 Sustainable Development Goals. Various factors, including demographics and cultural influences, impact a country's Female Labor Force Participation (FLFP). Enhancing FLFP is essential for maximizing workforce resources and achieving sustainable development objectives. This study explores FLFP's significance in sustainable development, analyzing its effects on economic, social, and environmental dimensions worldwide from 1991 to 2018. It reveals the intricate relationships among FLFP, social advancement, economic prosperity, and environmental sustainability, offering insights for innovative policymaking. The research highlights the variability of FLFP's effects on the pillars of sustainable development, which aids in formulating effective policies. It also examines the connection between FLFP and economic and human development, comprehensively understanding its diverse influences for policymakers.

Finally, the research examines the global environmental implications of FLFP. The study addresses cross-sectional dependence in panel data analysis by applying various econometric techniques, including CADF and CIPS unit root tests, LM bootstrap cointegration tests, Driscoll-Kraay robust standard error regression, and the Dumitrescu-Hurlin causality test. These robust methodologies provide dependable insights into the relationship between FLFP and environmental development, aiding countries in understanding and tackling this critical aspect of sustainable development.

Methodological Overview

This study uses a global panel and advanced econometric techniques for panel data analysis to ensure robust findings. These methods address biases from unobserved heterogeneity, non-stationarity, and dynamic relationships. Comprehensive diagnostics validate model assumptions, enhancing credibility. The research establishes a strong foundation for understanding data dynamics and causal relationships by accounting for heterogeneity, cross-sectional dependence, and autocorrelation, ensuring accurate outcomes.

The research employs pretests, including slope homogeneity tests, cross-sectional dependence (CD) tests, CADF and CIPS unit root tests, and error-correction-based panel cointegration tests. For estimation, it adopts Driscoll and Kraay standard errors for coefficients assessed via pooled OLS and Newey-West standard errors for OLS regression in linear cross-sectional time series models. Additionally, the Dumitrescu-Hurlin panel individual causality estimation test is utilized to uncover causal relationships, enhancing the analysis.

LITERATURE REVIEW

In 2015, the United Nations launched the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs), establishing a global framework to eradicate extreme poverty and combat inequality. Building upon the Millennium Development Goals, the 17 SDGs and 169 targets emphasize a people-centered, rights-based approach that integrates economic, social, and environmental dimensions of development (Turra & Fernandes, 2020). Goals 1 and 2 focus on eradicating poverty and hunger, yet poverty is rising in regions vulnerable to droughts and climate change (UN, 2015). Goals 6, 7, and 8 target universal access to clean water, sanitation, energy, and employment, addressing areas with significant resource gaps. Goal 12 highlights sustainable consumption and production, which growing populations and resource demands. Climate change intensifies these challenges. Goal 9 aims for resilient infrastructure, while Goal 11 seeks safe, sustainable cities.(Benjamin Hunter, 2015). Population dynamics present opportunities, as declining fertility rates and slower growth can lead to a demographic bonus, enhancing economic and social development (Turra & Fernandes, 2020).

The United Nations' sustainable development goals aim to protect the planet and ensure peace and prosperity for all (Gavin, 2019). These goals have notably improved women's quality of life, particularly in health and education(Osundina, 2020). Addressing demographic transitions during the SDG period requires forward-thinking policies considering population dynamics. Progress towards these goals is closely tied to population trends, influencing countries' ability to provide social protection like pensions and healthcare. Effective policies must consider population numbers, locations, and age structures. Thus, the success of the 2030 Agenda is linked to anticipating and addressing demographic changes during the SDG period(Turra & Fernandes, 2020).

Countries in Asia and the Pacific have experienced notable economic growth and human development, which are closely linked to demographic stability. Implementing shared development policies that align demographic trends with economic, human, and environmental objectives is vital; however, the region's diversity necessitates customized strategies. (Gavin, 2019). UN (2015) emphasize the connections between Nepal's demographic dividend, digital economy, and sustainable development. Although Nepal is primarily an agricultural nation, methane emissions significantly contribute to its greenhouse gas levels, highlighting the need for innovative resource efficiency policies. Approaches such as green bonds and a robust national digital strategy can connect the digital and green economies, thereby maximizing demographic dividends. With a declining dependency ratio, increasing life expectancy, and a growing workforce, Nepal can leverage its demographic advantage through strategic public policies.

Population dynamics, climate change, and conflict will increasingly affect communities throughout the 21st century. Achieving sustainable development requires urgent expansion of family planning and support for sexual and reproductive health rights. Migration and urbanization need policies and investment in resilient infrastructure, public services, and employment. Investing in girls' education fosters gender equality and empowers women. Universal access to secondary education is crucial for the demographic dividend as it is linked to delayed marriage, reproductive autonomy, economic productivity, and better health outcomes. Combined with family planning, girls' education promotes gender equality and sustainable development(Benjamin Hunter, 2015). Sustainable development relies on investing in economic, human, and environmental capital. Women's contributions to economic growth, social improvement, and environmental protection are undervalued. Utilizing the female population effectively can boost economic growth, reduce poverty, enhance societal well-being, and support sustainable development globally. Addressing the gender gap requires government policies that take gender dimensions into account. Closing the gender gap in labor market participation is essential for achieving the United Nations' Sustainable Development Goals by 2030. Despite increased higher education and lower birth rates in Iran, female labor force participation (FLFP) remains stagnant (Benjamin Hunter, 2015).t. This stagnation highlights demand-side issues, such as occupational discrimination, rather than supply-side factors (Taheri E, Güven Lisaniler F, Payaslioğlu C, 2021).. Banerjee M. (2019) emphasizes that gender inequality is not only a moral and social issue but also an economic challenge, as the global economy suffers if women, who make up half of the working-age population, do not reach their economic potential.

Discussing women's work issues involves multiple dimensions with no easy solutions, varying across regions and countries. While Latin American countries do not hinder gender equality in the workforce, cultural norms around caregiving roles, household duties, and discrimination create obstacles. Key barriers include inadequate education, training, and time constraints, impacting vulnerable groups. The new Sustainable Development Goals (SDGs) have increased awareness of women's economic empowerment, and early actions to reduce workforce constraints can aid in achieving these goals(Beneke de Sanfeliú et al., 2016).

Additionally, the United Nations Population Fund highlights that achieving sustainable development is contingent on ensuring that all women and men, as well as girls and boys, can exercise their dignity and human rights to enhance their abilities, access reproductive health and rights, secure suitable employment, and contribute to economic growth (UNFPA, n.d.). To foster this future, emerging policies and resources necessitate that governments understand the current and projected demographics in terms of size, gender, location, and age distribution. Countries poised for the most significant demographic growth must prioritize health, quality education, and employment opportunities for their working-age populations while reducing rates of youth addiction. A larger number of minors in a household leads to increased resources per child, greater autonomy for women joining the workforce, and enhanced savings for retirement. Consequently, the national economic advantages can be considerable.

METHODOLOGY

Study population of the Study

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118 of the 193 countries worldwide were chosen for the study due to the availability of relevant data on the study variables from 1990 to 2019.

Methods of Data Collection

This empirical study separately examines the impact of female labor force participation (FLFP) on sustainable development's economic, social, and environmental pillars and identifies the connections among these variables. In this study, economic development, social development, and ecological development are measured by the indicator variables Gross Domestic Product per capita (GDP), Human Development Index (HDI), and Carbon Dioxide emissions per capita (CO2), respectively. Other variables in the study include the Female Labor Force Participation Rate (FLFPR), Male Labor Force Participation Rate (MLFPR), total mid-year population (POP), and energy consumption per capita (ENG). This study is based on secondary data published by standard databases. Table 01 presents the data sources and other relevant information.

Table 01: Data (Main Variables) to be Considered for the Study and Data Sources

Label	Variable	Definition	Unit	Source
GDP	Gross Domestic Product (per capita)	Metrics of human demand on ecosystems	Constant 2015 US$	WDI (2022)
CO2	Carbon dioxide emission (per capita)	Carbon dioxide emissions stem from the burning of fossil fuels and the manufacture of cement.	Metric tons	WDI (2022)
HDI	Human Development Index	The Human Development Index (UNDP) is a summary measure of key dimensions of human development: A long, healthy life, good education, and decent living standard.	Index	Human Development Data (1990-2019). United Nations Development Programme 2020. https://hdr.undp.org/en/data
FLFPR	Female Labor Force Participation Rate	The female labor force participation rate is % of the female population ages 15-64. (modeled ILO estimate)	%	WDI (2022)
MLFPR	Male Labor Force Participation Rate	The male labor force participation rate is % of the male population ages 15-64. (modeled ILO estimate)	%	WDI (2022)
ENG	Energy use (per capita 2020)	Energy use refers to primary energy before transformation to other end-use fuels.	KWh	Our World in Data based on B.P. & Shift Data Portal (2022)
POP	Total mid-year population	Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. The values shown are mid-year estimates.	count	WDI (12/22/2022)

Source: Created by the author

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Data Analysis

The analysis begins with a descriptive statistical evaluation of the data, leading to a correlation analysis that identifies relationships among the variables. Following these initial evaluations, the study estimates the general forms of empirical equations using the panel estimation process outlined in the estimation strategy, aiming to fulfill both the overall objective and specific goals.

The empirical model of the specific objective 1 (Economic Model):

$$GDP = f(POP, ENG, HDI, FLFPR, MLFPR) \quad (1.1)$$

$$GDP = f(POP, ENG, HDI, FLFPR, FLFPR^2, MLFPR) \quad (1.2)$$

The empirical model of the specific objective 2(Social Model):

$$HDI = f(POP, GDP, ENG, FLFPR, MLFPR) \quad (2.1)$$

$$HDI = f(POP, GDP, ENG, FLFPR, FLFPR^2, MLFPR) \quad (2.2)$$

The empirical model of the specific objective 3(Environmental Model):

$$CO2 = f(POP, GDP, ENG, FLPFR, MLFPR) \quad (3.1)$$

$$CO2 = f(POP, GDP, ENG, FLPFR, FLFPR^2, MLFPR) \quad (3.2)$$

Estimation Strategy

This study employs a panel data analysis approach to address heterogeneity, cross-sectional dependence, and autocorrelation, resulting in more reliable findings. It conducts pretests, including tests for slope homogeneity, cross-sectional dependence (CD), CADF and CIPS unit root tests, and error-correction-based panel cointegration tests. The panel estimation techniques include Driscoll and Kraay standard errors for coefficients assessed through pooled OLS and Newey-West standard errors for OLS regression in linear cross-sectional time series models. Additionally, the Dumitrescu-Hurlin Panel test is employed to determine causal relationships.

Slope Homogeneity Tests

P. A. V. B. Swamy, (1970) Developed the framework to find if the slope coefficients of the cointegration equation are homogeneous. (Hashem Pesaran & Yamagata, 2008) improved Swamy's slope homogeneity test and formed two "**delta**" test statistics; $\tilde{\Delta}$ and $\tilde{\Delta}_{adj}$.

$$\tilde{\Delta} = \sqrt{N}\left(\frac{N^{-1}\bar{S}-k}{\sqrt{2k}}\right) \sim X_k^2 \quad (8)$$

$$\tilde{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\bar{S}-k}{v\sqrt{Tk}}\right) \sim N(0,1) \quad (9)$$

N symbolizes the number of cross-section units, **S** symbolizes the Swamy test statistic, and **k** symbolizes independent variables. The standard delta test requires errors not to be autocorrelated. However, a Heteroscedasticity and Autocorrelation Consistent (HAC) robust version of the slope homogeneity test has been developed to relax the assumptions of homoscedasticity and serial independence. If the p-value of the test is less than 5%, the cointegrating coefficients are considered non-homogenous. $\tilde{\Delta}$ and $\tilde{\Delta}_{adj}$ are fit for large and small samples, respectively, where $\tilde{\Delta}_{adj}$ Is the "mean-variance bias adjusted" version of $\tilde{\Delta}$. Therefore, the delta test ($\tilde{\Delta}$) wants the error not to be autocorrelated. (Hashem Pesaran & Yamagata, 2008), (Blomquist & Westerlund, 2013) developed a Heteroscedasticity and Autocorrelation Consistent (HAC) robust version of

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the slope homogeneity test By soothing the assumptions of homoscedasticity and serial independence ;

Δ_{HAC} and $(\Delta_{HAC})_{adj}$:

$$\Delta_{HAC}= \sqrt{N}\ \left(\frac{N^{-1}\,\bar{S}_{HAC}-k}{\sqrt{2k}}\right) \sim X_k^2 \qquad (10)$$

$$\tilde{\Delta}_{adj}= \sqrt{N}\ \left(\frac{N^{-1}\,\bar{S}_{HAC}-k}{v\,\sqrt{Tk}}\right) \sim N(0,1) \qquad (11)$$

Cross-sectional Dependence Tests

Cross-sectional dependence commonly exists in panel data because the countries are interlinked at the regional and global levels. If studies do not control for the cross-sectional dependence, the estimators will be inconsistent and biased (Peter C. Philllips and Donggyu Sul, 2003). Therefore, examining the cross-sectional dependence in the panel data is essential.

In doing so, this study uses three different tests to detect cross-sectional dependency among the selected variables. (N. Bailey, G. Kapetanios, 2015) along with (Bailey et al., 2019)), (Chudik & Pesaran, 2015), and (Pesaran, 2004) CD tests are estimated to examine the presence of cross-sectional dependence in residuals of the estimable model.

The following equation of the Bailey, Kapetanios, and Pesaran Cross-Sectional Dependence test is used to examine the study variables:

$$CD_{BKP} = \sqrt{\frac{TN(N-1)}{2}\ \hat{\bar{\rho}}N} \qquad (12)$$

Also, the following equation of the CD test is used for examining the cross-sectional dependence suggested by (Pesaran, 2004):

$$CD = \sqrt{\frac{2T}{N(N-1)}}\ \left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\rho_{ij}\right) \qquad (13)$$

Where N represents the sample size, T indicates the period and ρ_{ij} It shows the estimate of the cross-sectional correlation of errors in countries i and j.

Panel Unit Root Tests

The first-generation unit root results are ineffective in cross-sectional dependence (Dogan & Seker, 2016). Therefore, this study employs the augmented cross-sectional IPS (CIPS) and augmented cross-sectional ADF (CADF) approaches to investigate the variables' stationarity properties. Moreover, the reliability of the results increases when suitable unit root tests are used, with the existence of cross-sectional dependence within panel data. (Pesaran, 2007) suggested the following equation of the IPS cross-section augmented version test the unit root:

$$\Delta x_{it} = \alpha_{it} + \beta x_{it-1} + \rho_i T + \sum_{j=1}^{n}\theta_{ij}\,\Delta x_{i,t-j} + \varepsilon_{it} \qquad (14)$$

Where Δ represents the difference operator, x_{it} Shows the analyzed variable, α is an individual intercept, T denotes the time trend in the data, and ε_{it} The error term is the Schwarz information criterion (SIC) method, which determines the lag length. For both tests, the null hypothesis is that all individuals are not stationary within time series panel data, and the alternative hypothesis is that at least one individual is stationary within time series panel data.

Panel Cointegration Test

This study employs the Westerlund cointegration test to observe the long-run equilibrium among the model variables. (Westerlund, 2007) suggests four basic panel cointegration tests based on structural dynamics, thus not imposing any standard factor limitation. The importance of the error-correction term is analyzed using a restricted panel error correction model, with bootstrapped p-values demonstrating resilience against cross-sectional dependence. Westerlund's cointegration test employs two methods to test the alternative hypothesis of cointegration for the entire panel (Gt and Ga). In contrast, the other two methods consider the alternative that at least one cross-sectional unit is cointegrated (Pt and Pa). The first two methods are referred to as group statistics, while the latter are called panel statistics. When estimating group-mean statistics, the error-correction constants of each cross-sectional unit are evaluated independently, leading to the examination of average statistics. The null hypothesis in this approach can be stated as "there is no error correction." However, if the null hypothesis is rejected, it indicates evidence of cointegration among the variables.

Westerlund considers the following error correction model:

$$\Delta Y_{it} = \delta_i' d_t + \alpha_i Y_{i,t-1} + \lambda_i' X_{i,t-1} + \sum_{j=1}^{pi} \alpha_{ij} \, \Delta Y_{i,t-1} + \sum_{j=-qi}^{pi} \gamma_{i,j} \, \Delta X_{i,t-1} + \varepsilon_{it} \qquad (15)$$

Where *i* represents the cross-sections, t represents observations, d_t refers to the deterministic components and computes the convergence speed to the equilibrium state after an unexpected shock.

Panel Long-run Estimation Method

Efficient and robust estimation with due care of autocorrelation, heteroscedasticity, and cross-sectional dependence is necessary because, with their presence, the standard fixed effect model may not generate unbiased and efficient outcomes. (Z. Wang et al., 2021) emphasized that the existence of cross-sectional dependence makes the estimated results from conventional methods such as FMOLS and DOLS no longer accurate or unreliable. Therefore, the study uses (Driscoll & Kraay, 1998) standard error technique following the methodology of (Z. Wang et al., 2021) to estimate long-run coefficients in this study as the studies of (Kongbuamai et al., 2020), (Baloch et al., 2019); (Hashemizadeh et al., 2021) and (Rahman & Alam, 2022). This sophisticated method addresses all the problems of autocorrelation, heteroscedasticity, and cross-sectional dependence in the estimated model. Compared to many other methods, (Driscoll & Kraay, 1998) standard error technique provides various additional benefits: firstly, this can be adopted in the case of unbalanced panel data; secondly, this approach can be used in the case of missing values of the dataset; thirdly, it is a non-parametric procedure having flexible features and greater time dimension; finally, and most importantly, this approach can accurately cure about heteroscedasticity, autocorrelation, and cross-sectional dependence issues ((Hoechle, 2007); (Rahman & Alam, 2022); (Z. Wang et al., 2021); (Kongbuamai et al., 2020); (Baloch et al., 2019)).

After the estimation of Driscoll and Kraay's (1998) standard error technique, the robustness of the findings is to be checked through another well-known panel standard error estimating technique. The Newey-West standard errors regression (Newey & West, 2010) performs according to the methodology of (Z. Wang et al., 2021), and the model also addresses the issues of autocorrelation, heteroscedasticity, and cross-sectional dependence in the models efficiently and effectively.

Dumitrescu and Hurlin panel causality test

Long-run estimation methods reveal relationships between variables, but understanding short-run causality is crucial for policymaking. To address this, the study uses the (Dumitrescu & Hurlin, 2012) causality test accounts for unobserved heterogeneity through a VAR framework on stationary data. This modified Granger causality test, is suitable for both $T > N$ and $T < N$ scenarios and runs separate regressions for each cross-section to identify causal relationships.

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ANALYSIS

Descriptive Statistics of Study Variables

The global panel dataset includes seven variables and covers 118 countries over 30 years from 1990 to 2019. Table 2 presents descriptive statistics for the seven variables.

Table 2 - Descriptive statistics

Global Panel					
Variable	Obs	Mean	Std. Dev.	Min	Max
LGDP	3540	3.674	0.633	2.264	5.051
LCO2	3540	3.247	0.686	1.309	4.502
LPOP	3540	7.029	0.75	4.978	9.149
LENG	3540	3.984	0.68	2.166	5.337
LHDI	3540	1.803	0.124	1.299	1.981
LFLFPR	3540	1.713	0.18	.797	1.963
LMLFPR	3540	1.896	0.042	1.689	1.98

Authors Calculations

Empirical Results and Discussion

The global panel underwent the Pesaran and Yamagata slope homogeneity test. According to Table No. 4, the null hypothesis is "Homogeneous slope coefficients." Delta estimates are significant at the 1% level in each study model. The panel nations are heterogeneous, and this study employs heterogeneous panel approaches to address the heterogeneous slope problem.

Table 3 – Results of the Slope homogeneity tests.

Test Statistic	Global Panel (Economic)	Global Panel (Social)	Global Panel (Environmental)
$\bar{\Delta}$	70.215[a]	64.423[a]	50.404a
$\bar{\Delta}adj$	80.192[a]	73.577[a]	57.565a
Δ_{HAC}	54.066[a]	62.064[a]	57.091a
$(\Delta_{HAC})_{adj}$	61.747[a]	70.882[a]	65.202a

H_0: slope coefficients are homogenous. [a] represents statistical significance at 1%.

$\bar{\Delta}$ and $\bar{\Delta}$adj represent the "simple" and "mean-variance bias adjusted" slope homogeneity tests, respectively (Pesaran, Yamagata. 2008. Journal of Econometrics).

Δ_{HAC} and $(\Delta_{HAC})_{adj}$ represent the "Heteroscedasticity and Autocorrelation Consistent" versions of "simple" and "mean-variance bias adjusted" slope homogeneity tests, respectively (Blomquist, Westerlund. 2013. Economic Letters).

“a “p<.01, “b “p<.05, “c “p<.1

Authors Calculations

Tables 4, 5, and 6 provide the findings of the cross-sectional dependency tests: Cross-Sectional Dependence Exponent Estimation and Test, Pesaran (2015) Test for Weak (CD) Cross-Sectional Dependence, and Pesaran (2004). Moreover, Pesaran's Weak (CD) and CD tests demonstrate that the null hypothesis of cross-sectional independence is rejected at the 1% significance level, supporting the results from the previous tests. In other words, the available data support the cross-sectional dependence issue for the factors considered in this study.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue V May 2025

The findings support nations' global interdependence on LGDP, LCO2, LPOP, LENG, LHDI, LFLFPR, and LMLFPR.

Table 4 - Cross-Sectional Dependence Exponent Estimation and Test

Estimation of Cross-Sectional Exponent (alpha)

variable	Global
LGDP	0.998
LCO2	0.830
LPOP	1.004
LENG	0.878
LHDI	1.004
LFLFPR	0.971
LMLFPR	0.952

0.5 <= alpha < 1 implies solid cross-sectional dependence.

Authors Calculations

Table 5: Pesaran (2015) Test for Weak (CD) Cross-Sectional Dependence.

H0: Errors are weakly cross-sectionally dependent.

variable	Global
LGDP	274.364[a]
LCO2	40.421a
LPOP	330.290[a]
LENG	61.156[a]
LHDI	373.11[a]
LFLFPR	49.213[a]
LMLFPR	72.172[a]

“a “p<.01, “b “p<.05, “c “p<.1

Authors Calculations

Table 6: Pesaran (2004) Cross-Sectional Dependence (CD)Test

variable	Global
LGDP	274.360[a]
LCO2	40.420a
LPOP	330.290[a]
LENG	61.160[a]
LHDI	373.110[a]
LFLFPR	49.210[a]
LMLFPR	72.170[a]

“a “p<.01, “b “p<.05, “c “p<.1

Authors Calculations

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue V May 2025

Table 7 presents the findings from second-generation panel unit root tests that address heterogeneity and cross-sectional dependence (CADF and CIPS). The results indicate that LGDP, LCO2, LPOP, LENG, LHDI, LFLFPR, and LMLFPR are stationary at the first difference but non-stationary at their level. This means that all variables in the study are integrated at level 1 in the global panel.

Table 7: Results of the CADF and CIPS panel unit root tests.

	Global-Dividend Panel				
Variable	**CADF**		**CIPS**		
	Cons	**Trend**	**Cons**	**Trend**	
LGDP	-1.561	-2.207	-2.093[b]	-2.149	**I (1)**
Δ LGDP	-3.073[a]	-3.273[a]	-3.882[a]	-4.039[a]	
LCO2	-1.058	-2.242	-2.036[c]	-2.030	**I (1)**
ΔLCO2	-3.485[a]	-3.754[a]	-4.823[a]	-5.119[a]	
LHDI	-0.832	-1.271	-1.592	-1.986	
ΔLHDI	-2.418[a]	-2.909[a]	-3.497[a]	-4.087[a]	**I (1)**
LPOP	-2.160[a]	-2.212	-1.835	-2.079	
Δ LPOP	-3.425[a]	-4.326[a]	-2.183[a]	-2.678[a]	**I (1)**
LENG	-1.387	-2.074	-2.167[a]	2.343	
Δ LENG	-3.449[a]	-3.590[a]	-4.913[a]	-5.010[a]	**I (1)**
LFFPR	-1.292	-2.025	-1.653	-1.704	
Δ LFFPR	-2.713[a]	-2.967[a]	-3.614[a]	-3.916[a]	**I (1)**
LMLFPR	-1.910[b]	-2.178	-1.448	-1.783	
Δ LMLFPR	-2.837[a]	-3.030[a]	-3.611[a]	-3.842[a]	**I (1)**

“a “p<.01, “b “p<.05, “c “p<.1

Authors Calculations

Table 8 presents the results of the Westerlund cointegration test for the linear and non-linear models. The Global panel results show that the null hypothesis of the Gt statistic in the linear model is rejected at the 1% significance level (based on a robust p-value). Both models demonstrate long-term stability concerning the study's variables.

Table 8 Results of the Westerlund (2007) cointegration test.

Ho: No cointegration

Pre-Dividend Panel				
Statistic	Linear Model		Non-linear Model	
	Value	Z-Value	Value	Z-Value
Economic Model				
Gt	-2.415[a]	-2.310	-2.574[b]	-1.570
Ga	-5.533	8.758	-5.392	11.024
Pt	-19.011	1.167	-20.234	2.393
Pa	-4.389	4.976	-4.745	6.528

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue V May 2025

Social Model				
Gt	-2.476[a]	-2.963	-3.040[a]	-6.531
Ga	-6.345	7.609	-6.948	8.998
Pt	-15.750	3.836	-19.626	2.903
Pa	-2.982	6.898	-3.183	8.466
Environmental Model				
Gt	-3.234[a]	-11.057	-3.565[a]	-12.124
Ga	-7.135	6.491	-6.772	9.227
Pt	-29.696[a]	-7.575	-30.646[a]	-6.331
Pa	-6.717	1.796	-5.972	5.006

“a “p<.01, “b “p<.05, “c “p<.1

Authors Calculations

The results of Driscoll-Kraay standard error estimates and Newey-West standard error estimates for the economic, social, and environmental models are presented in Tables 9, 10, and 11, respectively, and are divided into linear and non-linear models. The Newey-West standard error regression is used to check the robustness of Driscoll-Kraay standard error regression estimates. The estimated values of the coefficients are the same as the Driscoll-Kraay standard error regression estimations. However, the t-statistics of the coefficients are significantly greater than the Driscoll-Kraay standard error regression estimates. Conforming to the robustness of the Driscoll-Kraay standard error regression estimates, the explanatory variables in both the linear and non-linear models are significant based on the Newey-West standard error regression estimates and F-statistics.

Economic Development Model

The long-run estimates of the economic model presented in Table 9 yield several key findings.

The data show a notable long-term negative correlation worldwide between total population (LPOP) and GDP per capita (LGDP), with an elasticity of- 5.2% and a confidence level of 99%. Furthermore, the relationship between GDP and HDI indicates an elasticity of 189.6% globally, emphasizing the positive and statistically significant effect of HDI on per capita GDP. The analysis also reveals that per capita energy consumption (LENG) has a substantial and positive impact on global GDP, as noted by Ouedraogo (2013). Additionally, the elasticity between GDP and ENG is measured at 53.5% globally. The linear model estimate shows an elasticity of 20.3% for FLFPR about GDP, with a significance level of 1%, suggesting that improvements in FLFPR can positively influence global GDP. The male labor force participation rate (MLFPR) significantly affects GDP, exhibiting an elasticity of 483.0%. The linear model explains 86.18% of the total variation in global GDP. Overall, the variables HDI, ENG, FLFPR, and MLFPR contribute positively to GDP, whereas POP serves as a reducing factor.

The non-linear model, utilizing Driscoll-Kraay standard errors regression and Newey-West standard error estimates, indicates that the elasticities of POP, ENG, HDI, FLFPR, and MLFPR are- 5.2%, 53.5%, 189.6%, 20.3%, and 48.3%, respectively. POP stands out as the only variable negatively impacting GDP, while HDI demonstrates the strongest positive influence. Moreover, female labor force participation exhibits a significant U-shaped relationship with global GDP.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue V May 2025

Table 9 - Driscoll-Kraay standard error estimates and Newey-West standard error estimates of the economic model.

	Driscoll-Kraay standard error estimates		Newey-West Standard Error Estimates	
Dependent Variable -LGDP	**Linear Model**	**Non-linear Model**	**Linear Model**	**Non-linear Model**
Panel	**Global**	**Global**	**Global**	**Global**
Independent Variables	**Coef.**	**Coef.**	**Coef.**	**Coef.**
LPOP	-0.052a	-0.055[a]	-0.052a	-0.055[a]
LENG	0.535a	0.533[a]	0.535a	0.533[a]
LHDI	1.896a	1.925[a]	1.896a	1.925[a]
LFLFPR	0.203a	-0.726	0.203a	-0.726[a]
$LFLFPR^2$		0.299		0.299[a]
LMLFPR	0.483b	0.429[c]	0.483b	0.429[a]
Cons	-2.774a	-1.991[a]	-2.774a	-1.991[a]
Num of obs	3540	3540	3540	3540
Num of groups	118	118		
F (6, 29)	51014.08	156862.30	4392.505	3744.481
Prob > F	0.0000	0.0000	0.0000	0.0000
R-squared	0.8618	0.8624		
Root MSE	0.2356	0.2351		

"a "p<.01, "b "p<.05, "c "p<.1

Authors Calculations

Social Model

The findings of the long-run estimates of the social model in Table 10 can be summarized as follows.

The results show a notable long-term positive correlation between the total population (LPOP) and the Human Development Index (LHDI) worldwide, with an elasticity of 0.9 % at a 99% confidence level. Furthermore, the elasticity between GDP and HDI stands at 9.1% globally, underscoring GDP's positive and statistically significant impact on HDI. The analysis also indicates that per capita energy consumption (LENG) substantially and positively affects HDI. Additionally, globally, the elasticity between ENG and HDI is 8.7%. The linear model estimates the elasticity of the Female Labor Force Participation Rate (FLFPR) concerning HDI at 1.2%, with a significance level of 1%. Enhancing FLFPR can improve HDI globally. However, male labor force participation (MLFPR) negatively and significantly impacts HDI, with an elasticity of -11.2%. The linear model explains 82.84% of the total variation in global HDI. While POP, GDP, ENG, and FLFPR contribute positively to HDI, MLFPR is the only variable that detracts from it globally.

The non-linear regression models using the Driscoll-Kraay and Newey-West standard error estimates for the social model reveal that the elasticities for POP, GDP, ENG, FLFPR, and MLFPR are 1 %, 9%, 8%, 39%, and – 8.9%, respectively. Among these, MLFPR stands out as the only factor that negatively influences HDI, while FLFPR has the most substantial positive effect. Additionally, female labor force participation shows a significant inverse U-shaped correlation with global HDI.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue V May 2025

Table 10 - Driscoll-Kraay standard error estimates and Newey-West standard error estimates of the social model.

	Driscoll-Kraay standard error estimates		**Newey-West Standard Error Estimates**	
Dependent Variable -LHDI	**Linear Model**	**Non-linear Model**	**Linear Model**	**Non-linear Model**
Panel	**Global**	**Global**	**Global**	**Global**
Independent Variables	**Coef.**	**Coef.**	**Coef.**	**Coef.**
LPOP	0.009[a]	0.010[a]	0.009[a]	0.010[a]
LGDP	0.091[a]	0.091[a]	0.091[a]	0.091[a]
LENG	0.087[a]	0.085[a]	0.087[a]	0.085[a]
LFLFPR	0.012[b]	0.394[a]	0.012[b]	0.394[a]
$LFLFPR^2$		-0.123[a]		-0.123[a]
LMLFPR	-0.112[c]	-0.089	-0.112[a]	-0.089[a]
Cons	1.253[a]	0.916[a]	1.253[a]	0.916[a]
Num of obs	3540	3540	3540	3540
Num of groups	118	118		
F (6, 29)	100973.35	77750.42	2811.786	2443.192
Prob > F	0.0000	0.0000	0.0000	0.0000
R-squared	0.8284	08311		
Root MSE	0.0515	00.0511		

“a “p<.01, “b “p<.05, “c “p<.1

Authors Calculations

Environmental Model

The findings of the long-run estimates of the environmental model in Table 11 can be summarized as follows.

The findings demonstrate a significant long-term positive correlation between total population (LPOP) and global per capita carbon emissions (LCO2), showing an elasticity of 5.1 % at a confidence level of 99%. Additionally, the elasticity between GDP and CO2 is 10.8% worldwide, highlighting GDP's positive and statistically significant influence on CO2 emissions. The results further reveal that per capita energy consumption (LENG) substantially and positively affects CO2 levels, with a global elasticity of 88.8% for ENG and CO2. In contrast, the linear model estimates the elasticity of the Female Labor Force Participation Rate (FLFPR) concerning CO2 at -20.8%, yielding a significance level of 1%, indicating that FLFPR lowers CO2 emissions globally. Furthermore, male labor force participation (MLFPR) also negatively affects CO2 emissions significantly, with an elasticity of -98.5%. The linear model accounts for 94.43% of the total variation in global CO2 emissions. While LPOP, GDP, and LENG tend to increase CO2 emissions, FLFPR and MLFPR significantly reduce them.

The non-linear regression models incorporating Driscoll-Kraay and Newey-West standard error estimates for the environmental model indicate that the elasticities for POP, GDP, ENG, FLFPR, and MLFPR stand at 5.3 %, 10.8%, 88.6%, 39.3%, and – 94.9%, respectively. Notably, MLFPR is the sole factor that negatively affects CO2 emissions, while ENG exerts the strongest positive influence. Furthermore, female labor force participation displays a significant inverse U-shaped relationship with global CO2 emissions.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue V May 2025

Table 11 - Driscoll-Kraay standard error estimates and Newey-West standard error estimates of the environmental model.

	Driscoll-Kraay standard error estimates		**Newey-West Standard Error Estimates**	
Dependent Variable – LCO2	**Linear Model**	**Non-linear Model**	**Linear Model**	**Non-linear Model**
Panel	**Global**	**Global**	**Global**	**Global**
Independent Variables	**Coef.**	**Coef.**	**Coef.**	**Coef.**
LPOP	0.051[a]	0.053[a]	0.051[a]	0.053[a]
LGDP	0.108[a]	0.108[a]	0.108[a]	0.108[a]
LENG	0.888[a]	0.886[a]	0.888[a]	0.886[a]
LFLFPR	-0.208[a]	0.393[b]	-0.208[a]	0.393[a]
LFLFPR^2		-0.194[a]		-0.194[a]
LMLFPR	-0.985[a]	-0.949[a]	-0.985[a]	-0.949[a]
Cons	1.176[a]	0.647[a]	1.176[a]	0.647[a]
Num of obs	3540	3540	3540	3540
Num of groups	118	118		
F (6, 29)	42935.22	57044.01	12195.617	10262.405
Prob > F	0.0000	0.0000	0.0000	0.0000
R-squared	0.9443	0.9445		
Root MSE	0.1619	0.1617		

“a “p<.01, “b “p<.05, “c “p<.1

Authors Calculations

Tables 12, 13, and 14 present an analysis of the Dumitrescu-Hurlin panel non-causality test applied to economic, social, and environmental models, respectively. In the economic model, empirical results support the long-run estimates, revealing bidirectional causality between POP and GDP, ENG and GDP, HDI and GDP, FLFPR and GDP, as well as MLFPR and GDP across the global panel. Similarly, the social model's findings indicate bidirectional causality among POP and HDI, GDP and HDI, ENG and HDI, FLFPR and HDI, and MLFPR and HDI on a global level. Furthermore, the environmental model's estimates affirm that there is also bidirectional causality between POP and CO2, GDP and CO2, ENG and CO2, HDI and CO2, FLFPR and CO2, and MLFPR and CO2 emissions globally. These results underscore the interdependency of the study variables within the research panel.

Table 12 - Dumitrescu Hurlin Panel Causality Test Results

Economic Model

	LGDP	**LPOP**	**LENG**	**LHDI**	**LFLFPR**	**LMLFPR**
LGDP		19.2785[a]	5.77945[a]	4.29070[a]	5.28146[a]	6.71312[a]
LPOP	7.10077[a]		6.47873[a]	6.77662[a]	6.32815[a]	6.53637[a]
LENG	4.30280[a]	12.3572[a]		3.93566[a]	4.07464[a]	3.91763[a]
LHDI	5.13760[a]	16.4755[a]	4.81952[a]		6.57759[a]	5.75614[a]
LFLFPR	4.72377[a]	16.4647[a]	4.22384[a]	9.01882[a]		4.85720[a]
LMLFPR	4.13995[a]	14.2720[a]	3.78957[a]	10.6909[a]	6.38168[a]	

“a “p<.01, “b “p<.05, “c “p<.1

Authors Calculations

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue V May 2025

Table 13 - Dumitrescu Hurlin Panel Causality Test Result

Social Model

	LHDI	LPOP	LGDP	LENG	LFLFPR	LMLFPR
LHDI		16.4755a	5.13760a	4.81952a	6.57759a	5.75614a
LPOP	6.77662a		7.10077a	6.47873a	6.32815a	6.53637a
LGDP	4.29070a	19.2785a		5.77945a	5.28146a	6.71312a
LENG	3.93566a	12.3572a	4.30280a		4.07464a	3.91763a
LFLFPR	9.01882a	16.4647a	4.72377a	4.22384a		4.85720a
LMLFPR	10.6909a	14.2720a	4.13995a	3.78957a	6.38168a	

“a “p<.01, “b “p<.05, “c “p<.1

Authors Calculations

Table 14 - Dumitrescu Hurlin Panel Causality Test Results

Environmental Model

	LCO2	**LPOP**	**LGDP**	**LENG**	**LFLFPR**	**LMLFPR**
LCO2		13.5609a	4.26031a	4.01330a	3.33973a	4.16723a
LPOP	6.85149a		7.10077a	6.47873a	6.32815a	6.53637a
LGDP	6.08162a	19.2785a		5.77945a	5.28146a	6.71312a
LENG	4.03835a	12.3572a	4.30280a		4.07464a	3.91763a
LFLFPR	4.74196a	16.4647a	4.72377a	4.22384a		4.85720a
LMLFPR	3.58781a	14.2720a	4.13995a	3.78957a	6.38168a	

“a “p<.01, “b “p<.05, “c “p<.1

Authors Calculations

CONCLUSIONS AND RECOMMENDATIONS

Economic development model

The findings of this study generate new knowledge to give decision-makers insight into how the Gross Domestic Product per capita (GDP) is impacted by female labor force participation globally. On that, policymakers can create efficient global strategies for maximizing GDP with optimum female labor force participation and enhancing GDP by determining the dynamics of the effects of male and female labor force participation on GDP. It can conclude the findings of the study as follows:

This study reveals a significant long-term connection between population size and GDP globally. The findings suggest that an increasing population may hinder GDP growth worldwide, which contradicts previous studies that argued population and growth rates contribute to higher GDP. Furthermore, the analysis indicates that energy consumption has a significant and positive impact on GDP. Estimates show that the Human Development Index (HDI) is the most crucial factor in GDP enhancement, with a positive effect. Thus, it can be inferred that the quality of the population is more important for boosting GDP than its size. The data also demonstrates that the Female Labor Force Participation Rate (FLFPR) has a significant and favorable effect on GDP worldwide, indicating that changes in FLFPR are closely tied to GDP. Policymakers should take this FLFPR behavior into account. The results further suggest that the Male Labor Force Participation Rate

(MLFPR) also significantly influences GDP on a global scale. Additionally, a country's GDP is notably affected by its population, energy consumption, and labor force participation rates. The non-linear model used in this study provides a clearer understanding of how FLFPR relates to GDP, revealing a U-shaped relationship. Moreover, the cointegration analysis supports the long-term reliability of this non-linear model within the study's panel. These results highlight the necessity of recognizing the non-linear dynamics between FLFPR and GDP. Overall, the findings shed light on the complex interactions among energy, labor force participation, and human development, potentially guiding policymakers in developing strategies to enhance GDP.

The findings from the Dumitrescu-Hurlin panel non-causation test indicate a bidirectional causality between the independent variables (POP, HDI, ENG, FLFPR, and MLFPR) and GDP, highlighting their global interdependence. This suggests that the research variables significantly impact each other and are deeply interconnected.

Social Development Model

The total population has a notable but relatively minor influence on the Human Development Index (HDI). Contrary to earlier research suggesting negative impacts of population size and growth rates on HDI, this study finds that a larger population may enhance HDI on a global scale. The analysis reveals a positive correlation between per-capita GDP and HDI with varying elasticities. Additionally, energy consumption significantly affects HDI in diverse ways.

One study highlights a long-term relationship between the Female Labor Force Participation Rate (FLFPR) and HDI, showing that FLFPR significantly impacts HDI worldwide. FLFPR exhibits an inverse U-shaped effect on HDI, with cointegration analysis confirming the long-term stability of this nonlinear model. These findings underscore the importance of considering the nonlinear relationship between FLFPR and HDI when formulating strategies to boost HDI. Increasing male labor force participation, however, could negatively impact overall welfare.

These insights hold significant implications for policymakers aiming to advance human development. According to the Dumitrescu-Hurlin panel non-causation test, there is a bidirectional causal relationship between the independent variables (population, GDP, energy use, FLFPR, and male labor force participation rate) and HDI, indicating their significant interrelation. The study concludes that a country's HDI is influenced by its population, GDP, energy use, and gender-differentiated labor force participation rates. Policymakers can leverage this evidence to enhance a country's HDI. Specifically, FLFPR substantially improves HDI globally, suggesting that policies should focus on increasing female employment and participation rates. Moreover, the bidirectional causality confirms that improvements in HDI enhance FLFPR within a country. Optimizing FLFPR fosters human development by empowering women and contributes to achieving Sustainable Development Goals (SDGs). Ultimately, the study concludes that FLFPR is positively associated with sustainable development through its enhancement of human development.

Environmental Development Model

Population growth, GDP, and energy consumption (ENG) contribute to increased global CO_2 emissions. However, the Female Labor Force Participation Rate (FLFPR) and Male Labor Force Participation Rate (MLFPR) help reduce these emissions. The relationship between FLFPR and CO_2 emissions is globally an inverse U-shaped. These findings, supported by the Westerlund cointegration test, are crucial for policy development. The Dumitrescu-Hurlin panel non-causality test confirms long-term stability and bidirectional causality among the study variables. Countries should strategize to manage optimal population sizes for the long run. Increasing FLFP can decrease fertility rates and population growth, leading to lower carbon emissions.

Policies promoting low-carbon lifestyles and sustainable practices are essential. Education on carbon reduction, sustainable practice incentives, carbon tax implementation, and sustainable urban planning can aid in these efforts. The GDP's effect on CO2 emissions varies, with the Environmental Kuznets Curve (EKC) hypothesis suggesting a long-term balance between environmental protection and economic growth. Studies support this hypothesis, showing that FLFP can boost GDP while reducing emissions by fostering economic growth.

To reduce CO2 emissions, policies should focus on sustainable business practices, industrial emission regulations, green transportation, urban planning, and sustainable consumption and production patterns. Reducing individual energy consumption significantly decreases carbon emissions, necessitating policies to encourage lower energy use. Energy sources include fossil fuels, renewable/nuclear energy, and combinations thereof. Fossil fuels are the main carbon emission source, while renewable/nuclear energy is cleaner.

Empowering women through FLFP can enhance socioeconomic status and promote cleaner energy adoption, reducing carbon emissions. Investing in renewable energy sources like solar, wind, and hydropower can be increased through financial incentives and government research. A comprehensive strategy to reduce CO2 emissions should involve investing in renewable energy, implementing energy efficiency measures, and creating financial incentives for reduced energy consumption. Improving FLFPR is vital for leveraging FLFP benefits while minimizing environmental impacts. FLFP can reduce CO2 emissions by influencing women's eco-friendly behavior and increasing employment. Optimizing FLFPR helps achieve sustainable economic, societal, and environmental development goals, but overcoming institutional and cultural barriers is necessary for higher FLFPR.

Female Labor Force Participation and Sustainable Development

Sustainable development encompasses the comprehensive growth of the economy, society, and environment. The study aimed to identify the impact of female labor force participation on these three dimensions of sustainable development to better understand the role of women in the global pursuit of sustainability.

Economic and social analyses indicate that increasing female labor force participation significantly enhances global per capita GDP and the human development index, while notably reducing per capita carbon emissions. By incorporating more women into the workforce, nations can achieve economic growth and improved societal well-being. This integration not only boosts per capita GDP but also elevates the human development index. Moreover, it can decrease carbon emissions per capita, as diverse perspectives often lead to more sustainable practices. Policies that support women's employment, such as equal pay, parental leave, and flexible work arrangements, can further magnify these advantages. As more women enter and succeed in the workforce, the resulting ripple effects can transform economies, making them more resilient and equitable.

The study's findings are highly beneficial for policymakers aiming to achieve sustainable development by enhancing GDP per capita, improving human development, and reducing carbon emissions, all while maximizing female labor force participation to reap multiple benefits.

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