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Effect of Fintech on Sustainable Development Goals: An Empirical Analysis

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Abstract

This paper empirically examines the impact of financial technology (FinTech) and financial inclusion on sustainable development goals (SDGs). The adoption of FinTech has a significant positive effect on key SDGs in developing nations. Specifically, FinTech contributes to reducing income inequality and poverty, while promoting gender equality, access to basic sanitation, clean energy, and education. Additionally, the increasing adoption of FinTech is linked to overall economic growth. To address potential biases from heteroscedasticity and endogeneity, we conduct robustness checks using simultaneous equation modeling and Poisson pseudo-maximum likelihood estimations. Our findings confirm that the benchmark results are robust.

JEL Codes: O1, O19, O20, Q01.

Keywords: Sustainable Development Goals, SDG, Fintech, Financial Inclusion, Pseudo – Poisson Maximum Likelihood (PPML), Simultaneous Equations Model (SEM).

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1 Introduction

Just like the industrial revolution after World War II that ignited economic growth and development, the advent of the internet in the early 1990s has created a new phase of economic growth and development opportunities around the world in every aspects, most importantly, in the technology-oriented service sector. As the Internet of Things (IoT) has been reshaping various aspects of the global economy, it also enhanced technological innovation into financial services systems, especially in payments and money transfers globally, and particularly in financial inclusion in the developing nations. The pace of innovation has been phenomenal in recent years, leading to the "era of fintech and financial inclusions" worldwide and making significant contributions to disadvantaged people and economies. Many new entrants are evolving and bringing stiff competition to traditional financial institutions. These entrants and those traditional institutions who have adopted fintech are helping to improve the economy in several ways: 1. Increased access to financial services for people, particularly those traditionally underserved by banks and other financial institutions. 2. The finance industry, including new entrants, can operate with lower overhead costs than traditional financial institutions, which allows them to offer services at lower prices and helps increase economic activity by making it more affordable for people to access financial services. 3. Fintech-based financial institutions are using technology to automate many financial processes, helping reduce errors and improving the speed of transactions. This can help increase economic activity by making it easier for businesses to access the capital they need to grow. 4. Fintech institutions are constantly experimenting with new technologies and business models, which can drive innovation and help to create new economic opportunities and job creation. Thanks to fintech, financial inclusion to people in under-served areas have become possible, spurring economic growth faster in developing nations and alleviating poverty. Financial inclusion to people, especially those who would not have access to credit and banking services due to their lack of assets to have as collateral, has now increased their ability to access a range of financial services, such as banking, credit, money transfer, financial protection, and financial literacy. Growing evidence shows financial inclusion substantially benefits the excluded population, especially women and poor adults in many countries. Policymakers in many countries have embraced financial inclusion as the key to economic empowerment and a solution to rising poverty levels in developing nations.

In this research we investigate the relationship between the advancement in financial technology, financial inclusion, and sustainable development goals in emerging market economies. We hypothesize that the advancement of fintech will help increase the amount of financial inclusion and thus have a positive effect on sustainable development goals. The United Nations 2030 agenda has developed 17 sustainability development goals (SDGs) covering three significant dimensions – economic, social, and environmental.[3,4] And Out of these 17 sustainable development goals; we test the impact of fintech on ten goals: 1) Poverty, 2) Income Inequality, 3) Gender Equality, and 4) Economic Growth, 5) Hunger, 6) Sanitation, 7) Energy, 8) Education, 9) Research and Development, and 10) Health. We analyze this relationship first by using the fixed – effects estimation and then further test the robustness of our benchmark results by correcting for the biases arising because of heteroskedasticity and endogeneity using the Poisson – Pseudo Maximum Likelihood (PPML) and Simultaneous Equations Method (SEM) estimations, respectively. As a preliminary analysis of the effect of fintech on SDGs, we graph average SDGs against average fintech. Figure 1 has scatter plots for each SDGs. Here we see with increasing adoption of fintech, decrease in income inequality, hunger (i.e., prevalence of undernourishment) , poverty, and health (i.e., percentage of total population who are undernourished). Whereas we witness increase in gender equality, access to basic sanitation, clean energy, education, and research and development. The regression results we get are in line with this preliminary analysis.

[3] For a complete description of the sustainable development goals, see (Desa, 2016).

[4] For a systematic and thematic literature review see (Hasan, Hoque, Abedin, & Gasbarro, 2024), whereby concentrating on the dimensions of inclusive finance, economy, and environment they identify how FinTech may influence the sustainable development goals.

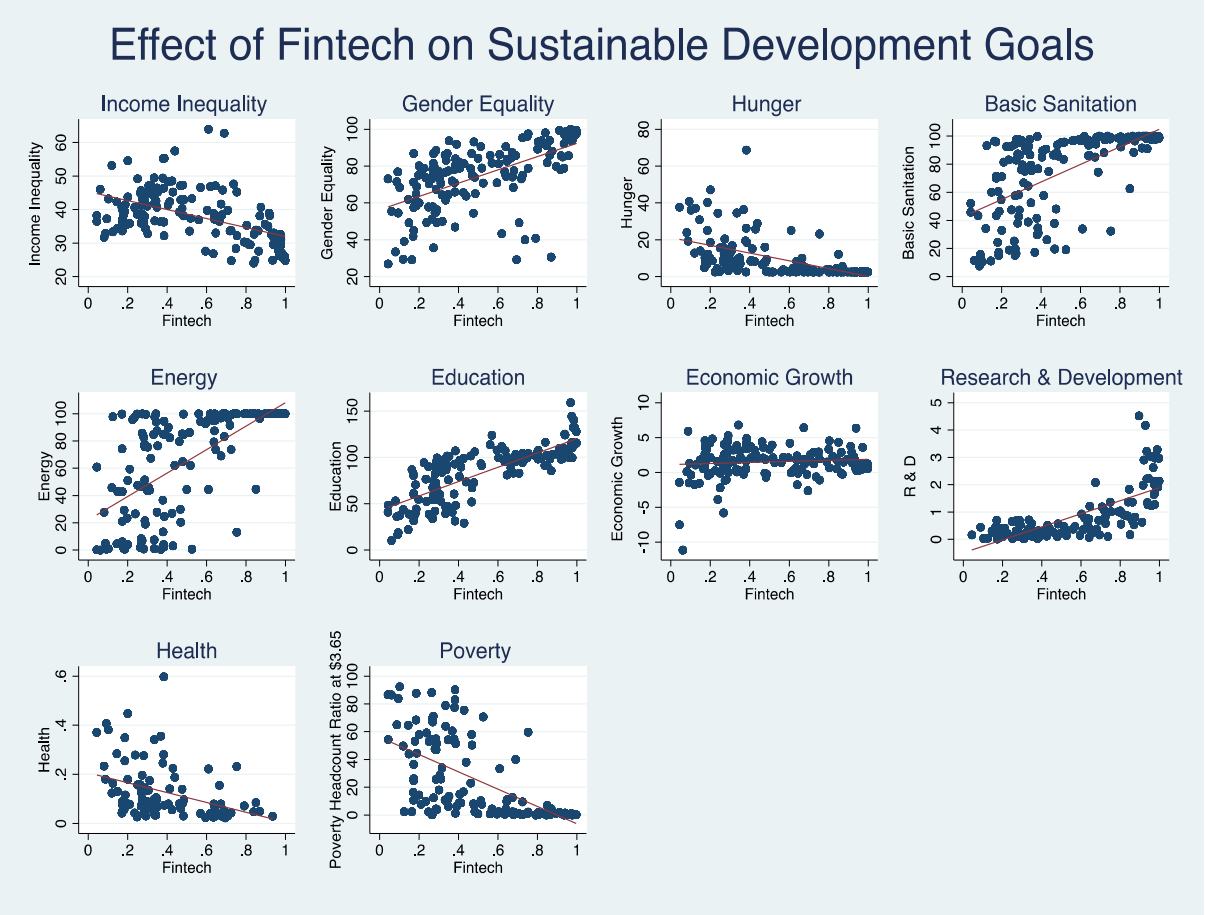

Figure 1: Effect of fintech on sustainable development goals

Financial inclusion has received much attention from policymakers and academics for four reasons. One, financial inclusion is a primary strategy used to achieve the United Nation's sustainable development goals (Sahay et al., 2015; Demirguc-Kunt et al., 2017); secondly, financial inclusion helps to improve the level of social inclusion in many societies (Bold, et al., 2012); thirdly, financial inclusion can help in reducing poverty levels to a desired minimum ((Chibba, M., 2009), (Neaime, S., and Gaysset, I., 2018)), and lastly, financial inclusion brings other socio-economic benefits (Sarma & Pais, 2011; Kpodar & Andrianaivo, 2011). As a result, policymakers in several countries continue to commit significant resources to increase financial inclusion in their countries to reduce financial exclusion. Prior studies have examined several themes in financial inclusion research, such as: promoting development through financial inclusion (Sarma & Pais, 2011; Ghosh, 2013), the effect of financial inclusion on financial stability (Hannig & Jansen, 2010; Cull et al., 2012); the correlation between financial inclusion and economic growth (Mohan, 2006; Kim et al., 2018); country-specific financial inclusion practices (Fungáčová & Weill, 2015; Mitton, 2008), achieving financial inclusion through microfinancing and financial institutions (Ghosh, 2013; Marshall, 2004), and the role of financial innovation and technology in promoting financial inclusion (Donovan, 2012; Ozili, 2019; Gabor & Brooks, 2017; Ozili, 2018), among others. However, these studies present findings that do not aid comparison across countries and regions.

There is extant literature on a single country and regional studies. Bongomin et al. (2018) show improved financial inclusion in Uganda through social networks and cohesion. De Matteis (2015), on migrants residing in the EU, shows that they are deeply affected by the economic crisis in Italy and face social and financial exclusion. Policies aimed at meeting the financial needs of migrants have led to greater integration into the destination society for migrants. Nanziri (2016) focuses on financial inclusion concerning the

gender gap in South Africa and finds that women mainly use formal transactional products and informal financial mechanisms while men use formal credit, insurance, and savings products. Mitchell and Scott (2019) show that the government of Argentina has used financial inclusion to generate a significant amount of public revenue in taxes. Ghosh and Bhattacharya (2019) show that financial inclusion is achieved in Bangladesh through financial innovations such as 'SureCash' to reach women and poor adults. Ali (2019) shows barriers deter access to Islamic financial services for disadvantaged women in Comoros. Wang and Shihadeh (2015) show that the magnitude of financial inclusion has improved after Palestine joined the Alliance for Financial Inclusion (AFI). Marshall (2004) observes that the British policies, drawing on the US experience, treat financial exclusion as an individual problem and pay little attention to the wider interconnections between people and their location. Mitton (2008) shows that people outside the UK's traditional financial sector suffer financial disadvantages such as higher interest on a loan, lack of insurance, no bank account for depositing income, and higher costs of utilities. Collard (2007) argues that as the UK becomes increasingly cashless in its economy, the consequences of being outside the mainstream financial sector are becoming more serious. Fonté (2012) shows that the mobile payment ecosystem in the United States helps individuals gain access to a broader range of financial services at a lower cost. Financial inclusion has also received increased attention in many African countries. (Feng & Li, 2024) do not study the effect of FinTech on all the SDGs, but they do empirically show that FinTech like environmental taxes do help in reducing carbon emission in the ASEAN – 6 countries.

Beck et al. (2014) study and find that African countries witness improved access to finance; specifically, foreign banks from emerging markets help improve access to finance. Zins and Weill (2016) find that richer, more educated, and older men are associated with greater financial inclusion in African countries. Allen et al. (2014) show that innovative financial services help overcome infrastructural problems and improve access to finance in some African countries. Evans (2018) finds that the internet and mobile phones have improved individuals' access to basic financial services and increased financial inclusion. Chikalipah (2017) finds that illiteracy is the major hindrance to financial inclusion in Sub-Saharan Africa. In Europe, financial inclusion is achieved primarily by granting access to credit markets to increase the number of borrowers in the credit market and ensure the stability of the credit market. Sinclair (2013) finds that there are problems in accessing mainstream banking services for low-income customers and a lack of appropriate and affordable credit provisions for these customers. Corrado and Corrado (2015), looking at 18 Eastern European economies and 5 Western European countries, find that households affected by unemployment or income shocks without any assets to pledge are likely to be financially excluded, especially in Eastern Europe. Infelise (2014) examined the initiatives to increase access to finance for small- and medium-sized enterprises (SMEs) in the five biggest European economies: Germany, France, the UK, Italy, and Spain, and observed that greater access to finance in these countries was achieved through government subsidization of bank loans to SMEs to promote financial inclusion for small businesses. Our main contribution to the literature is twofold: First, to the best of our knowledge ours is the first study to look at the impact of advancement of FinTech on 10 sustainable development goals. Until now the research has been focused mainly on individual goals and majority of the research looks at the effect of financial inclusion on the sustainable development goals. And second, we make use of estimation techniques which takes care of the estimation bias because of heteroscedasticity and endogeneity by using the PPML and SEM methodologies respectively. And for SEM we are also able to find out if there is any indirect effect of FinTech on SDGs via financial inclusion.

The rest of the paper is organized as follows: Section 2 explains data and methodology, section 3 has benchmark estimation results, section 4 has robustness checks, and finally conclusion in section 5.

2 Data and Empirical Methodology

We begin our empirical analysis with the below given econometric model using pooled OLS estimation model using pooled OLS estimation technique.

$$ln(SDG_{it}) = \beta_0 + \beta_1 Fintech_{it} + \beta_2 Trade\ Openness_{it} + \beta_3 Inflation_{it} + \beta_4 Govt.Spending_{it} + \beta_5 Population_{it} + \beta_6 Regulatory\ Quality_{it} + \alpha_i + \epsilon_{it} \quad (1)$$

Using equation (1) we test the direct effects of advancement in fintech on the sustainable development goals. Our dependent variable SDG_{it} is the sustainability development goals of country *i* at time *t.* We use 10 different types of sustainable development goals – poverty, income inequality, gender equality, hunger, sanitation, energy, education, economic growth, research and development, and health. Below is the description of each of these 10 SDG goals:

- Poverty ➔ Poverty headcount ratio at $3.65 as percent to population from the World Bank's WDI is used a measure of poverty. We interpret this variable as percentage of people living below $3.65 a day. These poverty headcount ratios measures the percentage of population living below the given dollar amount.
- Income Inequality ➔ We use the Gini index for income inequality of disposable income from Standardized World Income Inequality Database (SWIID) by (Solt, 2020) as a proxy to measure for inequality, where a Gini coefficient of 0 indicates perfect equality and 100 as perfect inequality.[5]
- Gender Equality ➔ We proxy the gender equality goal with the Women Business and Law Index from the World Bank WDI. This index measures how law and regulations affect women's economic opportunity. The overall score is the average score of each index on mobility, workplace, pay, marriage, parenthood, entrepreneurship, assets, and pension, 100 represents the highest score (i.e., no gender inequality).
- Hunger ➔ This goal is proxied by the variable which measures the prevalence of undernourishment as a percentage of population from the World Bank WDI. It is calculated using the percentage of population whose regular food consumption is insufficient to provide the dietary energy levels that are required to maintain a normal active and healthy life.
- Sanitation ➔ This goal measures the percentage of people using at least basic sanitation services.
- Energy ➔ The goal 7 in the SDG is to ensure access to affordable, reliable , sustainable, and modern energy for all. Here, we proxy this goal using a variable which measures the access to clean fuels and technologies for cooking as a percentage of population from the World Bank WDI.
- Education ➔ Goal 4 in the SDG talks about ensuring inclusive and equitable quality education and promote lifelong learning opportunities for all. Secondary school enrollment is used a proxy for this goal.
- Economic Growth ➔ Goal 8 talks about promoting sustained, inclusive, and sustainable economic growth, full and productive employment and decent work for all. We use the annual percentage growth in the per capita gross domestic product (GDP) as a measure for economic growth.
- Research and Development ➔ We use the research and development expenditure as a percentage of GDP as a proxy for goal 9 which looks at building resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

[5] For detailed explanation of the SWIID Gini index construction please see (Solt, 2020). This is one of the most used measure for income inequality, for example, (Demir, 2022) use the net inequality to see the effect of fintech and financial inclusion on income inequality, (Beck, 2007) uses this SWIID Gini index to test the impact of financial development on the poor by estimating relationship between finance and changes in poverty and inequality. Also see (Vogel, 2021), (Lee, 2022), etc.

- Health ➔ We use the variable that measures percentage of people who are undernourished to proxy for goal 3 which looks at ensuring healthy lives and promote well-being for all at all ages.

Our variable of interest here is $Fintech_{it}$, whose effect we analyze on the SDGs. And to do this we also control for a country's trade, inflation, government spending, population growth, and regulatory quality. All the control variables are taken from the World Bank's World Development Indicator database. Below we provide detailed explanation and sources for each independent variables:

- $Fintech_{it}$ ➔ we proxy the advancement of financial technology in a country by using a variable that measures the percentage of 15+ age of population making or receiving digital payments. We get our data on fintech from the FINDEX database. This database is constructed by surveying more than 200,000 households for 2011, 2014, 2017 and 2021.
- $Financial\ Inclusion_{it}$ ➔ variable measures the access and use of the formal financial services in country i at time t.
- $Trade\ Openness_{it}$ ➔ This variable measures the country's trade relation with other countries. It is the sum of total exports and imports of country i in year t. We get this data from the World Bank's WDI database.
- $Inflation_{it}$ ➔ The overall change in prices is controlled using the annual percentage change in consumer prices (CPI).
- $Government\ Spending_{it}$ ➔ General government final consumption expenditure as a percent of GDP for country i at time t. It measures the governments' redistributive policies
- $Population_{it}$ ➔ Annual percentage growth in total population of country i in year t.
- $Regulatory\ Quality_{it}$ ➔ This variable captures the perception of people in a country about the government's ability to formulate and implement sound policies and regulations that boosts private sector development.

Table 1: Summary Statistics

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Variable	N	Mean	Standard Deviation	Minimum	Maximum	Source	Expected Effect of Fintech
Inequality	1136	37.24	7.78	22.60	64.20	SWIID	−
Poverty at $3.65 (% of population)	701	12.43	20.32	0.00	92.40	WDI	−
Gender Equality (scale 1 to 100)	636	73.90	18.97	26.25	100	WDI	+
Hunger (% of population)	423	10.04	11.31	2.50	81.70	WDI	−
Sanitation (% of population)	629	74.47	29.31	6.28	100.00	WDI	+ \ −
Energy (% of population)	618	66.46	38.06	0.00	100.00	WDI	+ \ −
Education (% of population)	1031	86.62	29.16	9.69	163.93	WDI	+ \ −
Economic Growth (% annual growth)	1698	1.49	5.45	-50.73	85.69	WDI	+
Research & Development (% of GDP)	870	1.05	1.03	0.01	5.44	WDI	+ \ −
Health (% of total population)	910	0.13	0.11	0.02	0.70	WDI	+ \ −
Fintech (Digital Payments)	413	0.54	0.30	0.04	1.00	FINDEX	
Financial Inclusion (Account at Fin. Inst.)	557	0.55	0.32	0.00	1.00	FINDEX	+
Financial Inclusion - Female	557	0.52	0.33	0.01	1.00	FINDEX	+
Financial Inclusion – Male	557	0.58	0.30	0.00	1.00	FINDEX	+
Trade Openness (% of GDP)	1631	87.62	58.91	0.78	442.62	WDI	
Government Spending (% of GDP)	1609	16.05	5.76	3.59	56.85	WDI	
Population (% annual growth)	1753	1.38	1.33	-4.53	9.23	WDI	
Inflation (% annual growth)	1627	6.21	23.44	-4.29	557.20	WDI	
Regulatory Quality	1758	-0.00	1.00	-2.37	2.26	WDI	

Table 1 has the descriptive statistics for all the dependent variables, variables of interest, and macroeconomic control variables, along with their respective data sources and the expected effect of fintech on each SDG measure. Our analysis uses data from 161 countries for four years – 2011, 2014, 2017, and 2021. These cover countries from all seven regions of the world and all the four-income groups as separated by the WB based on the country's gross national income (GNI). In our sample of 161 countries, we see the average Gini coefficient to be 36.48, a maximum of 63, and a minimum of 23.20, making none of the countries in our sample of countries perfectly equal. The average inequality remains around 40 for low-income, lower-middle, and upper middle-income countries, but for high-income countries, the average inequality is 31. Poverty is proxied by the poverty headcount ratio of $3.65. For the entire sample, on average, 12% of the population lives below $3.65 per day, whereas on average, 68% of the population lives below $3.65 per day in low-income countries followed by 25% in lower-middle income countries and less than 8% in upper-middle and high-income countries.[6]

On average, there is more gender equality, with a mean of 74. Similarly, 75% of the population has access to essential sanitation services, 66% has access to clean fuel for cooking, and 86% is in secondary schools. However, for the goal of hunger reduction, we see that, on average, 10% of the population is undernourished. For our variable of interest – Fintech – we see 54% of people over 15 make and/or receive digital payments. Almost the same number of people also have an account in a financial institution which we use to measure the degree of financial inclusion.

3 Estimation Results

Table 2 has the benchmark results for the effect of fintech on financial inclusion. The results here show evidence that broader adoption of financial technology positively affects financial inclusion.

Table 2: Effect of Fintech on Financial Inclusion

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
	Fin. Inst. Account			Fin. Inst. Account (Female)			Fin. Inst. Account (Male)		
Fintech	0.551***	0.409***	0.571***	0.530***	0.373***	0.592***	57.283***	45.155***	55.259***
	(0.047)	(0.060)	(0.067)	(0.049)	(0.066)	(0.076)	(4.782)	(5.878)	(6.936)
Fin. Sector		0.006			0.012			0.097	
Rating		(0.017)			(0.018)			(2.057)	
Education			0.002*			0.001			0.232*
			(0.001)			(0.001)			(0.129)
GDP			-0.005			-0.006*			-0.280
Growth			(0.003)			(0.003)			(0.295)
Population			-0.021**			-0.003			-3.252***
			(0.010)			(0.010)			(1.224)
Constant	0.287***	0.141*	0.171*	0.268***	0.097*	0.170*	30.885***	18.753***	17.132
	(0.0258)	(0.052)	(0.092)	(0.027)	(0.056)	(0.102)	(2.617)	(5.886)	(11.066)
Observations	398	120	171	398	120	171	398	120	171
R^2	0.956	0.897	0.985	0.975	0.880	0.980	0.972	0.888	0.982
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[6] The authors can provide a similar breakdown by income group for each variable upon request.

Here, we present results for the overall total account in a financial institution in models 1 to 3, accounts in a financial institution by a female in models 4 to 6, and accounts in a financial institution by a male in models 7 to 9. We consistently find a positive effect of advancement and adoption of financial technology as proxied by the percentage of the population over 15 years of age who made or received digital payments. In addition, education has a positive and significant effect on males, indicating that educated individuals opt to be part of the financial system by having an account in a financial institution. These results are in line with those (Demir, 2022), (Mbiti, 2013), and (Gosavi, 2018).

Table 3 has the benchmark results for the effect of fintech on sustainable development goals (SDGs). Here, we choose 10 SDG goals out of 17 based on the data availability. In table 2, we have provided the expected signs for each SDG indicator, showing what we expect the effect of fintech on these indicators. Furthermore, the benchmark results in table 3 are as per our expectations. The adoption of fintech has a negative effect on inequality, poverty, hunger, and health. The effect on inequality and poverty is statistically significant out of these four. We see a unit increase in fintech adoption (i.e., with a 1% increase in the 15+ age population using making and/or receiving mobile payments), decreases in inequality by 8.3%, and poverty at $3.65 (i.e., a percentage of the population living below $3.65 per day) by 3.86%. Our result for fintech is in line with the extant literature; for example, (Demir, 2022) also finds inequality decreasing with the adoption of fintech.[7]

On the other hand, the adoption of fintech has a positive and statistically significant effect on gender equality, sanitation, energy, education, and economic growth. We see that with one unit increase in fintech increases gender equality by 10 points, thus showing that the laws and regulations that increase economic opportunity for working women. Access to basic sanitation also increased by 22% with a unit increase in fintech adoption, and similarly, access to modern energy increased by 32%, and education increased by 21%.[8] These increases in access to sanitation, energy, and education are in line with decreases in income inequality and poverty. And finally, the biggest effect of an increase in the adoption of fintech by a country is on its economic growth as more people get into the regular banking system. Here, a unit of fintech adoption increases economic growth by more than 400%. [9] Regarding the macroeconomic control variables, we see its effect on SDGs as per our expectation as mentioned in table 1. An increase in population is positively correlated with education and research and development, whereas negatively correlated with economic growth and health. Peterson (2017) have shown that the effect of increase in population on economic growth varies by a country's income level: A rapid population growth can have a negative effect on a lower income country's economic growth in short to medium term, whereas for a high income country which tend to have slow or negative population growth can also have a negative impact as there are less number of working age adults to support retired population.[10] Increasing trade openness increases overall economic growth but it also increases gender inequality. The effect trade openness having positive relationship with economic growth is accepted widely, as well as barriers to trade having negative effect on economic growth, but in some cases where if the country is a low income country, trade barriers may help

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[7] Asongu (2015) and Asongu and Odhiambo (2019) also found decrease in income inequality with increasing mobile penetration. Similarly, with increasing fintech adoption, Abor, Amidu, and Issahaku (2018) shows decline in poverty in Ghana, and Beuermann, McKelvey, and Vakis (2012) shows decline in extreme poverty in rural Peru, Suri and Jack (2016) shows similar results for Kenya,

[8] Croutzet and Dabbous (2021) show the presence of significant positive relation between fintech and renewable energy. For a detailed resport on the effect of fintech on water sector (including sanitation) see Ikeda and Liffiton (2019). Song and Appiah-Otoo (2022) shows a positive relation between fintech adoption and economic growth in case of China. Similar to our study, Sadigov et. al. (2020) condut a cross-cournty analysis and show fintech development having positive contribution to economic growth (i.e., increasing GDP).

[9] Positive association of fintech adoption with better health and education is also shown by Aker and Mbiti (2010). Loko and Yang (2022) shows significant increase in female employment and decreasing gender inequality with fintech adoption.

[10] For a more detailed survey on the relationship between population growth and economic growth see Heady and Hodge (2009).

in developing the local domestic industry as well (see Yannikaya (2003)).[11] Government spending also increases gender inequality, this could be an indication that women participation in industries related to infrastructure development needs to be increased. Finally, regulatory quality increases percentage of population having secondary education, but it also increases poverty headcount ratio, gender inequality, and reduces R & D and health.

We conduct the sensitivity analysis by estimating equation 1 for the non-advanced countries. To do this, we make use of the world bank's country classification, where they divide all the countries in the world based on their Gross National Income (GNI) into four groups: Low income, lower–middle income, upper–middle income, and high-income. We reclassify the countries in our dataset as non-advanced economies, which fall under low, lower – middle and upper – middle income countries. The results of the sensitivity analysis are presented in table 4. The results for non-advanced economies are similar to the benchmark results. We still see a decline in income inequality and poverty with an increase in Fintech adoption, as well as a positive and significant effect on access to basic sanitation, access to clean fuel (energy), secondary enrollment (education), and economic growth.

Table 3: Benchmark Results: Effect of Fintech on Sustainable Development Goals (SDGs)

	Inequality	Poverty	Gender Equality	Hunger	Sanitation	Energy	Education	Economic Growth	R & D	Health
Fintech	-0.080***	-1.583***	10.110***	-0.161	0.204***	0.282***	0.194**	1.740***	0.587	-0.250
	(0.020)	(0.414)	(2.472)	(0.134)	(0.037)	(0.103)	(0.088)	(0.538)	(0.474)	(0.170)
Trade	0.000	0.002	-0.049**	0.000	-0.001*	-0.001	0.000	0.018**	-0.004	-0.001
Openness	(0.000)	(0.005)	(0.023)	(0.001)	(0.000)	(0.001)	(0.001)	(0.007)	(0.002)	(0.002)
Government	-0.001	0.045	-0.385*	0.003	-0.001	-0.004	-0.008	0.023	-0.030	-0.006
Spending	(0.002)	(0.057)	(0.230)	(0.007)	(0.003)	(0.009)	(0.007)	(0.047)	(0.051)	(0.014)
Inflation	-0.001	-0.006	-0.050	0.006	0.000	0.008	0.002	0.007	-0.003	0.005
	(0.001)	(0.023)	(0.086)	(0.004)	(0.001)	(0.006)	(0.002)	(0.016)	(0.009)	(0.004)
Population	-0.004	-0.191*	-0.227	0.031	0.005	0.011	0.034***	-0.501***	0.238*	-0.121***
	(0.004)	(0.113)	(0.369)	(0.035)	(0.007)	(0.013)	(0.010)	(0.164)	(0.126)	(0.023)
Regulatory	0.014	0.740**	-3.860**	-0.041	-0.011	0.042	0.101*	-0.301	-0.540**	-0.359*
Quality	(0.016)	(0.308)	(1.807)	(0.075)	(0.028)	(0.083)	(0.054)	(0.437)	(0.226)	(0.211)
Constant	3.626***	0.350	82.501***	1.647***	4.184***	3.789***	4.357***	-1.409	0.276	-2.102***
	(0.041)	(1.548)	(4.409)	(0.195)	(0.060)	(0.247)	(0.184)	(0.964)	(1.084)	(0.262)
N	186	113	240	220	238	230	157	281	140	128
R^2	0.995	0.986	0.992	0.994	0.998	0.997	0.995	0.575	0.987	0.983
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[11] A detailed survey is on the effect of trade openness on economic growth among other growth strategies is done by Rodrick (2017).

Table 4: Effect of Fintech on Sustainable Development Goals (SDGs) for Non – Advanced Economies

	Inequality	Poverty	Gender Equality	Hunger	Sanitation	Energy	Education	Economic Growth	R & D	Health
Fintech	-0.064***	-1.321***	10.338***	-0.165	0.222***	0.325**	0.222*	1.218*	0.733	-0.236
	(0.021)	(0.407)	(2.610)	(0.156)	(0.044)	(0.131)	(0.113)	(0.612)	(0.468)	(0.171)
Trade	0.000	-0.003	-0.038	0.000	-0.001*	-0.001	0.001	0.020**	-0.005	-0.001
Openness	(0.000)	(0.004)	(0.038)	(0.002)	(0.001)	(0.002)	(0.001)	(0.009)	(0.005)	(0.002)
Government	-0.002	0.070	-0.457	-0.001	-0.001	-0.008	-0.009	0.056	0.071	-0.009
Spending	(0.003)	(0.075)	(0.363)	(0.012)	(0.004)	(0.016)	(0.012)	(0.064)	(0.055)	(0.015)
Inflation	-0.001	0.027	-0.096	0.006	0.000	0.008	0.002	-0.010	0.002	0.005
	(0.001)	(0.024)	(0.100)	(0.004)	(0.001)	(0.006)	(0.002)	(0.017)	(0.010)	(0.004)
Population	-0.006	-0.034	-0.349	0.037	0.010	0.035	0.040**	-0.505***	0.068	-0.133***
	(0.008)	(0.105)	(0.544)	(0.044)	(0.013)	(0.024)	(0.018)	(0.170)	(0.153)	(0.023)
Regulatory	0.006	0.970***	-4.398*	-0.063	-0.018	0.052	0.129*	-0.952*	-0.806**	-0.385*
Quality	(0.018)	(0.342)	(2.235)	(0.105)	(0.039)	(0.120)	(0.076)	(0.542)	(0.338)	(0.213)
Constant	3.705***	1.398	75.838***	2.032***	4.011***	3.421***	4.212***	-1.216	-2.317**	-2.033***
	(0.041)	(1.558)	(5.352)	(0.213)	(0.074)	(0.326)	(0.227)	(1.131)	(0.989)	(0.260)
N	103	57	156	140	154	148	87	177	66	118
R^2	0.993	0.984	0.986	0.990	0.998	0.997	0.994	0.568	0.983	0.983
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

4 Robustness Check

We use two different methods to test the robustness of our benchmark results: 1) System of equation method (SEM), and 2) Poisson – Pseudo Maximum Likelihood (PPML),

A problem that this type of analysis often has is that of endogeneity and reverse causality. To correct for any bias because of endogeneity or reverse causality, we do a robustness check using the simultaneous equation modeling (SEM) estimation technique. This allows us the test both the direct effect of fintech on the SDGs as well as the indirect effect via financial inclusion. Below are the two equations we use for SEM analysis:

Financial Inclusion (FI) Equation:

$$\boldsymbol{FI_{it} = \beta_0 + \beta_1\, Fintech + \beta_2\, SDG_{it} + \beta_3\, Trade\ Openness_{it} + \beta_4 Education_{it} + \beta_5 Population_{it} + \beta_6 Inflation_{it} + \alpha_i + \epsilon_{it}}$$

Here, the first equation is the first linear equation of the system of equations. The dependent variable is $Fintech_{it}$ shows the usage and adoption of financial technology of country *i* in year *t*, and the variable of interest is $Financial\ Inclusion_{it}$ which measures the use and access to formal financial services in country i in year *t*. α_i and δ_t are the country and time fixed effects, respectively, and ϵ_{it} is the error term. Here, we expect β_2 to be positive, indicating that as more people are covered by formal financial services of the banking system, there will be higher adoption of financial technology.

SDG Equation:

$$\boldsymbol{Ln(SDG_{it}) = \beta_0 + \beta_1 Fintech_{it} + \beta_2 FI_{it} + \beta_3 Education_{it} + \beta_4 Trade\ Openness_{it} + \beta_5 Government\ Spending_{it} + \beta_6 Regulatory\ Quality_{it} + \beta_7 Population_{it} + \alpha_i + \epsilon_{it}}$$

SDG equation is the second equation in our simultaneous equation model. Here, the dependent variable is the sustainability development goals (SDG_{it}) and the variable of interest $Fintech_{it}$. We expect β_1 to be positive when we use education and economic growth as dependent variable, indicating that as the acceptance of fintech increases in a country the level of education among its citizen increases as well as we

see positive economic growth. On the other hand, we expect β_1 to be negative when we use poverty, income inequality, gender inequality and hunger, showing a decrease in these variables as the country adopts financial technology more.

We test equations 1 and 2 simultaneously using three stage least square (3SLS) estimation technique. To check the robustness of the SEM results we follow (Davidson et. al., 1993) and do Durbin-Hu-Watson endogeneity test, which confirms the endogeneity. And after doing the 3SLS, we test its validity using the Breusch-Pagan LM diagonal covariance matrix test (Shehata, 2012).

Table 5 has the results for the SEM analysis. These results for the financial inclusion (FI) equation reinforces the benchmark result of the positive and statistically significant effect of fintech on financial inclusion, with the average increase in financial inclusion being 75% with unit increase in Fintech. Apart from correcting any endogeneity bias in the OLS results, one more reason to use the SEM estimation is to find out indirect effect of fintech on SDG via financial inclusion. For this, we see the effect of financial inclusion variable on SDG in the SDG equation, and we see this indirect effect on income inequality. Our results of indirect effect of financial inclusion on income equality are in line with the few studies done looking at the indirect effect: see Chinoda and Mashamba (2021) for the indirect effect on 25 African countries, and Demir et. al. (2022) shows similar results for a panel of 140 countries. Apart from income inequality, we also find positive and significant indirect effect of fintech on gender equality and access to basic sanitation. Furthermore, the SDG equation for inequality in model 1shows statistically significant decrease in inequality by 15.3% with a unit increase in fintech adoption, as well as inequality also declines with increase in government spending. Model 2 has results for poverty headcount ratio at $3.65, and we see a huge drop in number of people earning less than $3.65 per day with increasing adoption of Fintech. Similarly, in model 3 we see gender equality increasing by almost 8 points on a scale of 1 to 100, access to sanitation in model 4 increase by more than 23%. access to clean fuel (energy) increases by 52%, and finally secondary school enrollment (education) increases by 29%. In the second part of table 5, we show results for the remaining five SDG measures. Model 5 has results for access to clean fuel (energy) which also shows increase in access by 59% for unit increase in adoption of fintech technology, number of students with secondary enrollment (education) increases by 21% and economic growth and research and development increases by more than 1000% and 200% respectively.

For the macroeconomic control variables, in the financial inclusion equation we see education having positive and significant effect on bringing more people in the financial system, whereas increase in population has a negative and significant effect. Among the SDG equations, government spending has the desired effect on reducing inequality and increasing research and development as well as access to clean energy. Trade openness on the other hand show a negative association with gender equality and sanitation, and similarly inflation also has negative effect on access to good healthcare and basic sanitation. And finally, better quality regulations are shown to increase access to clean energy, education and helps in economic growth. We test the validity of SEM estimation using the Breusch-Pagan LM diagonal covariance matrix test (see Shehata (2012)), where we successfully reject the null hypothesis of running OLS over SEM for all the models expect for model 2 where we use poverty headcount ratio at $3.65 as the SDG measure. The Lagrange Multiplier test results are shown for each model at the bottom of the table for each model. And similarly, to test the robustness of using SEM over OLS, we follow Davidson et. al., (1993) and do Durbin-Wu-Hausman endogeneity test, which confirms the endogeneity.[12]

[12] For the Durbin-Wu-Hausman test, we get the p-value to be 0.000, thus indicating that OLS estimates are inconsistent.

Table 5: Simultaneous Equation Model Estimations

	Model 1		Model 2		Model 3		Model 4		Model 5	
	FI	Inequality	FI	Poverty	FI	Gender	FI	Sanitation	FI	Energy
SDG	-0.774		0.102*		-0.015**		-0.128		0.223	
	(0.852)		(0.060)		(0.007)		(0.423)		(0.402)	
Fintech	0.483***	0.194	0.734***	-10.092*	0.705***	-32.210*	0.566***	-0.099	0.465***	0.718*
	(0.123)	(0.200)	(0.083)	(5.367)	(0.085)	(18.035)	(0.096)	(0.176)	(0.175)	(0.367)
FI		-0.553*		14.803		69.278**		0.574*		-0.544
		(0.321)		(9.295)		(30.063)		(0.299)		(0.634)
Trade	-0.001***	-0.001*		0.003	-0.001***		-0.001***		-0.001***	
Openness	(0.000)	(0.000)		(0.007)	(0.000)		(0.000)		(0.000)	
Education	0.002*	0.000	0.004**	-0.052**	0.002*	0.005	0.002**	-0.000		0.002
	(0.001)	(0.000)	(0.001)	(0.026)	(0.001)	(0.073)	(0.001)	(0.001)		(0.002)
Population	-0.037**	-0.028***		0.115			-0.019**	0.019**	-0.020*	0.006
	(0.016)	(0.009)		(0.270)			(0.007)	(0.008)	(0.010)	(0.019)
Inflation	-0.000		0.000					-0.002***		
	(0.001)		(0.001)					(0.001)		
Government		-0.000		-0.038		-0.646**		-0.004		0.004
Spending		(0.003)		(0.101)		(0.308)		(0.003)		(0.009)
Regulatory		0.026	-0.018			-5.396***		-0.022		0.079*
Quality		(0.022)	(0.044)			(1.877)		(0.029)		(0.048)
Constant	3.009	3.802***	-0.378	3.930***	1.464**	78.199***	0.730	4.503***	-0.595	4.076***
	(3.171)	(0.059)	(0.270)	(1.324)	(0.639)	(7.586)	(1.917)	(0.092)	(1.676)	(0.228)
N	160	160	119	119	193	193	188	188	188	188
R^2	0.9938	0.9938	0.994	119	0.9890	0.990	0.994	0.998	0.993	0.998
BP-LM Test	67.373***		93.516***		0.791		10.182***		15.577***	
	Model 6		Model 7		Model 8		Model 9		Model 10	
	FI	Education	FI	Economic Growth	FI	Health	FI	R&D	FI	Hunger
SDG	0.683**		0.056		-0.264***		-0.174		-0.095	
	(0.271)		(0.036)		(0.078)		(0.167)		(0.140)	
Fintech	0.423***	0.474*	0.402***	4.371	0.469***	0.061	0.783***	1.782	0.532***	0.025
	(0.063)	(0.289)	(0.110)	(3.691)	(0.062)	(0.376)	(0.203)	(1.281)	(0.036)	(0.492)
FI		-0.498		-3.817		-0.559		-1.071		-0.150
		(0.498)		(6.714)		(0.569)		(2.203)		(0.859)
Trade	-0.001***		-0.001*		-0.002***		-0.000		-0.001***	
Openness	(0.000)		(0.000)		(0.001)		(0.000)		(0.000)	
Population	-0.036***	0.027**		-0.572**	-0.040**	-0.173***	0.001	0.112*	-0.012	-0.028
	(0.011)	(0.010)		(0.244)	(0.019)	(0.044)	(0.025)	(0.064)	(0.010)	(0.025)
Government	0.008**	-0.007*	0.008	-0.119**	-0.005	-0.012	0.018*	0.070**	0.007**	0.009
Spending	(0.003)	(0.004)	(0.006)	(0.052)	(0.006)	(0.016)	(0.010)	(0.031)	(0.003)	(0.011)
Education			0.002**	0.004	0.003*	0.002	-0.000	-0.007	0.001*	-0.001
			(0.001)	(0.020)	(0.001)	(0.004)	(0.001)	(0.004)	(0.000)	(0.002)
Inflation		0.001				-0.004		0.001		0.006**
		(0.001)				(0.003)		(0.005)		(0.002)
Regulatory		0.137***				-0.568***		-0.136		-0.065
Quality		(0.0450				(0.153)		(0.215)		(0.086)
Constant	-2.854**	4.688***	-0.069	2.227	-0.723*	-3.125***	-0.353	-1.730***	0.215	1.464***
	(1.244)	(0.101)	(0.181)	(1.513)	(0.272)	(0.479)	(0.314)	(0.572)	(0.235)	(0.245)
N	190	190	173	173	99	99	132	132	176	176
R^2	0.992	0.995	0.988	0.782	0.984	0.987	0.993	0.995	0.994	0.995
BP – LM Test	13.911***		47.058***		44.118***		32.268***		6.081**	

Table 6: Effect of Fintech on SDGs using Poisson Pseudo Maximum Likelihood (PPML) Estimation

	Inequality	Poverty	Gender Equality	Hunger	Sanitation	Energy	Education	Economic Growth	R&D
Fintech	-0.039***	-0.971***	0.141***	-0.033	0.053***	0.098***	0.039*	1.041	0.136
	(0.010)	(0.446)	(0.048)	(0.101)	(0.016)	(0.029)	(0.021)	(0.648)	(0.859)
Trade	-0.000	-0.002	-0.001**	0.000	-0.000	-0.000	0.000	-0.002	-0.003
Openness	(0.000)	(0.004)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.005)	(0.004)
Government	-0.001	-0.043	-0.007	0.005	-0.001	-0.006	-0.001	-0.029	0.008
Spending	(0.001)	(0.034)	(0.007)	(0.006)	(0.001)	(0.004)	(0.002)	(0.058)	(0.058)
Inflation	-0.000	-0.016	0.000	0.004*	-0.001*	-0.001	0.000	0.004	0.006
	(0.000)	(0.021)	(0.002)	(0.002)	(0.000)	(0.001)	(0.000)	(0.032)	(0.031)
Population	-0.004**	0.029	0.007	-0.020	0.002	-0.003	0.008***	0.068	-0.191
	(0.002)	(0.269)	(0.010)	(0.033)	(0.003)	(0.004)	(0.002)	(0.104)	(0.126)
Regulatory	0.005	0.525	-0.060**	-0.032	-0.000	0.011	0.024*	-0.054	0.377*
Quality	(0.006)	(0.331)	(0.030)	(0.077)	(0.007)	(0.021)	(0.013)	(0.293)	(0.205)
Education	-0.000	0.005	0.001	-0.001	0.000	0.001		-0.005	0.001
	(0.000)	(0.013)	(0.001)	(0.003)	(0.000)	(0.001)		(0.016)	(0.005)
Economic	0.000	-0.035	-0.005**	-0.001	-0.000	-0.005*	0.001		-0.053**
Growth	(0.001)	(0.027)	(0.002)	(0.003)	(0.001)	(0.003)	(0.001)		(0.027)
Constant	1.300***	1.527	4.474***	0.525**	1.454***	1.465***	1.470***	0.596	-0.662
	(0.031)	(1.283)	(0.152)	(0.263)	(0.032)	(0.032)	(0.044)	(2.082)	(1.507)
N	132	56	156	148	156	144	157	107	46
Pseudo R^2	0.0036	0.2477	0.4228	0.1239	0.0195	0.0586	0.0118	0.0969	0.1542
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Second type of robustness check we do is by using the Poisson – Pseudo Maximum Likelihood (PPML) estimations. Here we estimate equation 1 using PPML with country fixed effects. The advantage of using PPML over fixed effects OLS is that it takes care of the problem arising from heteroskedasticity because of numerous missing and zero values. The results for PPML estimations are given in table 6. After correcting for any heteroscedasticity, results are similar to the benchmark results. Still a unit increase in adoption of fintech technology have over all positive effect on sustainable development goals, where, inequality and poverty are reducing, and gender equality, access to basic sanitation, energy and education are increasing.

5 Conclusion

In this paper we study the effect of advancement in financial technology (Fintech) and its' adoption on the achievement of sustainable development goals (SDGs). We do cross-country analysis of 161 countries across the seven geographical regions. For our measure of Fintech, we use the percentage of population 15 and over made or received a digital payment from the FINDEX database, and for the SDGs we use goals 1 to 10. Our research, to the best of our knowledge, is the first to test the effect of fintech on these broad range of sustainable development goals. In the past there have been studies done on individual goal like income inequality and poverty only.

Our results show a clear positive correlation of adoption of new and upcoming financial technology on reducing income inequality, poverty, and increasing gender equality, access to basic sanitation, health, lower hunger, increasing economic growth and education both directly as well as indirectly via increase in financial inclusion. We use the Pseudo – Poisson Maximum Likelihood (PPML) and Simultaneous Equations Method (SEM) to test the robustness of our results, which also corrects for the biases because of endogeneity and heteroscedasticity. And the results for these PPML and SEM support our benchmark analysis of positive and significant effect of adoption of FinTech on sustainable development goals.

Using the findings of this paper, some of the areas in which it can be extend it by looking at the role of fintech innovation like AI driven credit scoring, mobile banking in enhancing financial inclusion for marginalized groups like rural populations, women and small businesses. Another avenue of research could be doing a comparative study on the impact of different FinTech models across regions and finally a more policy impacting research would be to study the policy and regulatory environments influence on FinTech's impact on SDGs.

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