Pakistan Economic Review
8:1 (Summer 2025), PP. 1-29

Financial development, Technological Advancement, and Income Inequality: Exploring the role of Human Capital as moderator

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Abstract

Income inequality is a critical issue that impacts social stability, poverty and economic growth. Therefore, understanding the factors that influence income inequality is essential to implement effective policies. This study explores the relationships among financial development (FD), technological advancement (TA), human capital (HC) and income inequality (INE) across 47 developing countries from 1990 to 2021. To achieve the objective, robust least squares estimation is employed. The findings reveal that FD positively affects income inequality. In contrast, TA and HC contribute to reducing income inequality. The interaction term between FD and HC suggests that HC can reduce the negative impact of FD on INE. Additionally, the interaction between TA and HC shows that human capital strengthens TA and INE relationship. The findings highlight the significance of investing in HC. By enhancing HC, FD and TA can help to minimise INE and stimulate inclusive economic growth. This policy may encourage a more balanced distribution of resources and opportunities.

Keywords: Developing countries, Income inequality, Financial development, Human Capital, Technological advancement

JEL classifications: D63, E44, I3, O15, E31

1. Introduction

Income inequality is one of the biggest obstacles to a nation's progress and well-being. There are many distinct types of inequality, including social, racial, sexual, handicapped, and economic inequality, as well as numerous forms of discrimination, but our focus is on Target 10.1, which aims to reduce income inequality[4].

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[4] https://en.wickcipedia.org/wiki/Sustainable_Development_Goal_10

Some scholars assert that income inequality(INE) arises from human effort, which they view as a constructive societal feature, while others contend that it stems from an unjust system that discourages hard work (Stiglitz, 2012; Bivens et al., 2014). Theoretically, increased access to funding for the poor facilitates borrowing for viable initiatives, hence diminishing INE (Galor & Moav, 2004). Credit market flaws, such as asymmetric information and moral hazard, make it hard for impoverished people without collateral or a history of repaying loans to obtain credit. So, making it easier for them to get credit is good for them (Beck et al., 2007).

There is significant disagreement over the link between FD and INE. Sotiropoulou (2025); Akisik and Gal (2022); Villanthenkodath et al. (2023); Altıner et al. (2022) Nguyễn & Nguyen (2021) discovered that financial development (FD) exacerbates income inequality.
These findings indicate that financial sector changes have not benefited the most impoverished elements of the population, and that the advantages derived from new opportunities have been appropriated by the well-connected elites (Claessens & Perotti, 2007). As usual, the financial sector often grows considerably faster than the real sector when the economy is growing. So, the effect on income distribution is skewed in favor of wealthy and urban households, worsening INE (Azis & Yarcia, 2014). On the other hand, Horobet et al. (2025); Suhrab et al. (2025) and Chisadza and Biyase (2022) argue that FD is a significant tool for addressing INE. Moreover, Nguyễn and Nguyen (2021) and Mikek (2023) identified an inverted U-curve relating FD to income distribution indicates that INE may rise during the initial phases of financial expansion and fall after a specific threshold is attained.

Technological advancement refers to the progress and improvement in technology over time. The dynamics of economic disparity are significantly influenced by technological advancement. It contributes to income disparity as well as being a cause of it. The findings indicate that TA is one of the primary forces behind economic growth and INE. Because skilled workers are more likely to gain from technological improvements, whereas unskilled workers would face temporary unemployment as they look for occupations requiring less expertise (Wahiba & Dina, 2023). It is probable that skill-biased technological development will be reinforced by the growth of automatization and computerization as well as other fourth Industrial Revolution-related improvements. As a result, new policies to combat income disparity are being considered, like Universal Basic Income (Deskoska & Vlčková, 2018). Technological advancement can potentially worsen income inequality, particularly in less developed economies without redistribution mechanisms (Antonelli & Gehringer, 2017).

Innovation in technology also spurs education and helps workers, which lowers the rent-wage gap and reverses inequality (Madsen & Strulik 2020). All things considered, one of the main factors underpinning the dynamics of economic inequality is the interplay between technological advancement and educational quality(Castelló-Climent &

Doménech, 2014). Research indicates that a rise in human capital corresponds with a decrease in the prevalence of poverty (Molla, 2021; Suhendra et al., 2020). Human capital can be useful to fight against the growing income disparities in the OECD countries (Cram., 2017). Nonetheless, HC and INE are positively correlated, pointing to inequitable access to economic resources and disparities in the educational system (Moyo et al., 2022).

This study focuses on developing countries because 85% of the world's population lives there, and they have considerably higher poverty and inequality rates than wealthy countries. The percentage of people trying to make ends meet on less than $2 per day is nearly zero in developed nations, compared to around 30% in a typical developing economy. Accordingly, poverty is a problem that only affects the underdeveloped nations. Although national household surveys typically document consumption expenditures in poor countries and income in industrialized ones, the disparities in INE are likely to be significant as well[5]. Reducing INE in developing nations is challenging, even with the implementation of numerous standard economic, institutional, and social policies, experts and academics should exercise greater caution when exploring the factors that contribute to INE. Developing nations are also frequently more vulnerable to the adverse consequences of global uncertainty Thus, it is often necessary for the majority of them to suspend their efforts at economic progress. which are meant to aid in lowering poverty and inequality, during times of extreme uncertainty[6]. Despite several studies analyzing the impact of FD, TA, and human capital on INE, there remains a considerable gap in the literature regarding the interactive effects of these factors. Prior research examining the direct impact of FD and TA on INE has failed to reach a consensus. This indicates that FD and TA alone is insufficient to reduce income inequality. So, HC can help break the link between FD and income disparity in developing nations. While individual studies have explored the influence of each variable separately, there is limited research that analyzes their combined effect on income inequality. To the best of our knowledge, we didn't find any study that explored the moderating role of HC in the relationship between FD and INE, and TA and INE.

Addressing these gaps will improve the understanding of INE and provide valuable insights to policymakers. The study has the following objectives 1) analyze the impact of FD, technological advancement (TA), and human capital on income inequality. 2) Investigate the moderating effect of HC on the relationship between FD and income inequality. 3) what is the moderating role of HC on the relationship between TA and income inequality.

[5] https://doi.org/10.1016/B978-0-444-59428-0.00010-2
[6] https://doi.org/10.1080/15140326.2024.2316969

This study is outlined in the following manners. Section 2 reviews the literature related to the relation between FD, TA, HC and income inequality. Methodology, Data and empirical model of the study are discussed in Section 3. Section 4 provides an overview of the results and discussion. Section 5 consists of the conclusion and policy implications.

2. Literature Review

The literature review consists of two sections. Section 2.1 theoretically reviews theories that examine the effects of financial development, human capital, and technological advancement on income inequality. It also describes the theoretical studies of the relationship between employment and poverty. Section 2.2 provides empirical evidence of the literature on FD, human capital, technological advancement and income inequality.

2.1 Theoretical literature

The theoretical framework entails investigating how FD, human capital, and TA may affect income disparities. The following are some important theoretical stances:

2.1.1 Financial development and income inequality

According to financial intermediation theory, allocation of capital and economic development can be improved by a fully developed financial system, which is typified by effective banks and other institutions. Thus, by encouraging more profitable investments, the creation of jobs, and general economic development, this may help to lessen income disparity (Diamond, 1984; Levine, 1997). According to Stiglitz and Weiss (1981), imperfections in the credit market can be used to show how better financial systems can remove obstacles to credit, making it possible for people with low starting wealth but great investment opportunities to obtain capital and support more equitable economic growth.

Krippner (2005) presented the idea of financialization and asset inequality, which provides insight into how economies are changing as financial markets become more and more important. This change may be a factor in the growing income gap, especially given the concentration of wealth in financial assets.

2.1.2 Technological advancement and income inequality

According to Skill-Biased Technological Change (SBTC), introduced in the 1980s and 1990s, those with high levels of talent are disproportionately benefited by technology breakthroughs, which raises the demand and earnings for skilled labor. This may exacerbate the pay disparity between unskilled and skilled workers, increase to

INE(Autor, et al., 2006). Building this Routine-Biased Technological Change (RBTC) in the 1990s focuses on how normal chores are impacted by technological advancements. When routine tasks are automated, workers who perform them may lose their jobs and INEmay increase if new job opportunities brought about by technology demand different skill sets (Levy & Murnane, 2004).

This viewpoint takes into account how technological advancement and globalization interact. Globalization and technological advancements may effect on INE by changing the demand for certain skills and the distribution of labor around the world (Acemoglu & Autor, 2011). Winner-take-all marketplaces imply that in some sectors of the economy, the highest achievers receive a disproportionately large part of the benefits. When it comes to technology innovation, this might exacerbate income disparity because some people or businesses are better at utilizing new technologies than others (Frank & Cook, 1996). According to the employment polarization idea, both high- and low-skill vocations are growing while middle-skill positions are declining. This tendency, linked to advancements in technology, worsen income disparity by limiting prospects for workers in occupations requiring a moderate level of expertise (Autor, 2014).

2.1.3 Human capital and income inequality

According to Schultz's human capital theory, people can increase their productivity and income by investing in their health, education, and training. In particular, education is regarded as a type of human capital that raises one's income by improving one's knowledge and abilities (Schultz, 1961). Signaling Theory by Spence (1973), suggests that a person's education might tell prospective employers about their intrinsic skills and work ethic. In addition to the skills gained, higher education can lead to higher-paying jobs since companies view education as an indicator of a person's inherent ability. Becker's human capital theory also discusses the mismatch between individual skills and the skills that companies require. This mismatch leads to inefficiencies that, in turn, worsen INE (Becker, 1975).

2.2 Empirical literature

This section is divided into three parts. In the first part, the literature regarding FD and INE is discussed. In the second part, we discuss the studies of TA and INE. And at last, we reviewed the papers discussed on the HC and INE links.

2.2.1 Financial development and income inequality

The previous studies showed conflicting results on the link between FD and INE. Studies generally present three types of relationships: positive, negative, and Kuznets' inverted U-shaped.

Some findings suggests that FD is a significant variable in reducing INE. For example, Horobet et al. (2025) employed GMM regression to examine financial variables and income inequality, revealing that financial inclusion and fintech adoption significantly reduced income disparity in European countries. Suhrab et al. (2025) found that digital financial inclusion reduced INE among BRICS nations using Driscoll-Kraay and fixed effects estimations. Additionally, Chisadza and Biyase (2022) examined the relationship between FD and INE for 148 countries (1980–2019) and found that FD reduced inequality in developing nations but had no significant effect in advanced countries. Similarly, Lassoued (2021) found that FD and microfinance contributed to reducing INE in 43 Sub-Saharan African nations from 1995–2015. Karim et al. (2022) found that, in the short-term, FD in South Asia reduced income disparity.

Conversely, other studies indicate a positive relationship between FD and INE. Sotiropoulou (2025) used data of 13 transition economies (2000–2020) and concluded that the financial sector's provision of private credit exacerbated income disparity through its effects on economic expansion. Akisik and Gal (2022) also found a link between financial institutions and income disparity, saying that deeper financial sectors, which have more bank loans and pension funds, make inequality worse. Villanthenkodath et al. (2023) discovered that financial openness exacerbated wealth inequality in middle- and high-income countries. Altıner et al. (2022) showed that FD exacerbates inequality. They argue that this link be contingent on the accessibility of financial resources. The same results are shown for Vietnam . Nguyễn & Nguyen (2021) analysed Vietnam for the period 2000–2020 and employed the ARDL model and concluded the same findings that FD widening INE.

Some studies show the nonlinear link between FD and INE. Nadabo et al. (2024) validate the inverse U-shaped association between the FD and INE for the Nigerian economy. Barhoom (2023) found mixed results, revealing that financial openness reduced inequality in the short term but intensified it in the long term for the dataset of Hungary. Mareš and Horvath (2025) analyzed 94 countries (2000–2014) and discovered that enhancements in financial intermediary efficiency and capital accessibility mitigate inequality, however increased financial market depth elevates top income shares, hence exacerbating disparity. Ridzuan et al. (2021) observed that FD diminished inequality in Malaysia, Indonesia, and Thailand, while exacerbating income dispersion in the Philippines.

2.2.2 Technological advancement and income inequality

Some research suggests that technical progress helps to lower economic disparity. Xu (2023) examined panel data from 49 countries (2010–2020) and discovered that the digital economy substantially diminished income inequality. Suphannachart (2019) similarly determined that technical developments, as assessed by total factor productivity (TFP), contributed to diminished inequality in Thailand. Sato et al. (2006) demonstrated that skill-biased technology progress elevated the wage premium for skilled workers, elucidating the trends of increasing and then decreasing income disparity. However, some research say that new technologies make economic disparity worse. Suhrab et al. (2025) discovered that knowledge-intensive technological advancements disproportionately advantage higher-income persons, exacerbating wealth inequalities in BRICS states. Xiao et al. (2024) discovered that technical innovation in both rich and developing nations tended to exacerbate economic inequality, contrary to its anticipated equalizing impact. Similarly, Petralia et al. (2023) showed that the financial benefits of TA have underpaid highly compensated employees that leads to increased income inequality. Therefore, they concluded that TA is a key driver of INE. The same conclusion is drawn by Wahiba and Dina (2023). They argue that INE and economic development are influenced by HC. The rationale of these findings is that only skilled workers benefit from TA, while unskilled workers experience temporary joblessness as they seek jobs that require less expertise. Guo (2021) explored that the U.S. labor market has become more polarized by skill requirements due to advances in automation. Their study demonstrates how automation technology has likely decreased upward mobility and increased downward mobility for children from middle- and lower-class families, leveraging regional variations in exposure to technological substitution. Acheampong (2020) states that countries with higher levels of technical progress and innovation also have higher income levels, is supported by quantitative assessments of GII scores and selected socioeconomic variables for 126 different countries. Kerkeni and Mnif (2020) studied 52 developing countries to analyze the impact of technology and education on INE. They found that at the initial stages of new technology adoption, the demand for skilled labour increases, but it is limited. As a result, the earnings of skilled workers rise, while those of unskilled workers either remain unchanged or decrease, widening income disparities.

2.2.3 Human capital and income inequality

Some studies show a negative relationship between HC and INE. Goh (2025) investigated how human capital growth affects economic inequality in five ASEAN nations from 1970 to 2019. Using the ARDL, the findings reveal that HC development significantly reduces INE over the long run in Indonesia, Malaysia, the Philippines, and Thailand, highlighting the value of education and skills in fostering fair wage distribution. However, in Singapore, an already developed labor market, the impact of HC on INE is negligible. Adeleye (2024) showed that stronger institutions and HC reduced INE in 46 Sub-Saharan African nations from 2010 to 2019. This result is

supported by an earlier study of Molla (2021), which demonstrated that HC reduces INE in Sub-Saharan Africa. Nga Ndjobo et al. (2023) showed that while the interaction between ICTs and HC reduces overall INE, it also increases the income shares of the poorest people in developing countries, particularly when compared to the richest. Singh & Mengesha (2023) used data of 15 Asia-Pacific nations from 1990 to 2020. The long run ARDL model's results, with human capital acting as a mediating variable, showed that innovation is helpful in reducing INE both globally and over time in most of the selected nations. For time series studies, Suhendra et al. (2020) also showed that HC significantly reduced INE in Indonesia. Sehrawat and Singh (2019) used data from 1970 to 2016 and utilized NARDL. They indicate that increasing education plays a significant role in mitigating the high levels of economic inequality in India. Similar findings are reported for Pakistan by Sheikh et al. (2016), utilising data from 1984 to 2012. The long-term coefficient indicates that, in Pakistan, human capital and foreign assistance are important factors in reducing income inequality. This pattern has been empirically verified at the provincial level in Thailand, where there is a tendency for conditional per capita growth rates to converge more quickly between 2000 and 2009.

Many studies also support a positive relationship between human capital and INE. Thye et al (2022) employed an NARDL model on Indonesian data from 1970 to 2019. Findings revealed that the uneven influence of HC development is widening the INE. Moyo et al. (2022) utilised the Pooled Mean Group. They found a positive link between HC and income inequality, a sign of unequal access to opportunities and disparities in the educational system. Anshari & Marta (2022) analysed data from 2016–2020 across 34 Indonesian provinces. The findings revealed that HC has a positive, though insignificant, impact on INE across all provinces in Indonesia.

While some studies identify a nonlinear link between HC and INE. The Castelló-Climent et al. (2021) study comprises 146 nations from 1950 to 2010. They revealed an inverse U-shaped relationship between HC and INE. They indicate that the point at which the relationship between INE and HC inequality turns positive varies significantly between nations. Fan (2003) examined how a person's upbringing and academic pursuits shape their human capital and influence poverty and wealth inequality across generations. The analysis demonstrates that, even with free education, income may not converge globally to the mean, and it offers several viable ways to break the poverty cycle.

2.3Literature Gap:

The literature review on the relationships among FD, TA, HC, and INE reveals a significant research gap in existing studies. Although numerous studies examine the influence of FD and TA on INE, there is a scarcity of research addressing the joint effect of these variables and the moderating role of HC in the link between FD and INE, as well

as TA and INE. Moreover, the majority of research in this field has been performed for developed nations, with limited investigation of developing economies.

3. Data and methodology

3.1 Theoretical Framework

The financial imperfections theory introduced by Galor and Zeira (1993) suggests that market constraints restrict individuals' access to finance, such as transaction and information costs. These limitations lead to negative consequences for INE (Mookerjee and Kalipioni 2010). These restrictions on financial access prevent individuals from investing in HC, thereby further exacerbating INE (Kling et al., 2022). Supporters of this theory, [Banerjee and Newman., 1993; Galor and Moav., 2004; and Galor and Zeira., 1993], argue that as the financial system develops, these limitations will diminish and access to financing will enhance. Therefore, the progress of the financial system should not be assessed solely by its size but by its ability to improve credit access. Without easy accessibility to credit, FD may worsen income inequality.

By widening the technological gap between those with access and those without, TA intensifies inequality [Odhiambo, 2022; Ye et al., 2022; D.C. Yildirim et al., 2022]. This gap widens socioeconomic disparities and restricts opportunities for individuals [Bordot, 2022]. For instance, people with more access to technology are more likely to learn new things. Consequently, increasing their employment chances and income. On the other hand, people with limited access might be excluded [Tchamyou,et al., 2019]. Consequently, low-skilled workers have fewer job options that increases unemployment. New TA have decreased job security because many jobs once considered secure are no longer so. Overall performance and job satisfaction among workers decrease [Bader & Mohammad, 2019]. Workers in many industries, especially low-skilled labor, have been displaced by automation and artificial intelligence [Tchamyou,et al., 2019]. They showed that in nations with poor institutional and regulatory frameworks and those with higher levels of inequality, there was a larger association between INE and access to ICTs. This has led to a fall in the wage share of national income and an increase in INE [Anakpo & Kollamparambil, 2022]. Furthermore, income and wealth inequality have increased as a result of the concentration of wealth within a very small number of people who control and get benefits from this new technology [Du & Wei, 2022].

The effects of FD and TA on INE are linked to HC, as HC shapes how individuals and groups benefit from economic opportunities. Individuals or businesses with higher HC are more likely to access and use financial resources effectively. In contrast, people with

lower HC may face challenges in leveraging financial opportunities, thus exacerbating income inequality.

Technological advancements often favour workers who have technical skills and higher education. As a result of taking advantage of the TA, these workers earn high incomes due to a surge in their productivity. On the other hand, low-skilled workers may find their jobs at risk due to automation and other TA. Consequently, INE increases. In addition, HC also influences how effectively society adapt to and embrace new technologies. Countries or regions with higher education and skills have more chances to get benefit from TA. In contrast, those countries or regions that have low HC and unskilled workers may struggle to utilise these innovations. Consequently, INE intensifies.

When human capital is more evenly distributed across different segments of society, there is a greater chance that people will have the skills to take advantage of FD and TA. This reduces the likelihood that INE will widen due to these factors. On the other hand, if human capital is unevenly distributed, the inequality gap can significantly widen. The highly skilled benefit disproportionately from financial and technological progress, while the less-skilled become more marginalized and thus exacerbate income inequality.

3.2 Model specification

In many nations around the world, income disparity plays a significant role in the dynamics of economic growth and poverty reduction. Addressing inequality can have a big impact on increasing growth and ending extreme poverty (Thorbecke 2013). In order to develop an empirical model appropriate for the phenomenon being studied, we examined pertinent theoretical literature. By assisting people in managing their money and enhancing their financial well-being, FD may be able to lessen income inequality. Based on our theoretical and empirical review of the literature, we have specified the following model to analyze the effect on income inequality. The underlying model is as follows.

$$INE_{it} = \alpha_o + \alpha_1 FD_{it} + \alpha_2 TA_{it} + \alpha_3 HC_{it} + \alpha_4 Z_{it} + \epsilon_{it} \qquad (1)$$

where *i* represent the country and t denote the time period. INE, FD, TA, and HC represent Income Inequality, Financial Development, Technological Advancement, and Human Capital, respectively. And ϵ_{it}, represents error term. Z_{it} is the set of control variables that includes Globalization index, Per Capita GDP, Inflation, and Unemployment.

We will evaluate the moderation effect of human capital on the FD–income inequality relationship. Therefore, we will estimate the equation (2)

$$INE_{it} = \gamma_o + \gamma_1 FD_{it} + \gamma_2 TA_{it} + \gamma_3 HC_{it} + \gamma_4 FD_{it} * HC_{it} + \gamma_5 Z_{it} + \theta_{it} \qquad (2)$$

In equation 2, $FD_{it} * HC_{it}$ the interaction term of FD and HC shows the joint impact of FD and HC on INE. From this equation, we will check the conditional and unconditional impact of FD on INE. The unconditional and conditional effects of FD on INE can be written by taking the partial derivative of eq.2 w.r.t FD as

$$\frac{\partial INE_{it}}{\partial FD_{it}} = \gamma_1 + \gamma_4 HC_{it} \qquad (2a)$$

In equation 2a, γ_1 shows the unconditional impact of FD on INE, where γ_4, indicate the impact of FD that is conditional on the HC.

If γ_4 is insignificant, then the moderating effect of HC is not significant. If $\gamma_4$is significantly positive, then HC has a significant positive moderating effect. If γ_4 is significantly negative, then HC has a significant negative moderating effect. If the sign of γ_4 are align with sign of γ_1, then HC strength the relationship of FD and INF, otherwise its weaken this relationship. Therefore, depending on the significance and sign of γ_4 , it indicates whether human capital strengthens, weakens, or has no significant effect on the relationship between FD and INE. If both have the same sign (either positive or negative), they indicate the complementary effect of FD and HC on INE; if they differ, they indicate a substitutionary effect.

In model three, we will introduce the moderator role of HC in relation to TA and INE.

$$INE_{it} = \lambda_o + \lambda_1 FD_{it} + \lambda_2 TA_{it} + \lambda_3 HC_{it} + \lambda_4 TA_{it} * HC_{it} + \lambda_5 Z_{it} + \nu_{it} \qquad (3)$$

In equation 3, the interaction term $TA_{it} * HC_{it}$ illustrates the combined effect of TA and HC on INE. This equation will be used to evaluate both the conditional and unconditional effects of TA on INE. The unconditional and conditional impacts of TA on INE can be expressed by calculating the partial derivative of equation 3 with respect to TA.

$$\frac{\partial INE_{it}}{\partial TA_{it}} = \lambda_2 + \lambda_4 HC_{it} \qquad (3a)$$

In equation 3a, λ_2 represents the unconditional effect of TA on INE, while λ_4 denotes the effect of TA that is contingent upon HC.

If λ_4 is insignificant, then the moderating impact of TA is negligible. If λ_4 is significantly positive, then HC exerts a significant positive moderating influence. If λ_4 is significantly negative, then HC exerts a significant negative moderating influence. If the sign of λ_4 aligns with the sign of λ_2, then HC strengthens the link between TA and INF; otherwise, it weakens this relationship. Consequently, based on the significance and sign of λ_4, it determines whether human capital enhances, diminishes, or exerts no meaningful influence on the link between FD and INE. If both have the same sign (either positive or negative), they signify the complementing influence of TA and HC on INE; if they differ, they imply a substitution effect.

3.3 Data and variable Description

In this study, we utilized annual data of 47 developing countries ranging from 1990 to 2021. The list of countries are Argentina, Armenia, Bangladesh, Brazil, China, Costa Rica, Dominican Republic, Ecuador, Egypt(Arab Rep), Ethiopia, Guatemala, Hungry, India, Indonesia, Iran(Islamic Rep), Jamaica, Jordan, Kazakhstan, Kenya, Korea, Kyrgyz Republic, Mozambique, Morocco, Mauritius, Malawi, Moldova, Mongolia, Madagascar, Pakistan, Panama, Peru, Philippines, Poland, Romania, Rwanda, Sierra Leone, Syria, Sri Lanka, Sudan, Tanzania, Tajikistan, Thailand, Tunisia, Turkey, Uganda, Ukraine, Venezuela(RB), Vietnam, Zambia. Variable descriptions and sources of data are presented in Table 3.1.

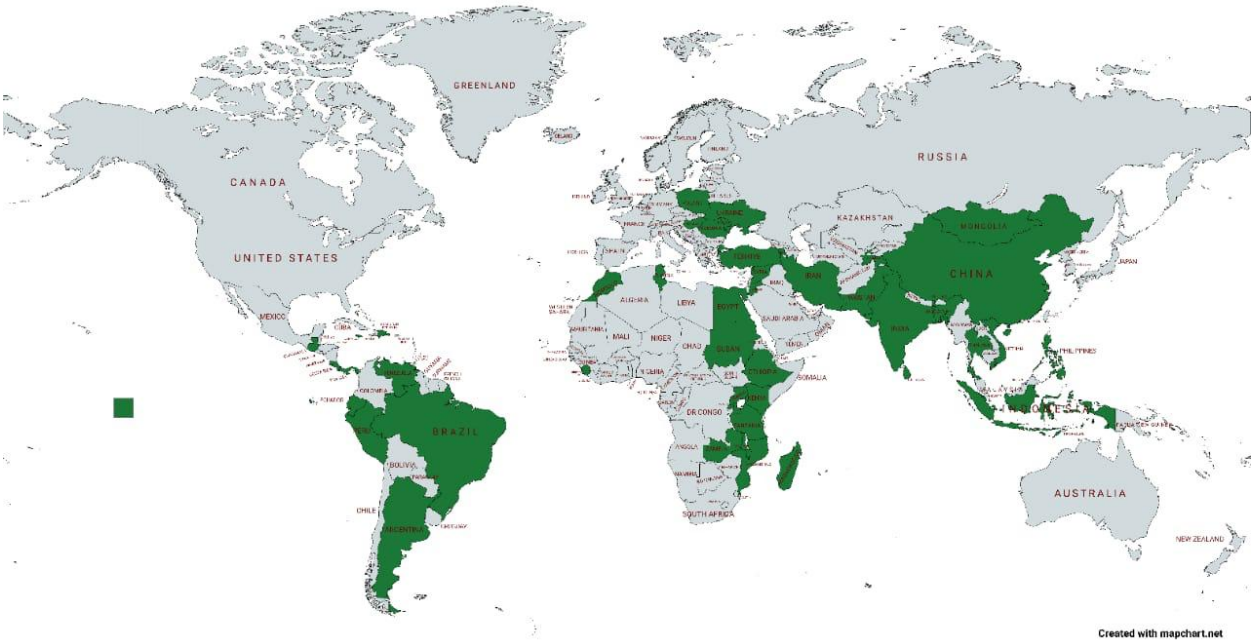

Figure 1: Selected sample countries

Table 3.1: Variable Description and data Sources

Variables	Definitions	Source
	Dependent variable (Income inequality)	
INE	Income inequality (Gini Index)	World Income Inequality Database (https://wid.world)
	Independent variables	
FD	Financial development index	IMF database (www. data. imf. org)
TA	Technological Advancement (residents patents).	WDI
HC	Human Capital	Penn World Table

Control Variables		
Glob	Globalization Index	KOF swiss economic institute
GDPpc	GDP Per Capita in constant 2015 USD	World bank
INF	Inflation	World bank
Unemp	Unemployment	World bank

3.4 Estimation techniques

A robust regression is a useful method addressing the issues posed by outliers and influential observations in the data, hence minimising their effect on the regression coefficients (Zaman et al. 2001). The primary aim of robust estimating is to derive dependable estimates or inferences for unknown parameters despite the presence of outliers. The robust approach substitutes the sum of squared residuals in OLS with an alternative function that is less affected by outliers. These approaches initially apply regression analysis on the data, then identifying outliers as observations with significant residuals. Robust approaches possess three desirable properties: efficiency, breakdown point, and restricted influence (Khan et al. 2021). Robust least squares have an edge over conventional least squares because to its applicability with fewer restrictive assumptions. A data set exhibiting non-normality, missing values, outliers, or multi-collinearity issues yields biased results. Nevertheless, the robust least squares method may address these concerns.

4. Result and discussion

The descriptive statistics of the study variables is presented in Table 4.1. All variables have positive means, minimums, and maximums. The highest standard deviation is observed for HC, followed by KOFGI, unemployment, LRP, FD, and GINI. This indicates that HC shows greater dispersion. Skewness statistics indicate that GINI, HC, and KOFGI are negatively skewed, while the rest of the variables are positively skewed. GDPpc, GINI, FD, and LRP have kurtosis values greater than 3, showing leptokurtic distributions. In contrast, HC, KOFGI, and unemployment kurtosis values below 3 show platykurtic distributions.

Table 4.1: Summary statistics

	GINI	FD	LRP	HC	GDPPC	Glob	Inf	Unemp
Mean	0.585379	0.285136	5.217090	2.441762	0.000487	58.15495	36.12859	7.517000
Median	0.591144	0.275668	4.955827	2.475250	0.000107	59.30040	7.672850	6.990000
Maximum	0.840896	0.736562	14.15198	3.765120	0.008428	85.40290	7481.660	22.97400
Minimum	0.321902	0.000000	0.000000	1.145390	6.17E-07	28.93680	-9.808770	0.249000
Std. Dev.	0.082059	0.131910	2.357994	0.537247	0.000994	11.22461	273.3520	4.366530
Skewness	-0.637389	0.663437	0.506873	-0.097440	4.430278	-0.116794	18.20199	0.658821
Kurtosis	3.105113	3.309049	3.519524	2.261960	28.33702	2.632596	404.9606	2.989932
Jarque-Bera	58.69537	66.58778	46.55087	20.90371	25847.01	6.800057	1183.7222	62.28904
Probability	0.000000	0.000000	0.000000	0.000029	0.000000	0.033372	0.000000	0.000000
Sum	504.0114	245.5023	4491.915	2102.357	0.419090	50071.41	63008.27	6472.137
Sum Sq. Dev.	5.790919	14.96412	4781.716	248.2258	0.000850	108353.1	1.30E+08	16397.26

The correlation matrix of the underlying variables is shown in Table 4.2 . The results indicate that FD, GDPpc, and Inf positively correlate with INE, implying that as FD, GDPpc, and Inf increase, INE tends to increase. Contrary, TA, HC, and Glob shows a negative correlation with INE. The negative sign suggests that higher values of these variables are associated with lower levels of INE. The strongest negative correlation is observed between TA and INE, indicating that TA has the most significant inverse relationship with INE, followed by HC, and Glob, respectively. The heat map of the correlation matrix for the study variables is shown in Figure 4.2.

Table 4.2: Matrix of correlations

	INE	FD	TA	HC	GDPpc	Glob	Inf	Unemp
INE	1.0000							
FD	0.0239	1.0000						
TA	-0.4340	0.4695	1.0000					
HC	-0.4193	0.0912	0.2195	1.0000				
GDPpc	0.0784	0.1165	-0.3821	0.1879	1.0000			
Glob	-0.2143	0.4895	0.1967	0.5670	0.2749	1.0000		
Inf	0.0569	-0.0697	0.0110	-0.0377	-0.0325	-0.1475	1.0000	
Unemp	-0.0026	-0.0934	-0.0077	0.0310	0.1000	0.0385	-0.0005	1.0000

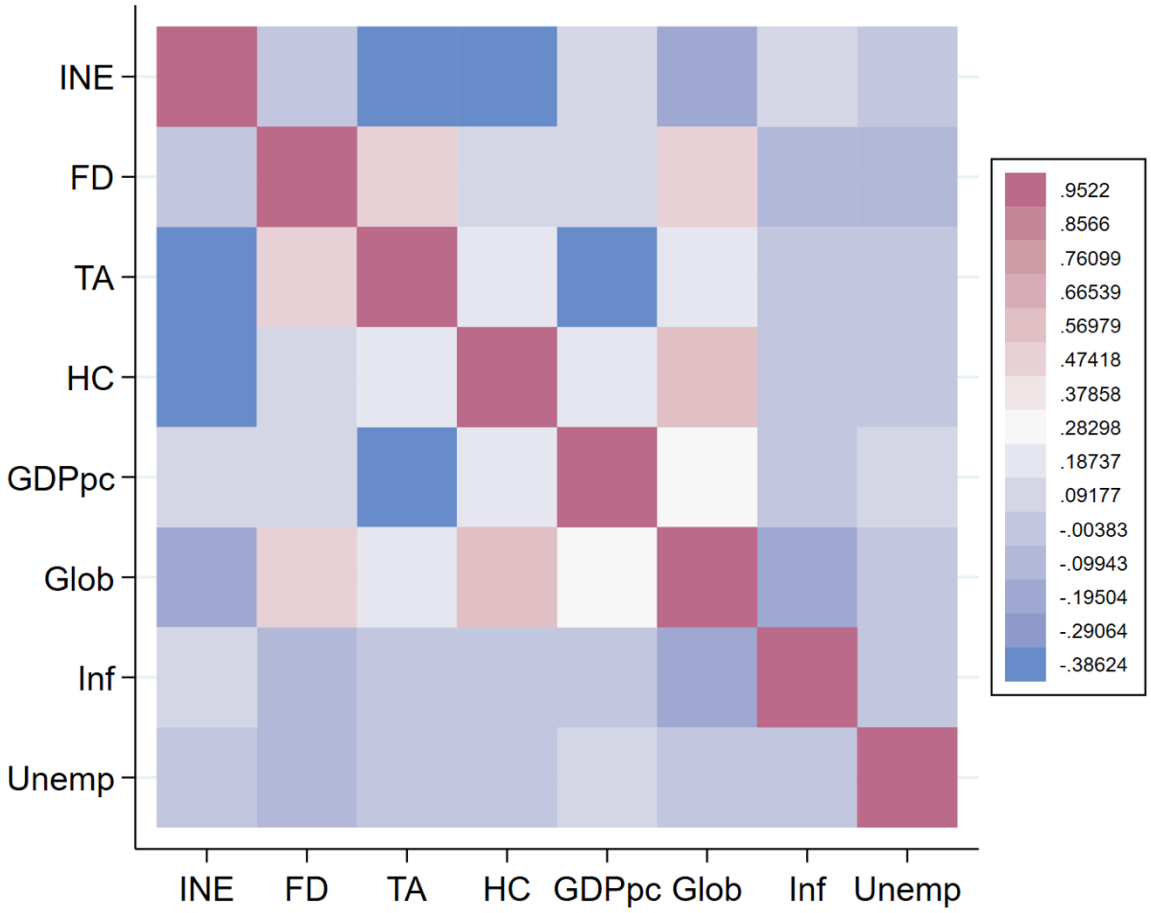

Figure 2: Heat map of correlation matrix

The findings of unit root tests are listed in Table 4.3. The findings indicate that all variables (INE, FD, HC, GDPpc, Glob, and Unemp) are stationary at first difference, i.e., they are integrated of order one, I(1). In contrast, the variables TA and Inf are stationary at levels. These findings indicate a mix of integration orders among the variables, with most of them requiring differencing to become stationary, while TA and Inf reveals stationarity at the level.

Table 4.3: Unit root

Variable	IPS		Fisher		
	Level	Ist difference	Level	Ist difference	Decision
INE_{it}	-1.2666	-21.1992***	1.8162	29.7742***	I(1)

FD_{it}	-1.6715	-25.6937***	-0.9212	71.4111***	I(1)
TA_{it}	-2.7839***	--------	3.2534***	--------	I(0)
HC_{it}	1.5880	5.8938***	-1.7962	14.0473***	I(1)
GDPPC_{it}	1.2950	-19.3062***	8.4666***	44.7498***	I(1)
Inf_{it}	-29.1278***	----------	37.9208***	---------	I(0)
$Glob_{it}$	0.2622	-19.5902***	-2.1800	41.5349***	I(1)
$Unemploy_{it}$	-0.3618	4.4734***	-0.3618	4.4734***	I(1)

Note: *** p<0.01, **p<0.05, *p<0.1.

Table 4.4: Robust least square

	Model 1	Model2	Model3
FD	0.245312*** [0.024768]	0.738655*** [0.103560]	0.215811*** [0.023818]
TA	-0.019829*** [0.001368]	-0.020800*** [0.001374]	-0.030912*** [0.005664]
HC	-0.038012*** [0.006079]	-0.06079*** [0.01922]	-0.06934*** [0.013073]
GDPpc	-9.170622*** [2.844098]	-9.530796*** [2.823895]	-12.73036*** [2.754780]
Glob	-0.00844** [0.00330]	-0.00635* [0.00332]	-0.00474** [0.00218]
Inf	0.00015** [0.0000715]	0.000153** [0.0000709]	0.000132* [0.0000684]
Unemp	0.001148** [0.000538]	0.001297** [0.000535]	0.000925* [0.000515]
FD*HC	--------	-0.189962*** [0.038635]	-------
TA*HC	--------	--------	-0.020719*** [0.002262]
C	0.759084 0.015087	0.635909*** [0.029913]	0.491297*** [0.032513]
R-squared	0.340282	0.355899	0.393231
Adjusted R-squared	0.334331	0.349250	0.386968

Note: ***, **, * Indicates significance at the 1%, 5%, and 10% levels.

4.1 Results and Discussion

The result shows that the relationship between FD and INE is positive and statistically significant. One unit rise in FD increases the 0.245312 units of INE. This result is justified because we are studying developing countries that are at an early stage of FD. FD generally involves improving the efficiency of financial markets, broadening access to capital, and fostering investments, these benefits are often not evenly distributed across all segments of society. Wealthier individuals or corporations are often in better situations to take advantage of the financial services and prospects that arise with FD. They can secure loans, invest in higher-return opportunities, and thus see a greater increase in wealth, It has the potential to increase the wealth gap. In addition, the financial sector's growth may disproportionately benefit urban or skilled labor sectors, leaving behind lower-income or unskilled workers who have limited access to these financial services. Consequently, FD thereby reinforces or even worsens the income gap. The study results are aligning with earlier findings of Sotiropoulou (2025), Makhlouf et al (2025), Altıner et al (2022), and Nguyễn & Nguyen (2021). Some earlier studies that contradict this results Horobet et al (2025), Almounsor and Mensi (2024), Karim et al (2022) and Lassoued (2021).

The link between TA and INE is negative and statistically significant, one-percent surge in TA will led to decrease -0.000198 units change of INE. With the TA, productivity increases, new businesses are created, and earnings for all skill levels rise, especially when paired with education and training. Increased access to technology can assist lower-income individuals in improving their financial situation by opening up opportunities in entrepreneurship, healthcare, and education. The study results align with earlier findings of Xu (2023); and Suphannachart (2019). While our findings contradict with Altinay et al., (2025); Petralia et al (2023).

The association between HC and INE is negative and statistically significant. One-unit increase in HC fall the 0.038012 units of INE. More people who have access to quality education and skill development have greater employment prospects and earn more money. It enables more individuals to obtain better employment and to adjust to economic changes. A well-educated workforce is more likely to adapt more easily to transform the labor market, thereby reducing INE. Furthermore, Barro (2000) argued that better education can help mitigate wealth disparity by expanding opportunities for marginalized groups. Past studies align with our result are Goh (2025), Adeleye (2023), studies that contradict our result Moyo et al (2022) Anshari & Marta, (2022).

The link between globalization and INE is negative and statistically significant. One unit increase in Glob will lead to a decrease of 0.000844 units of INE. By promoting economic growth and giving lower-income people more possibilities, especially in

emerging nations, globalization can lessen income gaps. Trade openness is one of the important determinants in reducing inequality among developing economies [Tabash (2024), Ndoya and Asongu (2024)]. Some studies find that Glob raises the INE in low-income economies while reducing INE for middle and high-income countries [Nazif Çatık (2024) and Villanthenkodath (2023)].

GDPPC is linked with INE negatively, and this relationship is statistically significant. A one-unit surge in GDPPC reduces the INE by 9.170622 units. Because a nation with higher GDP per capita tends to have better resources for social welfare programs that assist lower-income groups, healthcare, and education. Economic expansion also creates more jobs and higher pay, particularly in developing nations, helping to close the income gap and pull people out of poverty. Richer nations also frequently enact redistribution and progressive taxation measures, which further lessen inequality. Recent sudies align with our results are Nam and Ryu (2025), Samani et al (2024), Akpa et al (2024) and Harahap et al (2024). Studies that contradict our result are Nguyen et al (2024) and Velagic & Silajdzic (2024).

Relationship between inflation and INE is positive and statistically significant. One-unit increase in inflation cause a surge of 0.00015 units in INE. Because inflation reduces the real income of low-wage workers, whose earnings are sticky, and because wealthier people frequently own assets like stocks and real estate that increase in value with inflation. The income gap also grows as the rich profit from inflation-hedged assets while the poor save in cash, which depreciates. Some recent studies align our findings Asrofillah and Arimurti (2025), Rolim and Marins (2025), Tarnabi and Raghfar (2025), Aprea and Raitano (2025).

There is statistically significant and positive relationship between unemployment and INE. One-unit surge in income will lead to an increase of 0.001148 units of INE. Because unemployment primarily impacts low-skilled, low-income workers by lowering their incomes and employment opportunities, it exacerbates economic inequality. Higher earners, on the other hand, are less affected because they have steady jobs and other sources of income, such as investments. The gap in wealth between the rich and the poor gets wider as a result. Recent studies that align our findings are Rolim, L. (2025), Freire, C. (2025) and Magaji et al (2025).

In model 2, we introduced the interactive term of FD*HC. The coefficient of the interaction term (FD*HC) is statistically significant and negative. The coefficient of FD*HC suggests that a one-unit increase in FD*HC reduces the INE by 0.189962 units. This result highlights the critical moderating role of HC in the relationship between FD and INE. This negative effect can be understood through the lens of human capital theory. When FD is coupled with higher levels of human capital, the benefits of FD may

be more broadly distributed. Education and skills can improve the ability of individuals to access financial services, participate in more productive economic activities, and secure higher-paying jobs. In addition, more educated or skilled individuals benefit from financial services; they are more likely to use them to invest in businesses, education, or skills development, rather than accumulate wealth. This redistributes wealth more evenly across the population and helps reduce inequality. Moreover, HC increases the efficiency with which financial services are used. For instance, well-educated entrepreneurs can take advantage of credit markets more effectively, leading to better business outcomes, job creation, and wealth generation. This creates a virtuous cycle in which both FD and human capital reinforce each other to benefit broader economic well-being, thereby reducing INE.

In short, the coefficient of FD*HC suggests that FD alone does not help reduce INE. Without proper education, training, and skills, the benefits of FD will be enjoyed only by a few wealthy groups, worsening the INE. This explains why the positive effect of FD on INE is moderated and reduced when HC is included in the model.

In model 3, we introduced the interaction term TA×HC. The interaction term TA×HC is negative and statistically significant, indicating that a one-unit increase in the interaction of TA and HC reduces INE by about 0.0207 units. The moderating role of HC indicates that the relationship between TA and INE is conditional on the level of human capital. In countries with lower levels of human capital, TA may not reduce inequality significantly, or in most scenarios, exacerbate it. Conversely, in countries with higher levels of human capital, TA can lead to significant reductions in inequality. The reason is that there is a more skilled workforce that is in a position to benefit from innovations. Therefore, income distribution will be more equitable. In other words, TA can lower inequality if it creates opportunities for more people, improves productivity, and raises wages across skill levels, particularly when the workforce has sufficient skills (HC) to adopt and benefit from the technology. With high HC, workers are more capable to adapt new technology that help to reduce INE. This capability of employees reduces the chances that the benefits of innovation will be concentrated in the hands of a few. In contrast, if HC is low, TA may disproportionately benefit skilled or capital-owning individuals, widening inequality. Many developing economies face high levels of INE alongside rapid technological change and uneven access to education and skills. The findings suggest that investing in HC make enables the broader population to participate in and benefit from TA. Without adequate HC, TA may primarily benefit a small, skilled elite and thus exacerbate inequality. While technology itself can be a powerful tool for economic development, its ability to reduce inequality is contingent upon the capacity of the population to engage with and benefit from that technology. Human capital development is therefore essential in ensuring that technological advancements lead to more equitable outcomes.

5. Conclusion and policy implementations

The current study explored the relationships between FD, TA, and INE. In addition, the study explored the moderating role of human capital in the relationship of FD and INE, and TA and INE. To achieve the objective, we utilized annual data from 47 developing countries from 1990 to 2021. After preliminary tests, we used the robust least squares estimate method to examine how FD, TA, and HC affected INE. The results indicate that FD has a positive and statistically significant effect on INE. This shows that as FD increases, INE tends to rise. While TA and HC have a negative and statistically significant effect on INE. The results suggest that TA is a useful measure in reducing INE. In addition, HC also plays an important part in reducing INE. In addition, GDPpc and Glob are benefical to achieve the SDG goal of reducing INE. On the other hand, Inf and Unemp leads to widening INE. The interaction term FD*HC indicates that human capital moderates the harmful impact of FD on INE. Furthermore, TA also reduces INE, and the impact of TA remains significant (both conditional and unconditional).

The current study suggests several important policy implications for addressing INE. Based on the results, we suggest few policy recommendations. In order to ensure that the advantages of FD are dispersed more fairly throughout society may take initiatives to provide better access to financial services. This must consist of underserved or marginalised groups, such as women, rural populations, and small businesses. The study supports the essential role of human capital in reducing INE. Therefore, policymakers should invest in education and skills development. This can be achieved by making it easier for people of all ages to access a good education, expanding vocational and technical training, and ensuring that people can keep learning throughout their lives in ways that meet the needs of the job market. Governments should work to ensure that education systems and the skills required by modern sectors are better aligned. Governments, corporations, and schools might work together to create curricula that match the changing requirements of the economy.

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