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Impact of Fintech and Financial Inclusion on Sustainable Development Goals: Evidence from cross country analysis

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Highlights

- This paper investigates the impact of fintech and financial inclusion on sustainable development goals (SDGs)
- We developed a financial inclusion (FI) index using principal component analysis
- Using quantile regression for panel data of 86 countries, the result shows that an increase in fintech reduces maternal deaths (SDGs 3) at higher quantiles but has no effect at lower quantiles, while financial inclusion is negatively related to maternal deaths at all quantiles.
- However, fintech and financial inclusion significantly contribute to SDG 8 and SDG 9 up to the 50^{th} quantile, while at the greater percentile, its impact gets reduced.
- The findings of this paper highlight the evolving role of fintech and financial inclusion in supporting different SDGs.
- Further analysis demonstrates that financial inclusion and SDGs can promote each other, and similarly, fintech and SDGs can mutually reinforce each other.

Impact of Fintech and Financial Inclusion on Sustainable Development Goals: Evidence from cross country analysis

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Abstract

We investigate the dual influence of fintech and financial inclusion on diverse sustainable development goals, including SDG 2, 3, 4, 8 and 9, based on panel data of 86 countries. A quantile regression analysis shows that fintech has a favorable influence on education at higher quantiles. Additionally, Fintech and financial inclusion positively enhance GDP (SDG 8) and internet (SDG 9) upto 50^{th} quantiles, but their impact decreases at higher percentiles. The findings suggest that fintech and financial inclusion can drive progress towards achieving SDGs by encouraging economic growth, supporting zero hunger, reducing maternal deaths, enhancing quality education, and empowering innovation and infrastructure. Further analysis demonstrates that financial inclusion and SDGs can promote each other, and similarly, fintech and SDGs can mutually reinforce each other.

Keywords: Fintech: Financial inclusion: Sustainable development goals: Quantile regression:

JEL Codes: C21; O33; O47; Q01

1. Introduction

Fintech is viewed as the most viable advancement that can unravel the challenge of hardship, income disparity and lack of access to financial services (Banna et al., 2022). Chen & Shen (2024) note that fintech expands the scope of interbank business and contributes to the stability of the banking sector. Development of fintech involves the expansion of resources in the financial system by increasing access to internet, smartphones and other digital services like prepaid cards, which in turn support various Sustainable Development Goals (SDGs) (Arner et al., 2020; United Nations, 2018). The UN 2030 Vision for Resilient Growth highlights the prominent role of financial inclusion and fintech in attaining SDGs (Allen et al., 2016). However, the link between fintech, financial inclusion and sustainable development goals has seen sparse research. In this paper, the central theme we seek to explore is whether expansion of fintech and financial inclusion can stimulate the growth of SDGs. We draw on a balanced panel of data from 86 countries, employing Global Findex waves of survey data for 2011, 2014, 2017 and 2021, to examine how fintech and financial inclusion may ultimately shed light on achieving various SDGs including "SDG 2: zero hunger, SDG 3: good health and well-being, SDG 4: quality education, SDG 8: decent work and economic growth and SDG 9: industry, innovation, and infrastructure" (United Nations, 2018).

Financial inclusion which entails providing individuals with greater accessibility to financial services, including savings accounts, investments, credit cards and loans (Kara et al., 2021), directly contributes to several SDGs. For instance, extant evidence shows that greater access to financial services enhances savings (Allen et al., 2016), which supports SDG 1 (No poverty) by assisting individuals in building financial security and decreasing exposure to economic shocks. Financial inclusion also increases employment (Prasad, 2011), contributing to SDG 8 (Decent Work and Economic Growth) by enabling small firms and individuals to

access credit, fostering entrepreneurship and job creation, and further supporting education (Flug et al., 1998), which promotes SDG 4 (Quality Education) by enabling families to invest in their children's education. Likewise, fintech innovations such as mobile banking, digital payments, online lending and savings play a fundamental role in increasing household consumption (T. Yang & Zhang, 2022), optimizing investment outcomes (Tiberius et al., 2022) and advancing macroeconomic growth (Ni et al., 2023), minimizing firms' information asymmetry and alleviating firms' finance limitations, thus increasing their innovation capacity (Dong & Yu, 2023), and contributing to the achievement of various SDGs. Further, fintech and financial inclusion not only empower individuals but also accelerate progress towards several SDGs. Reducing information asymmetry and innovation diffusion theory are two plausible channels through which fintech and financial inclusion accelerate progress toward SDGs.

Innovation diffusion theory entails the creation of products through technological improvement at lower economic and societal costs (Daud & Ahmad, 2023). In a similar vein, fintech diffusion through groundbreaking technologies and business models offers more economical and expedient financial products and services, facilitating the advancement of finance and the economy (Fuster et al., 2019; Ni et al., 2023). Fintech diffusion and financial inclusion promote widespread access to financial services and accelerate the adoption of technologies by reducing information asymmetry and transaction costs (Choudhary & Thenmozhi, 2024; Daud & Ahmad, 2023; Dubey & Purnanandam, 2023) thereby supporting various SDGs. These two economic forces combine to form a more inclusive and efficient financial ecosystem that promotes several SDGs.

Research on fintech and financial inclusion often delves into specific SDG such as poverty (Tao et al., 2023), inequalities (Demir et al., 2022; Kanga et al., 2022; Suhrab et al., 2024) and economic growth (Daud & Ahmad, 2023; Liu et al., 2021), rather than exploring the influence of fintech and financial inclusion across varied facets of SDGs. There is considerable

evidence of the substantial impact of fintech on financial inclusion (Ghosh, 2016), which suggests that fintech has the potential to expand the outreach of the financial landscape. However, Xie & Zhu, (2022) highlight that the advancement of FinTech often promotes a more equitable distribution of capital, but at the expense of efficiency. Therefore, considering the combined impact of fintech and financial inclusion on SDGs is important as they work together to address multiple and interconnected global challenges.

Access to financial services helps farmers to invest in technology to boost crop yields (SDG 2) (Assouto & Houngbeme, 2023), smooth medical costs and lessen the impact of health emergencies (SDG 3) (Krishna, 2006), enables individuals with the capacity to invest in quality education (SDG 4) (Ashraf et al., 2010), and promote entrepreneurial activity, resulting in economic growth (SDG 8) and fostering innovation (SDG 9) (Banerjee et al., 2015; Kara et al., 2021). While other SDGs are crucial, these particular goals are directly influenced by the availability of financial resources and technological advancement, making financial inclusion and fintech an essential driver for its success.

Our analyses are based on a balanced panel of data from 86 countries, employing Global Findex waves of survey data for 2011, 2014, 2017 and 2021, to examine how fintech and financial inclusion may ultimately shed light on achieving various SDGs. Different proxies for fintech have been used in the literature including (i) Digital Inclusive financial index (Luo et al., 2022) (ii) natural log of fintech-based credit (Marcelin et al., 2022a) (iii) usage of mobile phones to pay bills (Demir et al., 2022) (iv) mobile phone penetration (Kanga et al., 2022) and, (v) total number of fintech companies (Lyons et al., 2022). To obtain credible country-level measures of fintech, we follow Kanga et al. (2022) and focus on mobile phone penetration to examine the diffusion of fintech capabilities rather than just the usage of specific fintech apps. This approach allows us to understand the foundational technology landscape that enables the

growth and spread of fintech services. It also indicates the level of access to mobile technology, which is fundamental for using fintech services.

Using quantile regression, we find that fintech and financial inclusion significantly reduce undernourishment at all quantiles. Likewise, an increase in fintech is associated with quality education at higher quantiles. However, financial inclusion has an insignificant impact on education, highlighting the gap in traditional banking services supporting secondary education. Fintech and financial inclusion have a significantly positive impact on GDP (SDG 8) and internet (SDG 9) up to 50th percentile, but its impact is reduced at the greater percentile. The positive fintech and financial inclusion effect on different SDGs remains robust after conducting a suitable endogeneity test, sensitivity analysis and alternative sample structure. However, using alternative measures of the SDGs, such as the overall SDG index, reveals interesting results. Financial inclusion significantly supports SDG 2, 3, 4, 8, and 9 indices. However, fintech's impact on SDG 2 and 8 is insignificant, suggesting that while it influences specific components of these goals, its effect on the overall indices is limited. For further analysis, we explore reverse causality through Simultaneous Equation model (SEM) and find that there is indeed bidirectional causality. Specifically, improvement in SDG performance has a consistently significant impact on fintech and financial inclusion, indicating that better progress towards the SDGs supports greater financial inclusion and fintech adoption. These findings give a road map for developing regulatory frameworks that fully leverage fintech and financial inclusion to promote sustainable and equitable development.

Our study complements the extant literature in several ways. First, previous studies on fintech and financial inclusion mainly focus on single SDGs, including economic growth (Daud & Ahmad, 2023) income inequality (Demir et al., 2022; Kanga et al., 2022) and poverty (Tao et al., 2023), but pays little attention to the other SDGs. Our study is one of the first attempts to examine the linkage between fintech, financial inclusion and different SDGs, Second, prior

literature primarily used a single indicator of financial inclusion either from access or usage of traditional financial services, including number of bank accounts, ATM per capita and borrowing from traditional financial institutions (Demir et al., 2022; Kanga et al., 2022; Marcelin et al., 2022b). We use both access and usage indicators of traditional financial services and combine these two indicators to develop a financial inclusion index using principal component analysis (PCA). Third, literature lacks adequate cross-country research, which accounts for different financial and technological development stages across different countries, resulting in a broader perspective and more generalized conclusions. Fourth, while the literature mainly uses a mean-focused regression analysis, we employ a quantile regression technique, which analyses the entire distribution of the dependent variable rather than simply its central distribution (Minh et al., 2022). This approach allows us to adjust for heterogeneity and lowers variation caused by outliers (Canay, 2011; Ito et al., 2004) and offers an extensive overview of how fintech and financial inclusion influence SDGs in different quantiles. Our investigation reveals areas where fintech and financial inclusion are less efficient, highlighting a gap that needs to be addressed through policy implementation.

The remainder of the paper is organized as follows: Research design is presented in Section 2, followed by results and discussions in Section 3. Robustness tests are highlighted in Section 4. In Section 5, we present an auxiliary analysis. Section 6 concludes the paper.

2. Research Design

2.1. Sample and data sources

We use SDGs-related proxy variables from the report developed by the Sustainable Development Solutions Network (SDSN) (Galabada, 2022; Sachs et al., 2023). To construct a financial inclusion index, we use data from the financial access survey (FAS) of the International Monetary Fund (IMF) and World Bank Global Findex (Findex) database. Data for control variables were sourced from the World Bank database. We collected data for 86

countries from Global Findex waves of survey for the year 2011, 2014, 2017 and 2021. The list of the countries with their respective financial inclusion (FI) index is presented in the Appendix A1. The table indicates that Canada has the maximum FI index of 0.981 among all the countries, while Madagascar has the lowest FI index of 0.017.

The appendix illustrates that a country's income level does not solely determine financial inclusion. Even within the same income group, there are significant differences in financial inclusion, which underscores that effective financial inclusion policies and initiatives can lead to higher FI-Index scores, regardless of a country's income classification. It encourages a more nuanced understanding of financial inclusion that goes beyond income levels, considering the broader socio-economic and regulatory context.

2.2. Variable design

2.2.1. Dependent variables

The variables are described in Table 1. We include one proxy for each SDG, as mentioned in the sustainable development report (Sachs et al., 2023). This approach is based on the guidelines and recommendations from the report, ensuring that the selected indicators are representative of different SDG and align with established benchmarks (Sachs et al., 2024). We use undernourishment (Eini-Zinab et al., 2020; Soriano & Garrido, 2016), maternal deaths (Sachs et al., 2023), secondary education (Mehry et al., 2021), GDP (Daud & Ahmad, 2023) and Internet usage (Haini, 2019) as the proxies for S*DGs* 2, 3, 4, 8, and 9 respectively. For robustness, we use an overall indicator of individual SDGs (Sachs et al., 2024).

2.2.2. Core explanatory variables

Fintech and financial inclusion are the main explanatory variables of the model. Following Kanga et al. (2022), we measure fintech by mobile subscriptions. The financial inclusion index is developed using a method similar to Banna et al. (2022). Initially, we winsorize each component at 1st and 99th percentiles to reduce the influence of outliers at the

lower and upper levels. Second, we normalize each component value between 0 and 1. We employ a three-stage principal components analysis (PCA) to create an index.

First, we construct supply-side sub-indices (access to bank infrastructure), denoted as FI_A. Second, we construct the demand-side index (FI_U), i.e., usage of traditional financial services. The details of the indicators, their respective definition and data sources are presented in Table 1. Finally, we combine the two indices (FI_A and FI_U) using PCA to create a FI index, reflecting financial inclusion through traditional financial services. All three indices are normalized using the minimum-maximum normalization method. We did not include wages and utility variables in constructing FI index for the year 2011, because data for these variables were not available for this year. However, these variables have been included for the years 2014, 2017 and 2021. The availability of financial inclusion variables restricts our sample. Descriptive statistics of the variables are presented in Table 2. It shows that fintech has moderate variation, with values ranging from 0.388 to 1.826. The mean being closer to the higher end suggests that most countries might have relatively higher fintech adoption.

The correlation matrix of financial inclusion indicators and Fintech is presented in Table 3. It shows that the FI index is positively correlated to Fintech. We use the variance inflation factor (VIF) to evaluate possible multicollinearity among financial inclusion index, its components and Fintech. We find that the mean value of VIF is 5.811, which is less than the critical value of 10 (F. Yang & Masron, 2024). To ensure that multicollinearity does not affect the results, we calculate and present the mean VIF for our regression (see Table 5-9), and find that the minimum value of VIF is 1.26 and the maximum value is 2.77, which is much lower than 10 indicating that there is no serious problem of multicollinearity (Ding & Xue, 2023).

2.2.3. Control variables

Based on prior literature, we integrate several control variables into our model to analyze the impact of fintech and financial inclusion on various SDGs. First, we control for

several country-specific factors. We control for GDP because GDP growth is a crucial economic indicator reflecting the overall economic health and development of a country. Higher GDP growth often correlates with increased national income and improved living standards, which can reduce undernourishment (Eini-Zinab et al., 2020; Soriano & Garrido, 2016). Prior literature suggests that faster annual economic growth leads to larger annual improvement in undernourishment rates (Soriano & Garrido, 2016). Therefore, by controlling for GDP growth, we account for the influence of economic performance on food security and nutritional outcomes. Prior literature further suggests that the growth effects of education also depend on the level of economic development (Glewwe et al., 2014; Petrakis & Stamatakis, 2002; Varsakelis, 2006). Existing studies also highlight that internet penetration encourages economic growth by providing innovative applications and opportunities through a new medium of information exchange (Haini, 2019; Harb, 2017). We winsorized variables at 1% and 99% level.

Existing literature suggests that investments in public health is identified as one of the major factors conducive to reducing undernourishment (Kumar, 2007; Subramanyam et al., 2011), and health and food security are closely interrelated (Soriano & Garrido, 2016). These factors can directly impact nutritional status by ensuring better prenatal and postnatal care, disease prevention, and treatment. By including health expenditure as a percentage of GDP as a control variable, we account for the critical role of healthcare investment in influencing nutritional outcomes.

Urbanisation poses a problem for food availability due to changing consumption habits, as well as food production and delivery systems (Szabo, 2016). We include urbanization as a control variable to account for the diverse and significant ways in which the urban-rural divide influences undernourishment (Subramanyam et al., 2011). Furthermore, Urbanization is often associated with differential access to healthcare services, infrastructure, and socioeconomic

conditions (Beyene, 2023). Controlling for urbanization accounts for these disparities and ensures that differences in maternal death rates are not merely a reflection of urban-rural divides but are influenced by the emergence of fintech diffusion and enhancement of financial inclusion.

Food instability harms human health. Hence food security and nutrition are critical to improving people's health outcomes (Beyene, 2023). Therefore, we control for undernourishment to accurately assess the impact of fintech and financial inclusion on maternal mortality without the confounding influence of nutritional deficiencies. Water and sanitation are significantly related to maternal health (Blencowe et al., 2011; Klugman et al., 2019). Access to water and improved sanitation are correlated with lower infant mortality (Cheng et al., 2012). We include water facility as a control variable to more accurately assess the impact of fintech and financial inclusion on maternal death. Prior literature suggests that reliable internet infrastructure can play a crucial role in promoting inclusive education (Asongu et al., 2020; Boeren, 2019). Accordingly, we control for the percentage of people using the internet in model 3.

Increased exports lead to increased returns to skills and thus motivate more youth to pursue higher education (Li et al., 2019; Munch & Skaksen, 2008). Additionally, trade in the country reflects physical and human capital accumulation and plays a vital role in economic development (Daud & Ahmad, 2023). A country with robust trade relations will likely have better access to technological advancements and investments, which can enhance internet infrastructure (Freund & Weinhold, 2004). We control for trade to account for the influence of international economic interactions on infrastructure development and innovation (Rosenzweig, 2017), allowing for a cleaner assessment of the impact of fintech and financial inclusion on internet penetration. Among the variables generally believed to drive internet access, the primary one is invariably income (Chaudhuri et al., 2005; Member, 2001). We use

pretax income as a proxy for income inequality. Higher levels of pretax income indicate greater income disparity within a population. With higher income inequality, a larger portion of the population might lack the financial resources to access technology and internet services, despite overall economic growth. To consider the economic disparities within the population, we include pretax income as a control variable.

Population size is a fundamental determinant of economic dynamics. A larger population can contribute to a greater labor force, potentially boosting economic productivity. However, it also poses challenges in terms of resource allocation and public service provision. By controlling for population, we account for its influence on GDP per capita and ensure that the effects of other variables are not conflated with population size (Daud & Ahmad, 2023; Kanga et al., 2022). Gross capital formation, which includes investments in infrastructure, machinery, and technology, is a critical driver of economic growth. It reflects the level of investment in productive assets that can enhance future economic output. Following prior literature (Daud & Ahmad, 2023; Kanga et al., 2022), we control for this factor. Finally, government expenditure can significantly impact economic growth by influencing aggregate demand and providing public goods. Controlling for government expenditure ensures that we account for the impact of fiscal policies on GDP per capita, enabling a clearer analysis of other determinants (Daud & Ahmad, 2023).

2.3. Empirical model

To examine the influence of fintech and financial inclusion on different SDGs, we estimate the following models:

$$\text{Undernourishment}_{it} = \beta_0 + \beta_1 \text{Fintech}_{it} + \beta_2 \text{FI index}_{it} + \beta_3 X_{it} + \alpha_i + \gamma_t + \epsilon_{it} \quad \ldots 1$$

$$\text{Maternal deaths}_{it} = \beta_0 + \beta_1 \text{Fintech}_{it} + \beta_2 \text{FI index}_{it} + \beta_3 X_{it} + \alpha_i + \gamma_t + \epsilon_{it} \quad \ldots 2$$

$$\text{Education}_{it} = \beta_0 + \beta_1 \text{Fintech}_{it} + \beta_2 \text{FI index}_{it} + \beta_3 X_{it} + \alpha_i + \gamma_t + \epsilon_{it} \quad \ldots 3$$

$$\text{GDP}_{it} = \beta_0 + \beta_1 \text{Fintech}_{it} + \beta_2 \text{FI index}_{it} + \beta_3 X_{it} + \alpha_i + \gamma_t + \epsilon_{it} \quad \ldots 4$$

$$Internet_{it} = \beta_0 + \beta_1 Fintech_{it} + \beta_2 FI\ index_{it} + \beta_3 X_{it} + \alpha_i + \gamma_t + \epsilon_{it} \quad \ldots 5$$

Undernourishment is the proxy for zero hunger, Maternal deaths are the proxy for good health and well-being, education is the proxy of quality education, GDP is the proxy of economic growth, and internet is the proxy of innovation and infrastructure. X_{it} is a vector of control variables, αi is the country-fixed effect, γt represents the time-fixed effect, and ϵit is the error term. To deal with serial correlation and heteroskedasticity, we use clustered standard errors. The main result presents the variance inflation factor (VIF) to check for multicollinearity issues, which indicates that there is no multicollinearity.

Prior literature has used mean-focused regression (Daud & Ahmad, 2023; Kanga et al., 2022; Tao et al., 2023). However, this method is not suitable for exploring differential populations (Canay, 2011). Accordingly, we analyze the effect of fintech and financial inclusion on different SDGs using quantile regression methods pioneered by Koenker & Bassett, (1978). This approach offers a clear picture of the role played by fintech and financial inclusion in achieving SDGs at different levels by following the model specification of Demir et al. (2022) and Altunbas & Thornton (2019).

3. Results and discussion

Table 4 reports preliminary regression results with FI_A, FI_U and FI index as the dependent variables. Column (1) of Table 4 reveals that an increase in fintech enhances the accessibility of traditional financial services, suggesting that fintech development complements the growth of ATM and Bank branches. Column (3) highlights the positive influence of fintech on the overall financial inclusion index. This result is consistent with prior literature (Demir et al., 2022; Gosavi, 2018). Thus, fintech innovations such as mobile banking and digital payment provide broader access to financial services by reducing geographical limitations, thereby enhancing overall financial inclusion.

The association between fintech, financial inclusion and SDGs is presented in Tables 5-9. Columns (1)-(5) of Table 5 report the quantile regression results. The signs of the quantile regression coefficients for both fintech and financial inclusion are negative, signifying that a rise in the percentage of mobile subscriptions (fintech) is linked with a reduction in undernourishment at all quantile levels. This relationship is consistent regardless of whether countries are at the bottom, middle, or top of the undernourishment continuum. Likewise, financial inclusion reduces undernourishment at all quantiles except the 10^{th} quantiles, such that undernourishment-reducing effects are greater in countries with higher levels of undernourishment. These findings show the positive role of fintech and financial inclusion in combating undernourishment.

The regression results on the relation between fintech, financial inclusion and maternal deaths are presented in Table 6. Columns (1)-(5) show a negative impact of fintech and financial inclusion on maternal deaths, demonstrating a positive contribution of financial inclusion in mitigating maternal death at all quantiles. However, Fintech shows a negative and significant impact on maternal deaths only at higher quantiles which highlights that an increase in fintech is associated with a reduction in maternal deaths among countries with higher maternal mortality rates. As such, our findings suggest that fintech and financial inclusion are crucial in enhancing SDG 3. Conceivably, fintech and financial inclusion provide financial security and access to better health care, reducing maternal mortality and increasing well-being.

Table 7 examines the influence of fintech and financial inclusion on education. Quantile regression in columns (1)-(5) indicates that financial inclusion has an insignificant impact on education, indicating that accessibility to traditional financial services may not directly influence quality of education. However, Fintech has a significantly positive impact on education, suggesting that an increase in the proportion of mobile subscriptions (fintech) is associated with an increase in quality of education in the countries at higher quantiles of the

education distribution. Overall, fintech's positive and considerable impact on education at higher quantiles highlights its potential to improve educational access, quality, and outcomes. This result is consistent with the notion that fintech diffusion simplifies school fee payment, offers personalized education savings, and facilitates digital learning through mobile subscriptions, thereby supporting SDG 3.

The results presented in Table 8 in columns (1)-(5) reveal that fintech and financial inclusion have a significantly positive impact on GDP at all the quantiles, and the coefficient increases in magnitude upto 50th percentile of GDP distribution, beyond which it starts to decline. This finding indicates that while fintech and financial inclusion significantly impact GDP, the gains are smaller for countries with higher GDP. The emerging growth associated with fintech and financial inclusion allows a larger portion of the population to participate in the financial system, facilitating economic transactions, savings, and investments by reducing information asymmetry, thereby contributing to the country‘s economic growth (Dubey & Purnanandam, 2023; Kanga et al., 2022).

Finally, results in columns (1)-(5) of Table 9 reveal that fintech and financial inclusion play a significantly positive role in supporting SDG 9. The result aligns with innovation diffusion theory by illustrating that fintech innovations spread through a population, improving access to financial services and digital infrastructure and contributing to the achievement of various SDGs. These findings further highlight that increased fintech diffusion and financial inclusion lead to a substantial increase in internet users. However, the strength of the relationship is lower for countries with high internet usage. This effect is consistent with the observed reduction in the coefficient from .334 at the 50th percentile to .126 at the 90th percentile. Fintech innovations, like mobile banking apps and digital payment platforms, enhance internet access, promote digital inclusion, and close the digital gap, thereby achieving

SDG 9. Hence, by integrating more people into the formal financial system, financial inclusion and fintech drive sustainable industrial development and infrastructure improvement.

4. Robustness tests

4.1. Sensitivity analysis

Sensitivity analysis evaluates the robustness and reliability of baseline results by analysing the effect of changes in model assumptions and specifications. It helps us to determine the stability of the outcomes and how sensitive they are to changes in the underlying data or model assumptions (Mertzanis, 2023). We re-estimate our model using fixed and random effects to further check our baseline results' robustness. Table 10 presents the results of the regression analysis using both fixed and random effects models. Columns (1)-(5) display the findings from the fixed effects model, while Columns (6)-(10) report the results from the random effects model. Consistent with our main findings, we find a significant influence of fintech and financial inclusion on different SDGs in both models. While we recognize the importance of exploring potential differences between Islamic and non-Islamic countries, the sample size of countries with a predominantly Islamic population in our study is relatively small (12 out of 86). The countries in this subset include Algeria, Bangladesh, Egypt, Indonesia, Jordan, Kazakhstan, Mauritania, Pakistan, Saudi Arabia, Tajikistan, Turkey and the United Arab Emirates. Given the limited size of this subsample, we believe it would be difficult to draw robust, meaningful conclusions solely based on these countries.

However, we have conducted fixed-effects and random effects (Table 10) and controlled for country-specific effects to address potential variations between countries. The results remain consistent with our overall findings, suggesting that the unique characteristics of Islamic religion do not significantly alter the outcomes in our analysis. We acknowledge that

a more detailed exploration of Islamic finance might require a larger sample size of predominantly Islamic countries to yield statistically significant insights.

4.2. Income analysis

Next, we re-estimate our model based on income level using OLS. Table 11, columns (1)-(5) reveal that financial inclusion in upper-middle-income countries reduces undernourishment, advances quality education, GDP, and nurtures innovation, while fintech primarily contributes to quality education and economic growth, suggesting that traditional financial services contribute more in achieving various SDGs. Columns (6)-(10) demonstrate fintech's positive impact on supporting various SDGs in lower-middle-income countries, with financial inclusion reducing maternal deaths and boosting economic growth. Thus, Fintech and financial inclusion are resilient strategies to support SDGs based on specific economic contexts. Fintech addresses the infrastructure and affordability issues by providing a broader range of financial services in lower-income countries. In contrast, financial inclusion aims to create a more balanced and inclusive financial system in high-income countries.

4.3. Endogeneity concerns: Instrumental variable approach

We adopt the two-stage least squares (2SLS) regression analysis to mitigate the potential endogeneity issue. Following prior literature (Demir et al., 2022; Marcelin et al., 2022), we use four instruments for financial inclusion and fintech variables – accountability, rule of law, government effectiveness, and regulatory quality. The validity of our instruments is confirmed by various identification tests reported in Table 12. For all reported specifications, the Kleibergen-Paap-rk LM statistic produces a zero or near-zero p-value, suggesting that the model is correctly identified (Klapper et al., 2006) and the excluded indicators are relevant external instruments for fintech and financial inclusion. The Hansen over-identification test

fails to reject the null that our instruments are exogenous (Hansen, 1982). The results from these tests show that the instruments used are valid. The two-stage least square regression results presented in Table 12 are in line with the baseline model. The result shows that fintech and financial inclusion remain significant in contributing to various SDGs.

4.4. Alternative measures

In our main baseline model, we use a single representative proxy for various SDGs. As part of the robustness test, we replace the dependent variable with individual SDG indices for each goal, which consist of different sub-components within each index (Sachs et al., 2024). Higher values in these indices indicate better performance. We normalize the value of each indicator between 0 and 1. The results of the pooled OLS regression, presented in Table 13, indicate that the estimated coefficients of the variables are statistically significant, with the direction of the effects consistent with those in the baseline model. This consistency confirms the robustness of our findings.

We find that financial inclusion plays a significant role in supporting the overall indices of SDG 2, 3, 4, 8, and 9. However, in our baseline model, financial inclusion is insignificant in relation to secondary education. When we consider the overall SDG 4 index, its impact becomes significant, suggesting that while financial inclusion may not directly contribute to secondary education, it has a notable impact on other sub-indices of SDG 4, such as literacy rate, primary enrolment rate and other related components.

Further analyses reveal that fintech significantly impacts individual proxies; however, when considering the overall SDG indices, fintech's impact on SDG 2 (Zero Hunger) and SDG 8 (Decent Work and Economic Growth) becomes insignificant. This result suggests that while fintech influences specific aspects within these goals, its effect on the broader, aggregate SDG indices is limited. This result implies that more broad adoption and integration of fintech solutions are required for meaningful progress towards various sustainable development goals.

5. Auxiliary analysis

To address reverse causality, we use a simultaneous equations model. Specifically, we estimate a system of three equations, where SDG proxies, fintech, and financial inclusion are each treated as dependent variables, which allows us to capture the mutual relationships between these variables. Column (1)-(15) of Table 14 demonstrate a bidirectional relationship between fintech, financial inclusion and the SDGs. To elaborate, the results indicate that an increase in fintech and financial inclusion significantly reduces undernourishment, consistent with our baseline results. However, the coefficient for the impact of undernourishment on fintech and financial inclusion is significant and higher, suggesting that while improvements in fintech and financial inclusion do contribute in reducing undernourishment, the effect is relatively modest compared to how reductions in undernourishment enhance fintech adoption and financial inclusion. This relationship implies that addressing basic needs such as food security may be a stronger driver of financial inclusion and fintech growth. However, there is a higher impact of fintech and financial inclusion on maternal deaths, GDP, and internet users, compared to the reverse relationship, which suggests that fintech and financial inclusion are key enablers of broader socioeconomic development.

Interestingly, we find that financial inclusion has no significant impact on education, consistent with our baseline results. However, education has a strong and significant impact on fintech and financial inclusion, suggesting that education is a key driver of financial inclusion growth and fintech diffusion. This finding indicates that higher levels of education are essential for fostering greater engagement with financial services and accelerating the adoption of fintech solutions. We also examine the impact of individual SDGs, including SDG 2, 3, 4, 8, and 9, on fintech and financial inclusion using pooled OLS regression. The detailed results of this analysis are presented in Appendix A2. Columns (1)-(5) of Appendix A2 present the impact of different SDG indices on financial inclusion, which show that SDG indices

significantly contribute to the growth of financial inclusion. Additionally, columns (6)-(10) show that except for SDG 2, other SDG indices, including 3, 4, 8, and 9, significantly contribute to the growth of fintech diffusion. Overall, these SDGs contribute to fostering an environment that supports fintech growth and financial inclusion by promoting better health, education and economic opportunities.

6. Conclusion

It is apparent from the extant literature that financial inclusion has numerous economic benefits, including economic development, poverty alleviation and financial soundness. However, despite the rapid improvement of fintech solutions and increased financial inclusion, there is a notable gap in the existing literature on the interrelationship between fintech, financial inclusion and Sustainable Development Goals (SDGs). Our goal is to shed light on the literature by creating a financial inclusion index and investigating the impact of fintech and financial inclusion on the various SDGs.

Using a quantile regression approach for a panel dataset of 86 countries, we find that Fintech and financial inclusion are crucial in mitigating the negative impact of undernourishment and maternal deaths, contributing to SDG 2 and SDG 3. The analyses further highlight the crucial role of fintech in contributing to quality education (SDG 4) at higher quantiles. However, financial inclusion has an insignificant impact on education. This effect could be because some groups in society have less privileged access to formal credit products, both in developed and developing nations, making this useful intermediary tool antiquated in accomplishing SDGs (Kara et al., 2021). Further results suggest that fintech and financial inclusion have a significantly positive impact on GDP (SDG8) and internet (SDG9) upto the 50^{th} percentile, while in the higher percentile, its impact is reduced. FinTech has the ability to contribute to a country's sustainable development by delivering new and creative financial solutions that can assist the transition to a more sustainable and environmentally friendly

economy (Mertzanis, 2023). Thus, Fintech diffusion and financial inclusion affect SDGs through the channel of information asymmetry and Innovation diffusion theory. Overall, our cross-country analysis revealed a robust and positive correlation between fintech, financial inclusion and SDGs.

These findings hold after controlling for endogeneity and a series of robustness tests. Additionally, overall individual SDG index reveals that financial inclusion strongly supports SDGs 2, 3, 4, 8, and 9. However, fintech's impact on SDG 2 and 8 is positive but insignificant, indicating its influence on specific aspects of these goals but not the overall indices. Further analysis suggests a bidirectional causality between fintech, financial inclusion, and SDGs. This indicates a mutually reinforcing cycle where improvements in fintech and financial inclusion will support SDGs while the increase in SDGs further enhances access to financial services and fintech adoption. The findings show that financial inclusion has no significant impact on education. However, when examining reverse causality, education contributes to the growth of fintech diffusion and financial inclusion. Therefore, policymakers should prioritize investment in education and integrate financial education to foster the expansion of fintech and financial inclusion.

Policymakers and stakeholders may benefit by prioritizing and incorporating fintech and financial inclusion policies into their development agendas and policy frameworks to support SDGs' efficient growth. The study has some limitations. The study measures fintech as mobile penetration, without delving into other aspects of fintech, such as digital payment, online banking, etc. Future studies can explore the broader dimensions of fintech, to better understand their impact on different SDGs. Additionally, examining fintech' role across diverse regions and socioeconomic contexts would offer deeper insights. Our study focuses on specific SDGs, future research can examine the impact of fintech and financial inclusion on a wider range of SDGs. This would help determine whether the growth of fintech and financial

inclusion influences other areas, such as environmental sustainability, gender equality, etc, providing a more comprehensive understanding of its broader effects.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Compliance with ethical standards

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Table 1

Description of the variables.

Variable	Definition/ measurement	Source
Fintech	Mobile subscription as the percentage of population	International Telecommunication Union (ITU)
Financial Inclusion index (Developed index using PCA)	**Access to bank infrastructure (**No. of ATMs per 100000 adults, No. of Branches per 100000 adults)	FAS IMF
	Usage of financial services (Financial institution account (% age 15+), Saved at a financial institution (% age 15+), Borrowed from a formal financial institution (% age 15+), Owns a debit card (% age 15+), Received wages: into a financial institution account (% age 15+), Made a utility payment: using a financial institution account (% age 15+)	WB Findex
SDG 2: Undernourishment	Prevalence of undernourishment (% of population)	Food and Agriculture Organization (FAO)
SDG 3: Maternal deaths	Log of Number of maternal deaths	WHO
SDG 4: Education	School enrolment, secondary (% gross)	WDI
SDG 8: GDP	Log of GDP per capita	WDI
SDG 9: Internet	Individuals using the Internet (% of population)	ITU
Trade	Trade (% of GDP)	WDI
Urbanisation	Urban population (% of total)	WDI
Population growth	Growth rate of population	WDI
Investment	Gross capital formation as percentage of GDP	WDI
Government spending	General government final consumption expenditure (% of GDP)	WDI
Water facility	People using at least basic drinking water services (% of population)	WHO
Health expenditure	Domestic general government health expenditure (% of GDP)	WDI
GDP growth	GDP per capita growth (annual %)	WDI
Pre-tax Income	Pre-tax national income Top 10%	World Inequality Database
Voice and Accountability	The indicator measures the extent to which a country's citizens can participate in selecting their government, and how they enjoy freedom of expression, freedom of association, and free media. The index ranges from −2.5 to +2.5. Higher values mean greater political rights.	World Governance Indicator (WGI), World Bank
Government effectiveness	The indicator measures the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. The index ranges from −2.5 to +2.5. Higher values mean higher quality of public and civil service	World Governance Indicator (WGI), World Bank

Regulatory quality	The indicator measures the ability of the government to formulate and implement sound policies and regulations that permit and promote market competition and private-sector development. The index ranges from −2.5 to +2.5. Higher values mean higher quality of regulation.	World Governance Indicator (WGI), World Bank
Rule of Law	The indicator measures the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, the police, and the courts, as well as the likelihood of crime and violence. The index ranges from −2.5 to +2.5. Higher values indicate stronger law and order	World Governance Indicator (WGI), World Bank
Political Stability (PS)	The indicator measures the perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including political violence and terrorism. The index ranges from −2.5 to +2.5. Higher values mean more stable political environment	World Governance Indicator (WGI), World Bank
Corruption Control (CC)	The indicator measures the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as ‘‘capture’’ of the state by elites and private interests. The index ranges from −2.5 to +2.5. Higher values indicate better control of corruption	World Governance Indicator (WGI), World Bank

Table 2

Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
FI_A	344	.303	.208	0	1
ATM	344	.242	.193	.001	1
Branches	344	.256	.204	0	1
FI_U	344	.369	.244	0	1
Account	344	.576	.304	0	1
Saving	344	.299	.249	0	.946
Borrowing	344	.269	.211	0	1
Debit Card	344	.447	.307	0	1
Wages	258	.36	.286	0	1
Payment	257	.306	.304	0	1
FI index	344	.396	.237	0	1
Fintech	344	1.145	.287	.388	1.826
GDPgr	344	3.595	3.428	-7.243	14.322
Trade	332	.921	.531	.253	3.197
GDP	344	8.85	1.222	6.148	10.993
Undernourishment	328	.077	.082	.025	.388
Internet	342	.557	.272	.035	.971
Maternal deaths	255	4.316	2.719	0	11.212
Education	268	.921	.24	.253	1.474
Population	344	.92	1.187	-2.416	3.377
GCF	332	.242	.067	.096	.459
Govt exp	330	.158	.049	.053	.283
Trade	332	.921	.531	.253	3.197
Water facility	335	.917	.12	.473	1
Health exp	261	.038	.021	.005	.09
Urbanisation	344	.63	.202	.171	1
PTI	340	.442	.095	.272	.653
CC	344	.016	.949	-1.368	2.252
PS	344	-.039	.84	-2.13	1.442
Individual SDG index					
SDG Index 2	340	.564	.217	0	1
SDG Index 3	340	.701	.232	0	1
SDG Index 4	340	.755	.239	0	1
SDG Index 8	340	.587	.206	0	1
SDG Index 9	340	.519	.252	0	1
Instrumental variables					
Accountability	344	.145	.846	-1.702	1.559
Gov effectiveness	344	.186	.864	-1.312	2.218
Rule of Law	344	.109	.896	-1.377	2.013
Regulatory Quality	344	.275	.855	-1.418	2.081

Table 3

Correlation matrix of financial inclusion index components and Fintech

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) **FI index**	1.000											
(2) **FI_A**	0.892***	1.000										
(3) ATM	0.837***	0.852***	1.000									
(4) Branches	0.684***	0.851***	0.456***	1.000								
(5) **FI_U**	0.894***	0.598***	0.648***	0.375***	1.000							
(6) Account	0.869***	0.639***	0.659***	0.436***	0.920***	1.000						
(7) Savings	0.750***	0.438***	0.533***	0.211***	0.905***	0.807***	1.000					
(8) Borrowings	0.683***	0.500***	0.589***	0.239***	0.721***	0.661***	0.715***	1.000				
(9) Debit card	0.833***	0.579***	0.616***	0.370***	0.914***	0.920***	0.795***	0.666***	1.000			
(10) Wages	0.820***	0.511***	0.564***	0.296***	0.954***	0.892***	0.849***	0.766***	0.913***	1.000		
(11) Utility payment	0.815***	0.514***	0.575***	0.289***	0.937***	0.833***	0.855***	0.769***	0.859***	0.891***	1.000	
(12) **Fintech**	0.342***	0.273***	0.329***	0.142***	0.349***	0.430***	0.284***	0.286***	0.411***	0.368***	0.276***	1.000
VIF			2.335	1.389		10.381	5.353	4.072	11.812	9.355	6.359	1.268
Mean VIF	5.811											

Source: Authors' computation based on the secondary data. Note: The table reports the pairwise correlations between financial inclusion index variables, fintech and VIF mean. The FI_A and FI_U were used to measure the FI_O, by using Principal component analysis. Note: *, **, and *** respectively indicate significance at the 10 %, 5 %, and 1 % statistical levels.

Table 4

Impact of fintech on financial inclusion

	(1)	(2)	(3)
	FI_A	FI_U	FI index
Fintech	.086**	.086*	.100**
	(.036)	(.045)	(.043)
GDPgr	-.001	.002	.001
	(.003)	(.003)	(.004)
Trade	.001	.121***	.066***
	(.019)	(.021)	(.021)
Urbanisation	.368***	.538***	.527***
	(.051)	(.063)	(.058)
Constant	-.022	-.186***	-.113***
	(.039)	(.046)	(.042)
Observations	332	332	332
R-squared	.164	.349	.297

Notes: Authors' computation based on secondary data. Robust standard errors are in parentheses, *** p<.01, ** p<.05, * p<.1

Table 5

Impact of fintech and financial inclusion on SDG 2 – Zero Hunger.

	(1)	(2)	(3)	(4)	(5)
	(.10)	(.25)	(.50)	(.75)	(.90)
	Undernourishment	Undernourishment	Undernourishment	Undernourishment	Undernourishment
Fintech	-.013*	-.034***	-.054***	-.081***	-.132***
	(.007)	(.008)	(.011)	(.019)	(.027)
FI index	-.011	-.033***	-.067***	-.139***	-.207***
	(.008)	(.008)	(.01)	(.018)	(.037)
GDPgr	-.001	-.001**	-.002**	-.004***	-.003
	(.001)	(0)	(.001)	(.001)	(.002)
Health exp	-.174	-.219**	-.243**	-.021	-.617
	(.171)	(.088)	(.096)	(.239)	(.459)
Urbanisation	-.014	-.019*	-.043***	-.061**	-.062
	(.01)	(.01)	(.016)	(.03)	(.047)
Constant	.064***	.114***	.192***	.294***	.462***
	(.021)	(.014)	(.021)	(.038)	(.039)
Observations	252	252	252	252	252
R- Squared	.008	.104	.249	.34	.426
Mean VIF	1.909				

Notes: Authors' computation based on secondary data. Robust standard errors are in parentheses, *** p<.01, ** p<.05, * p<.1

Table 6

Impact of fintech and financial inclusion on SDG 3 – Good health and well-being.

	(1) (.10)	(2) (.25)	(3) (.50)	(4) (.75)	(5) (.90)
	Maternal Deaths	Maternal Deaths	Maternal Deaths	Maternal Deaths	Maternal Deaths
Fintech	-1.042	-.63	-2.758***	-3.261***	-3.054***
	(.748)	(.545)	(.621)	(.61)	(1.117)
FI index	-2.41***	-4.094***	-5.172***	-4.66***	-5.744***
	(.786)	(.628)	(.785)	(.666)	(1.22)
Undernourishment	.658	1.947	.658	-.105	-10.887**
	(1.98)	(1.632)	(1.951)	(2.238)	(4.527)
Urbanisation	3.702***	.983	-.312	-2.356**	-2.762
	(1.245)	(.876)	(1.087)	(1.001)	(1.992)
Water facility	-12.298***	-7.72***	-2.467	-.115	-4.643*
	(2.222)	(2.398)	(1.614)	(1.987)	(2.615)
Constant	13.15***	11.571***	11.724***	12.773***	19.134***
	(.903)	(1.622)	(.956)	(1.726)	(2.679)
Observations	237	237	237	237	237
R -Squared	.28	.324	.372	.363	.315
Mean VIF	2.265				

Notes: Authors' computation based on secondary data. Robust standard errors are in parentheses, *** p<.01, ** p<.05, * p<.1

Table 7

Impact of fintech and financial inclusion on SDG 4 – Quality Education.

	(1) (.10)	(2) (.25)	(3) (.50)	(4) (.75)	(5) (.90)
	Education	Education	Education	Education	Education
Fintech	.087	.086	.166***	.153***	.216***
	(.053)	(.076)	(.036)	(.036)	(.056)
FI index	.107	-.111	.061	.039	.066
	(.08)	(.104)	(.062)	(.066)	(.073)
GDP	.075***	.107***	.075***	.093***	.094***
	(.022)	(.029)	(.014)	(.014)	(.021)
Internet	.399***	.361***	.274***	.192***	.095
	(.063)	(.124)	(.057)	(.052)	(.075)
Trade	-.017	-.05*	-.054***	-.067***	-.094**
	(.037)	(.029)	(.009)	(.013)	(.038)
Constant	-.309**	-.332	-.063	-.074	-.016
	(.132)	(.204)	(.096)	(.092)	(.15)
Observations	258	258	258	258	258
R -Squared	.534	.421	.366	.332	.358
Mean VIF	2.771				

Notes: Authors' computation based on secondary data. Robust standard errors are in parentheses, *** p<.01, ** p<.05, * p<.1

Table 8

Impact of fintech and financial inclusion on SDG 8 – Decent work and economic growth.

	(1)	(2)	(3)	(4)	(5)
	(.10)	(.25)	(.50)	(.75)	(.90)
	GDP	GDP	GDP	GDP	GDP
Fintech	.991***	1.044***	1.159***	.978***	.735***
	(.228)	(.152)	(.165)	(.184)	(.161)
FI index	3.02***	3.82***	3.673***	3.279***	3.313***
	(.462)	(.275)	(.175)	(.27)	(.167)
Population	-.003	.076**	.083**	.078	-.003
	(.057)	(.035)	(.04)	(.065)	(.046)
GCF	-2.008***	.401	.213	-.785	-1.388**
	(.748)	(.619)	(.628)	(.83)	(.655)
Govt exp	3.995***	3.433***	4.278***	3.042***	1.74*
	(1.127)	(.864)	(.948)	(.891)	(1.02)
Trade	.03	.124	.16**	.18	.325***
	(.179)	(.104)	(.075)	(.141)	(.108)
Constant	5.572***	4.982***	5.09***	6.329***	7.292***
	(.303)	(.214)	(.276)	(.362)	(.267)
Observations	330	330	330	330	330
R-squared	.47	.527	.534	.495	.481
Mean VIF	1.325				

Notes: Authors' computation based on secondary data. Robust standard errors are in parentheses, *** p<.01, ** p<.05, * p<.1

Table 9

Impact of fintech and financial inclusion on SDG 9 – Innovation and Infrastructure.

	(1)	(2)	(3)	(4)	(5)
	(.10)	(.25)	(.50)	(.75)	(.90)
	Internet	Internet	Internet	Internet	Internet
Fintech	.218***	.248***	.334***	.278***	.126**
	(.065)	(.045)	(.041)	(.056)	(.049)
FI index	.543***	.685***	.714***	.576***	.455***
	(.098)	(.07)	(.041)	(.075)	(.055)
Trade	.039	.03	.032*	.019	.014
	(.039)	(.03)	(.018)	(.02)	(.015)
PTI	-.524**	-.429***	-.309**	-.193	-.168
	(.216)	(.15)	(.129)	(.182)	(.157)
GDP gr	.003	.005	.009***	.009**	.006**
	(.004)	(.004)	(.002)	(.004)	(.002)
Constant	.058	.035	-.041	.141	.505***
	(.133)	(.091)	(.08)	(.117)	(.106)
Observations	326	326	326	326	326
R- Squared	.37	.438	.424	.312	.185
Mean VIF	1.268				

Notes: Authors' computation based on secondary data. Robust standard errors are in parentheses, *** p<.01, ** p<.05, * p<.1

Table 10
Panel Fixed effects and Random effects model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Undernourishment	Maternal Deaths	Education	GDP	Internet	Undernourishment	Maternal Deaths	Education	GDP	Internet
Fintech	-.025**	-.182**	.100**	.274***	.33***	-.036***	-.169**	.093**	.322***	.299***
	(.012)	(.072)	(.049)	(.052)	(.088)	(.011)	(.07)	(.045)	(.058)	(.055)
FI index	-.084***	-.273	.001	.382**	.626***	-.102***	-.506**	.043	.963***	.622***
	(.031)	(.213)	(.147)	(.147)	(.175)	(.027)	(.224)	(.105)	(.146)	(.079)
GDP gr	-.001				.014***	-.001				.009***
	(.001)				(.004)	(.001)				(.004)
Govt health exp	-.718*					-.566*				
	(.395)					(.294)				
Urbanisation	-.076	-4.03***				-.064*	-4.109***			
	(.195)	(1.304)				(.033)	(1.048)			
Undernourishment		.03					.115			
		(.583)					(.595)			
Water facility		-.629					-1.436			
		(1.092)					(.971)			
GDP			.031					.113***		
			(.065)					(.026)		
Internet			.119**					.092**		
			(.055)					(.043)		
Trade			-.012	.056	-.195			-.023	.184*	.002
			(.034)	(.112)	(.148)			(.02)	(.103)	(.026)
Population				-.015					-.024*	
				(.014)					(.014)	
GCF				.721***					.548**	
				(.259)					(.234)	
Govt exp				.536					.942*	
				(.499)					(.523)	
PTI					-.272					-.33*
					(.582)					(.181)
Constant	.214*	7.734***	.481	8.12***	.174	.221***	8.608***	-.247	7.701***	.07
	(.114)	(.791)	(.556)	(.152)	(.344)	(.026)	(.649)	(.185)	(.176)	(.111)
Observations	252	237	258	330	326	252	237	258	330	326
R-squared	.406	.303	.632	.606	.408	.428	.343	.627	.694	.570

Notes: Authors' computation based on secondary data. Robust standard errors are in parentheses, *** p<.01, ** p<.05, * p<.1

Table 11
Impact of fintech and financial inclusion on different SDGs for countries with different income

	A. Upper-Middle-Income Countries					B. Lower-Middle-Income Countries				
	(1) Undernourishment	(2) Maternal Deaths	(3) Education	(4) GDP	(5) Internet	(6) Undernourishment	(7) Maternal Deaths	(8) Education	(9) GDP	(10) Internet
Fintech	.025	-.135	.142**	.386***	.052	-.166***	-4.044***	.128*	.641***	.426***
	(.019)	(.784)	(.059)	(.143)	(.067)	(.031)	(1.123)	(.074)	(.17)	(.073)
FI index	-.178***	-1.465	.401***	1.267***	.247*	-.041	-2.247*	.237	1.013***	.196
	(.062)	(2.637)	(.125)	(.3)	(.146)	(.063)	(1.186)	(.187)	(.185)	(.164)
GDP gr	-.002				.006	-.003				-.002
	(.002)				(.005)	(.004)				(.007)
Govt health exp	-.18					.574				
	(.342)					(1.006)				
Urbanisation	-.048*	8.944***				.028	-1.88			
	(.028)	(1.58)				(.1)	(1.245)			
Undernourishment		9.63*					-6.003**			
		(5.722)					(2.469)			
Water facility		-6.954					-.804			
		(6.123)					(1.788)			
GDP			.055					.069		
			(.039)					(.059)		
Internet			.11					.351***		
			(.108)					(.12)		
Trade			-.179***	-.447***	-.082			-.011	-.188	-.057
			(.05)	(.131)	(.059)			(.062)	(.152)	(.071)
Population				.059**					-.049	
				(.029)					(.068)	
GCF				1.579*					-.064	
				(.799)					(.447)	
Govt exp				-1.22*					4.106***	
				(.691)					(.899)	
PTI					-.389**					.128
					(.176)					(.252)
Constant	.137***	5.106	.211	8.009***	.648***	.292***	13.668***	-.088	6.464***	-.198
	(.037)	(5.595)	(.358)	(.316)	(.134)	(.048)	(2.036)	(.414)	(.264)	(.149)
Observations	78	77	97	110	110	74	72	51	95	89
R-squared	.178	.391	.255	.193	.103	.245	.337	.421	.397	.334

Notes: Countries are classified according to the World Bank's 2015 income group classification. Authors' computation based on secondary data. Robust standard errors are in parentheses, *** p<.01, ** p<.05, * p<.1

Table 12

Endogeneity concerns: Instrumental variable approach

	(1) Undernourishment	(2) Maternal Deaths	(3) Education	(4) GDP	(5) Internet
Fintech	-.161***	-10.177***	.489***	3.3***	.766***
	(.05)	(3.569)	(.189)	(.859)	(.213)
FI index	-.148***	-7.785***	.402*	4.167***	.541***
	(.044)	(1.105)	(.244)	(.547)	(.144)
GDP gr	-.002				.003
	(.002)				(.005)
Govt health exp	.063				
	(.38)				
Urbanisation	.01	3.619**			
	(.038)	(1.544)			
Undernourishment		-5.79			
		(3.702)			
Water facility		2.731			
		(3.05)			
GDP			.008		
			(.044)		
Internet			.199**		
			(.095)		
Trade			-.07***	-.075	-.033
			(.019)	(.11)	(.03)
Population				.224***	
				(.056)	
GCF				-1.087	
				(.894)	
Govt exp				.282	
				(1.2)	
PTI					-.333*
					(.19)
Constant	.317***	14.731***	.058	3.494***	-.38**
	(.042)	(2.157)	(.244)	(.766)	(.151)
Observations	252	237	258	330	326
R-squared	.411	.122	.514	.476	.356
Kleibergen-Paap rk LM statistic (P-value)	17.601 (0.0005)	9.387 (0.0092)	12.459 (0.0060)	14.851 (0.0019)	11.175 (0.0108)
Hansen J statistic (P-value)	3.060 (0.2166)	0.787 (0.3751)	0.086 (0.9580)	2.637 (0.2676)	3.490 (0.1746)

Note: This table reports the results of 2SLS regression. Robust standard errors are in parentheses, *** p<.01, ** p<.05, * p<.1

Table 13

Alternative measures

	(1) SDG Index 2	(2) SDG Index 3	(3) SDG Index 4	(4) SDG Index 8	(5) SDG Index 9
Fintech	.035	.094**	.2***	.056	.183***
	(.053)	(.046)	(.055)	(.042)	(.045)
FI index	.194**	.166***	.297***	.45***	.576***
	(.086)	(.055)	(.07)	(.055)	(.073)
GDP gr	.003				-.001
	(.004)				(.003)
Govt health exp	3.039***				
	(1.067)				
Urbanisation	-.025	.268***			
	(.087)	(.054)			
Undernourishment		-1.011***			
		(.132)			
PTI		-.452***			-.203*
		(.108)			(.113)
GDP			.031		
			(.02)		
Internet			.126*		
			(.072)		
PS			-.005		.003
			(.014)		(.018)
Govt exp			-.915***	-.009	
			(.231)	(.239)	
Population				.001	
				(.012)	
GCF				.342**	
				(.161)	
Trade				-.008	.039*
				(.02)	(.022)
Constant	.337***	.633***	.218	.436***	.134*
	(.051)	(.079)	(.143)	(.074)	(.081)
Observations	261	328	324	326	328
R-squared	.227	.624	.404	.331	.506

Note: This table reports regression results with the overall individual SDG index. Robust standard errors are in parentheses, *** p<.01, ** p<.05, * p<.1

Table 14
Simultenous Equation Model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Undernourishment	Fintech	FI index	Maternal Deaths	Fintech	FI index	Education	Fintech	FI index	GDP	Fintech	FI index	Internet	Fintech	FI index
Fintech	**-.088*** **			**-2.379*** **			**.149*** **			**.988*** **			**.27*** **		
	(.016)			**(.547)**			**(.04)**			**(.134)**			**(.038)**		
FI index	**-.126*** **			**-5.274*** **			**.054**			**3.303*** **			**.618*** **		
	(.023)			**(.549)**			**(.061)**			**(.23)**			**(.053)**		
Undernourishment		**-1.122*** **	**-.818*** **	.971											
		(.183)	**(.105)**	(2.158)											
Maternal Deaths					**-.012**	**-.037*** **									
					(.008)	**(.005)**									
Education								**.405*** **	**.278*** **						
								(.099)	**(.056)**						
GDP							.082***				**.063*** **	**.176*** **			
							(.016)				**(.022)**	**(.012)**			
Internet							.297***							**.236*** **	**.326*** **
							(.064)							**(.072)**	**(.057)**
GDP gr	-.003*	.002	-.001		.01*	.001		0	-.002				.005	.004	-.001
	(.002)	(.004)	(.003)		(.006)	(.004)		(.004)	(.003)				(.004)	(.004)	(.003)
Gov health exp	-.193														
	(.277)														
Urbanization	-.042	.209***	.046	.453	.36***	.013		.078	-.08		.066	-.315***		.137	-.062
	(.025)	(.079)	(.05)	(.855)	(.09)	(.058)		(.088)	(.056)		(.096)	(.054)		(.084)	(.06)
Trade		.044	.029**		.05	-.075***	-.052***	.061**	.025	.242***	.037	-.016	.026	.029	-.001
		(.033)	(.015)		(.035)	(.024)	(.013)	(.026)	(.016)	(.077)	(.026)	(.015)	(.017)	(.026)	(.016)
PS		.059***			.093***			.056**			.073***			.085***	
		(.021)			(.026)			(.024)			(.024)			(.022)	
COC			.123***			.136***			.111***			.027**			.116***
			(.015)			(.016)			(.017)			(.013)			(.014)
Gov exp			.768***			.024			1.022***	3.562***		.398**			.438*
			(.261)			(.297)			(.285)	(.823)		(.189)			(.237)
Water facility				-4.115**											
				(1.795)											
Population										.036					
										(.037)					

GCF										-.907					
										(.583)					
PTI													-.304**		
													(.126)		
Constant	.269***	1.073***	.295***	12.551***	.895***	.599***	-.134	.689***	.025	5.819***	.524***	-1.01***	.088	.896***	.191***
	(.024)	(.071)	(.052)	(1.421)	(.08)	(.085)	(.104)	(.092)	(.06)	(.249)	(.168)	(.082)	(.076)	(.059)	(.047)
Observations	252	317	315	237	249	248	258	258	256	330	332	330	326	330	328
R-squared	.468	.32	.633	.547	.316	.628	.648	.312	.602	.743	.27	.698	.575	.282	.602

Note: This table reports simultaneous equation model result with individual SDGs proxies. Robust standard errors are in parentheses, *** p<.01, ** p<.05, * p<.1

References

- Allen, F., Demirguc-Kunt, A., Klapper, L., & Martinez Peria, M. S. (2016). The foundations of financial inclusion: Understanding ownership and use of formal accounts. *Journal of Financial Intermediation*, *27*, 1–30. https://doi.org/10.1016/j.jfi.2015.12.003
- Altunbaş, Y., & Thornton, J. (2019). The impact of financial development on income inequality: A quantile regression approach. *Economics Letters*, *175*, 51–56. https://doi.org/10.1016/j.econlet.2018.12.030
- Arner, D. W., Buckley, R. P., Zetzsche, D. A., & Veidt, R. (2020). Sustainability, FinTech and Financial Inclusion. *European Business Organization Law Review*, *21*(1), 7–35. https://doi.org/10.1007/s40804-020-00183-y
- Ashraf, N., Karlan, D., & Yin, W. (2010). Female Empowerment: Impact of a Commitment Savings Product in the Philippines. *World Development*, *38*(3), 333–344. https://doi.org/10.1016/j.worlddev.2009.05.010
- Asongu, S. A., Nnanna, J., & Acha-Anyi, P. N. (2020). Finance, inequality and inclusive education in Sub-Saharan Africa. *Economic Analysis and Policy*, *67*, 162–177. https://doi.org/10.1016/j.eap.2020.07.006
- Assouto, A. B., & Houngbeme, D. J. L. (2023). Access to credit and agricultural productivity: Evidence from maize producers in Benin. *Cogent Economics and Finance*, *11*(1). https://doi.org/10.1080/23322039.2023.2196856
- Banerjee, A., Duflo, E., Glennerster, R., & Kinnan, C. (2015). The miracle of microfinance? Evidence from a randomized evaluation. *American Economic Journal: Applied Economics*, *7*(1), 22–53. https://doi.org/10.1257/app.20130533
- Banna, H., Mia, M. A., Nourani, M., & Yarovaya, L. (2022). Fintech-based Financial Inclusion and Risk-taking of Microfinance Institutions (MFIs): Evidence from Sub-Saharan Africa. *Finance Research Letters*, *45*(May 2021), 102149. https://doi.org/10.1016/j.frl.2021.102149
- Beyene, S. D. (2023). The impact of food insecurity on health outcomes: empirical evidence from sub-Saharan African countries. *BMC Public Health*, *23*(1), 1–22. https://doi.org/10.1186/s12889-023-15244-3
- Blencowe, H., Cousens, S., Mullany, L. C., Lee, A. C., Kerber, K., Wall, S., Darmstadt, G. L., & Lawn, J. E. (2011). Clean birth and postnatal care practices to reduce neonatal deaths from sepsis and tetanus: A systematic review and Delphi estimation of mortality effect. *BMC Public Health*, *11*(SUPPL. 3). https://doi.org/10.1186/1471-2458-11-S3-S11
- Boeren, E. (2019). Understanding Sustainable Development Goal (SDG) 4 on "quality education" from micro, meso and macro perspectives. *International Review of Education*, *65*(2), 277–294. https://doi.org/10.1007/s11159-019-09772-7
- Canay, I. A. (2011). A simple approach to quantile regression for panel data. *Econometrics*

Journal, *14*(3), 368–386. https://doi.org/10.1111/j.1368-423X.2011.00349.x

- Chaudhuri, A., Flamm, K. S., & Horrigan, J. (2005). An analysis of the determinants of internet access. *Telecommunications Policy*, *29*(9–10), 731–755. https://doi.org/10.1016/j.telpol.2005.07.001
- Chen, Q., & Shen, C. (2024). How FinTech Affects Bank Systemic Risk: Evidence from China. *Journal of Financial Services Research*, *65*(1), 77–101. https://doi.org/10.1007/s10693-023-00421-7
- Cheng, J. J., Schuster-Wallace, C. J., Watt, S., Newbold, B. K., & Mente, A. (2012). An ecological quantification of the relationships between water, sanitation and infant, child, and maternal mortality. *Environmental Health: A Global Access Science Source*, *11*(1), 1–8. https://doi.org/10.1186/1476-069X-11-4
- Choudhary, P., & Thenmozhi, M. (2024). International Review of Financial Analysis Fintech and financial sector : ADO analysis and future research agenda. *International Review of Financial Analysis*, *93*(October 2023), 103201. https://doi.org/10.1016/j.irfa.2024.103201
- Daud, S. N. M., & Ahmad, A. H. (2023). Financial inclusion, economic growth and the role of digital technology. *Finance Research Letters*, *53*(December 2022), 103602. https://doi.org/10.1016/j.frl.2022.103602
- Demir, A., Pesqué-Cela, V., Altunbas, Y., & Murinde, V. (2022). Fintech, financial inclusion and income inequality: a quantile regression approach. *European Journal of Finance*, *28*(1), 86–107. https://doi.org/10.1080/1351847X.2020.1772335
- Ding, L., & Xue, P. (2023). Incentives or disincentives ? Intellectual property protection and FinTech innovation - Evidence from Chinese cities. *Finance Research Letters*, *58*(PB), 104451. https://doi.org/10.1016/j.frl.2023.104451
- Dong, X., & Yu, M. (2023). Does FinTech development facilitate firms' innovation? Evidence from China. *International Review of Financial Analysis*, *89*(April 2023), 102805. https://doi.org/10.1016/j.irfa.2023.102805
- Dubey, T. S., & Purnanandam, A. (2023). Can Cashless Payments Spur Economic Growth? *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4373602
- Eini-Zinab, H., Edalati, S., Sobhani, S. R., Kezabi, M. F., & Hosseini, S. (2020). Undernourishment trends and determinants: an ecological study of 76 countries. *Public Health*, *186*, 230–239. https://doi.org/10.1016/j.puhe.2020.07.013
- Flug, K., Spilimbergo, A., & Wachtenheim, E. (1998). Investment in education: do economic volatility and credit constraints matter? *Journal of Development Economics*, *55*(2), 465–481. https://doi.org/10.1016/S0304-3878(98)00045-5
- Freund, C. L., & Weinhold, D. (2004). The effect of the Internet on international trade. *Journal of International Economics*, *62*(1), 171–189. https://doi.org/10.1016/S0022-1996(03)00059-X

- Fuster, A., Plosser, M., Schnabl, P., & Vickery, J. (2019). The Role of Technology in Mortgage Lending. *Review of Financial Studies*, *32*(5), 1854–1899. https://doi.org/10.1093/rfs/hhz018
- Galabada, J. K. (2022). Towards the Sustainable Development Goal of Zero Hunger: What Role Do Institutions Play? *Sustainability (Switzerland)*, *14*(8). https://doi.org/10.3390/su14084598
- Ghosh, S. (2016). Does mobile telephony spur growth? Evidence from Indian states. *Telecommunications Policy*, *40*(10–11), 1020–1031. https://doi.org/10.1016/j.telpol.2016.05.009
- Glewwe, P., Maïga, E., & Zheng, H. (2014). The contribution of education to economic growth: A review of the evidence, with special attention and an application to sub-Saharan Africa. *World Development*, *59*, 379–393. https://doi.org/10.1016/j.worlddev.2014.01.021
- Gosavi, A. (2018). Can Mobile Money Help Firms Mitigate the Problem of Access to Finance in Eastern sub-Saharan Africa? *Journal of African Business*, *19*(3), 343–360. https://doi.org/10.1080/15228916.2017.1396791
- Haini, H. (2019). Internet penetration, human capital and economic growth in the ASEAN economies: evidence from a translog production function. *Applied Economics Letters*, *26*(21), 1774–1778. https://doi.org/10.1080/13504851.2019.1597250
- Hansen, lars peter. (1982). Large Sample Properties of Generalized Method of Moments Estimators Author(s): Lars Peter Hansen Source: *Econometrica*, *50*(4), 1029–1054.
- Harb, G. (2017). The economic impact of the Internet penetration rate and telecom investments in Arab and Middle Eastern countries. *Economic Analysis and Policy*, *56*, 148–162. https://doi.org/10.1016/j.eap.2017.08.009
- Ito, I., Sasaki, T., Yoneyama, N., Kobayashi, N., Hanasaki, N., Tajima, H., Ito, T., & Iwasa, Y. (2004). Infrared optical conductivity and the electronic phase diagram in the organic superconductor κ-(BEDT-TTF)2X. In *Journal De Physique. IV : JP* (Vol. 114). https://doi.org/10.1016/j.asieco.2004.02.005
- Kanga, D., Oughton, C., Harris, L., & Murinde, V. (2022). The diffusion of fintech, financial inclusion and income per capita. *European Journal of Finance*, *28*(1), 108–136. https://doi.org/10.1080/1351847X.2021.1945646
- Kara, A., Zhou, H., & Zhou, Y. (2021). Achieving the United Nations' sustainable development goals through financial inclusion: A systematic literature review of access to finance across the globe. *International Review of Financial Analysis*, *77*(June), 101833. https://doi.org/10.1016/j.irfa.2021.101833
- Klapper, L., Laeven, L., & Rajan, R. (2006). Entry regulation as a barrier to entrepreneurship. *Journal of Financial Economics*, *82*(3), 591–629. https://doi.org/10.1016/j.jfineco.2005.09.006
- Klugman, J., Li, L., Barker, K. M., Parsons, J., & Dale, K. (2019). How are the domains of

women's inclusion, justice, and security associated with maternal and infant mortality across countries? Insights from the Women, Peace, and Security Index. *SSM - Population Health*, *9*(August 2018). https://doi.org/10.1016/j.ssmph.2019.100486

- Koenker, R., & Bassett, G. (1978). Regression Quantiles Author (s): Roger Koenker , Gilbert Bassett and Jr . Published by : The Econometric Society Stable URL : https://www.jstor.org/stable/1913643 The Econometric Society is collaborating with JSTOR to digitize , preserve and extend acce. *Econometrica*, *46*(1), 33–50.
- Krishna, A. (2006). Pathways out of and into poverty in 36 villages of Andhra Pradesh, India. *World Development*, *34*(2), 271–288. https://doi.org/10.1016/j.worlddev.2005.08.003
- Kumar, A. K. S. (2007). Why are levels of child malnutrition not improving? *Economic and Political Weekly*, *42*(15), 1337–1345.
- Li, J., Lu, Y., Song, H., & Xie, H. (2019). Long-term impact of trade liberalization on human capital formation. *Journal of Comparative Economics*, *47*(4), 946–961. https://doi.org/10.1016/j.jce.2019.08.002
- Liu, Y., Luan, L., Wu, W., Zhang, Z., & Hsu, Y. (2021). Can digital financial inclusion promote China's economic growth? *International Review of Financial Analysis*, *78*(August), 101889. https://doi.org/10.1016/j.irfa.2021.101889
- Luo, S., Sun, Y., & Zhou, R. (2022). Can fintech innovation promote household consumption? Evidence from China family panel studies. *International Review of Financial Analysis*, *82*(March), 102137. https://doi.org/10.1016/j.irfa.2022.102137
- Lyons, A. C., Kass-Hanna, J., & Fava, A. (2022). Fintech development and savings, borrowing, and remittances: A comparative study of emerging economies. *Emerging Markets Review*, *51*(PA), 100842. https://doi.org/10.1016/j.ememar.2021.100842
- Marcelin, I., Sun, W., Teclezion, M., & Junarsin, E. (2022a). Financial inclusion and bank risk-taking: the effect of information sharing. *Finance Research Letters*, *50*(July), 103182. https://doi.org/10.1016/j.frl.2022.103182
- Marcelin, I., Sun, W., Teclezion, M., & Junarsin, E. (2022b). Financial inclusion and bank risk-taking: the effect of information sharing. *Finance Research Letters*, *50*(May), 103182. https://doi.org/10.1016/j.frl.2022.103182
- Mehry, E.-B., Ashraf, S., & Marwa, E. (2021). the Impact of Financial Inclusion on Unemployment Rate in Developing Countries. *International Journal of Economics and Financial Issues*, *11*(1), 79–93. https://doi.org/10.32479/ijefi.10871
- Member, R. M. (2001). Characteristics and Choices of Internet Users. *Energy*, *February*.
- Mertzanis, C. (2023). FinTech finance and social-environmental performance around the world. *Finance Research Letters*, *56*(April). https://doi.org/10.1016/j.frl.2023.104107
- Minh, T. N., Ngoc, A. M., Tuan, A. N., & Dao, T. N. (2022). Corporate social responsibility,

market rivalry and firm leverage: new evidence from a fixed-effect quantile regression approach. *Finance Research Letters*, *47*(PB), 102794. https://doi.org/10.1016/j.frl.2022.102794

- Munch, J. R., & Skaksen, J. R. (2008). Human capital and wages in exporting firms. *Journal of International Economics*, *75*(2), 363–372. https://doi.org/10.1016/j.jinteco.2008.02.006
- Ni, Q., Zhang, L., & Wu, C. (2023). Fintech and commercial bank risks–The moderating effect of financial regulation. *Finance Research Letters*, *58*(PC), 104536. https://doi.org/10.1016/j.frl.2023.104536
- Petrakis, P. E., & Stamatakis, D. (2002). Growth and educational levels: A comparative analysis. *Economics of Education Review*, *21*(5), 513–521. https://doi.org/10.1016/S0272-7757(01)00050-4
- Prasad, E. S. (2011). Financial sector regulation and reforms in emerging markets: An overview. *Financial Market Regulation and Reforms in Emerging Markets*, 3–24. https://doi.org/10.2139/ssrn.1693330
- Rosenzweig, S. (2017). The effects of diversified technology and country knowledge on the impact of technological innovation. *Journal of Technology Transfer*, *42*(3), 564–584. https://doi.org/10.1007/s10961-016-9492-5
- Sachs, J. D., Lafortune, G., & Fuller, G. (2024). The SDGs and the UN Summit of the Future. Sustainable Development Report 2024. In *Sustainable Development Solkutions Network*. https://doi.org/10.25546/108572
- Sachs, J. D., Lafortune, G., Fuller, G., & Drumm, E. (2023). *Sustainable Development Report 2023 (with indicators)*. *June*, 1–534. https://dashboards.sdgindex.org/
- Soriano, B., & Garrido, A. (2016). How important is economic growth for reducing undernourishment in developing countries? *Food Policy*, *63*, 87–101. https://doi.org/10.1016/j.foodpol.2016.07.004
- Subramanyam, M. A., Kawachi, I., Berkman, L. F., & Subramanian, S. V. (2011). Is economic growth associated with reduction in child undernutrition in India? *PLoS Medicine*, *8*(3). https://doi.org/10.1371/journal.pmed.1000424
- Suhrab, M., Chen, P., & Ullah, A. (2024). Digital financial inclusion and income inequality nexus: Can technology innovation and infrastructure development help in achieving sustainable development goals? *Technology in Society*, *76*(November 2023), 102411. https://doi.org/10.1016/j.techsoc.2023.102411
- Szabo, S. (2016). Urbanisation and Food Insecurity Risks: Assessing the Role of Human Development. *Oxford Development Studies*, *44*(1), 28–48. https://doi.org/10.1080/13600818.2015.1067292
- Tao, Z., Wang, X., Li, J., & Wei, X. (2023). How can digital financial inclusion reduces relative

poverty? An empirical analysis based on China household finance survey. *Finance Research Letters*, *58*(PC), 104570. https://doi.org/10.1016/j.frl.2023.104570

- Tiberius, V., Gojowy, R., & Dabić, M. (2022). Forecasting the future of robo advisory: A three-stage Delphi study on economic, technological, and societal implications. *Technological Forecasting and Social Change*, *182*(October 2021). https://doi.org/10.1016/j.techfore.2022.121824
- United Nations. (2018). *Igniting Sdg Progress Through Digital*. 45. https://www.betterthancash.org/tools-research/reports/igniting-sdg-progress-through-digital-financial-inclusion
- Varsakelis, N. C. (2006). Education, political institutions and innovative activity: A cross-country empirical investigation. *Research Policy*, *35*(7), 1083–1090. https://doi.org/10.1016/j.respol.2006.06.002
- Xie, X., & Zhu, X. (2022). FinTech and capital allocation efficiency: Another equity-efficiency dilemma? *Global Finance Journal*, *53*(January), 100741. https://doi.org/10.1016/j.gfj.2022.100741
- Yang, F., & Masron, T. A. (2024). Role of financial inclusion and digital transformation on bank credit risk. *Journal of International Financial Markets, Institutions and Money*, *91*(December 2023), 101934. https://doi.org/10.1016/j.intfin.2023.101934
- Yang, T., & Zhang, X. (2022). FinTech adoption and financial inclusion: Evidence from household consumption in China. *Journal of Banking and Finance*, *145*, 106668. https://doi.org/10.1016/j.jbankfin.2022.106668

Appendix A1:
list of countries with financial inclusion index

High Income	FI_index	Low Income	FI_index	Lower Middle Income	FI_index	Upper Middle Income	FI_index
Canada	0.9817	Malawi	0.1498	Mongolia	0.7705	Bulgaria	0.6880
Spain	0.9042	Uganda	0.1032	Bolivia	0.4402	Thailand	0.5106
Australia	0.8881	Madagascar	0.0178	Indonesia	0.2751	Brazil	0.5043
Portugal	0.8758			Honduras	0.2243	Serbia	0.4583
Japan	0.8011			India	0.2114	Mauritius	0.4398
Austria	0.7797			El Salvador	0.1981	North Macedonia	0.4392
New Zealand	0.7503			Kenya	0.1937	Romania	0.4302
Italy	0.7259			Philippines	0.1859	Turkey	0.4300
Slovenia	0.7026			Vietnam	0.1716	Bosnia and Herzegovina	0.4286
Croatia	0.6993			Nepal	0.1685	Georgia	0.4261
Denmark	0.6910			Nigeria	0.1569	Costa Rica	0.4150
Israel	0.6755			Kyrgyz Republic	0.1534	Moldova	0.4103
Ireland	0.6585			West Bank and Gaza	0.1495	Malaysia	0.4034
Malta	0.6219			Bangladesh	0.1425	South Africa	0.3588
Cyprus	0.6133			Ghana	0.1391	Kazakhstan	0.3381
Slovak Republic	0.5871			Cambodia	0.1380	Panama	0.3378
Estonia	0.5854			Nicaragua	0.1305	Guatemala	0.3282
Netherlands	0.5835			Zimbabwe	0.1222	Armenia	0.3276
Finland	0.5797			Algeria	0.1185	Argentina	0.2953
Poland	0.5597			Zambia	0.1064	Lebanon	0.2936
Czech Republic	0.5448			Mauritania	0.1045	Peru	0.2908
Latvia	0.5323			Tajikistan	0.1005	Albania	0.2700
Singapore	0.5240			Egypt	0.0923	Dominican Republic	0.2698
Greece	0.4869			Pakistan	0.0784	Mexico	0.2695
Hungary	0.4522			Congo, Republic	0.0507	Colombia	0.2681
United Arab Emirates	0.4242					Ecuador	0.2421
Uruguay	0.4235					Botswana	0.2228
Lithuania	0.4165					Jordan	0.2059
Chile	0.3829						
Saudi Arabia	0.3739						

Appendix A2:

Impact of individual SDG index on fintech and financial inclusion

	(1) FI index	(2) FI index	(3) FI index	(4) FI index	(5) FI index	(6) Fintech	(7) Fintech	(8) Fintech	(9) Fintech	(10) Fintech
SDG index 2	**.169*** **					**.066**				
	(.051)					**(.074)**				
SDG index 3		**.314*** **					**.315*** **			
		(.063)					**(.097)**			
SDG index 4			**.287*** **					**.373*** **		
			(.05)					**(.078)**		
SDG index 8				**.311*** **					**.187*** **	
				(.048)					**(.071)**	
SDG index 9					**.271*** **					**.254*** **
					(.07)					**(.061)**
GDP gr	.002	.001	-.001		.001	.007	.006	.003		.007
	(.003)	(.003)	(.003)		(.003)	(.004)	(.004)	(.004)		(.004)
Urbanisation	.112**	.01	.055	.17***	.08*	.458***	.297***	.33***	.42***	.328***
	(.048)	(.052)	(.044)	(.048)	(.046)	(.077)	(.089)	(.076)	(.077)	(.082)
Trade	.008	-.004	.002	.021	.003	.093***	.071***	.073***	.102***	.072***
	(.017)	(.016)	(.016)	(.015)	(.016)	(.025)	(.025)	(.024)	(.025)	(.024)
COC	.13***	.118***	.122***	.104***	.102***					
	(.014)	(.016)	(.016)	(.017)	(.019)					
Gov Exp	.79***	.781***	.879***	.69***	.701***					
	(.262)	(.232)	(.243)	(.249)	(.252)					
Constant	.096*	.046	.008	-.019	.091*	.721***	.658***	.585***	.689***	.729***
	(.052)	(.05)	(.058)	(.055)	(.053)	(.059)	(.057)	(.055)	(.057)	(.053)
Observations	326	326	326	326	326	328	328	328	328	328
R-squared	.578	.606	.613	.608	.597	.194	.233	.268	.203	.23

Note: This table considers the SDG individual index including 2, 3, 4. 8 and 9 as dependent variable and Fintech and financial inclusion as independent variable. Robust standard errors are in parentheses, *** p<.01, ** p<.05, * p<.1

Author Statement

We would like to express our deepest gratitude for your and referees' thoughtful and constructive comments on our paper. Your feedback has been instrumental in helping us enhance the quality and rigor of our work.

In response to your and referees' recommendations, we have conducted additional analysis and incorporated further theoretical underpinnings to support and strengthen our findings. Moreover, we have carefully addressed and integrated all the suggestions and comments provided by the reviewers, ensuring that each aspect has been comprehensively reflected in the revised manuscript.

We deeply appreciate the time and effort you have invested in reviewing our paper, and we hope that the revisions meet your expectations.

Thank you once again for your thoughtful guidance. We look forward to your further feedback.