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Abstract

Title: What if banking was green? An essay to quantify the effect of fintech on financial inclusion and environmental sustainability.

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Abstract:

With the emergence of financial technology, the banking industry has witnessed a paradigm shift that is revolutionizing traditional banking services. As the world faces escalating environmental challenges and an urgent need for sustainable development, the convergence of fintech and sustainability has opened new avenues for creating more inclusive and environmentally responsible banking services. Thus, taking the banking sector from its traditional role to a more futuristic, moral, and ethical direction, sustaining the transition to the net-zero goals of the United Kingdom.

a. The purpose of the paper:

This study aims to quantify the relationship between fintech, financial inclusion, and environmental sustainability. The study examines the effects of fintech adoption, represented by ATM and mobile banking, on the financial inclusion index and environmental sustainability indicators, including CO2 emissions and bioenergy production.

b. Methods and results:

This research adopts a Bayesian vector autoregressive model and Granger causality test to capture the dynamic nature of the relationship between fintech, financial inclusion, and environmental sustainability over time. It enables uncertainty quantification, forecasting capabilities, and flexibility in incorporating prior knowledge, thereby providing valuable insights into the interactions among variables.

To conduct this study, we have used a dataset (1998-2022) organized into three groups:

- Fintech indicators: mobile banking usage, ATMs.
- Financial inclusion index, which focuses on two dimensions: supply and demand.
- environmental sustainability metrics: carbon emissions, bioenergy.

c. Results:

The results reveal that financial technology contributed to expanding financial inclusion within the country especially when using mobile banking apps and online payment platforms, where it helps to incur lower transaction costs, overcome barriers, offer diverse services, and expand access to financial services. Further, our findings show that via leveraging technology and promoting financial inclusion, the UK can advance both financial access and environmental sustainability, fostering an inclusive-green economy. The causality is coherent with the results of the impulse response functions and shows bi-directional feedback between the financial

inclusion index and Fintech with special attention to decarbonization and the adoption of renewable energies.

d. Originality:

Our study aims to quantify the interconnectedness of the financial sector and environmental matters in a time of uncertainty, acknowledging the available theory, by using a Bayesian modeling approach, this study adds robustness to our findings and draws practical advice to pave the way for a “Green banking era” that sustain the transition to the net-zero goals of the UK. To the best of our knowledge, this study is the first attempt to quantify such a dynamic relationship in the UK.

e. Keywords:

Fintech, Financial inclusion, sustainability, green projects, Bayesian model.

f. Paper type: research paper

1. introduction:

‘Green’ seems to be the trend color in the banking industry nowadays. Indeed, some nuance of ‘green’ can be seen through a rich vocabulary among practitioners in the financial sector: environmental matters, climate change, economic resilience, and sustainability, all these terms marked their presence as the new lexicon of policymakers and economists worldwide. A green bank is seen as an ethical bank operating as an intermediary institution performing conventional banking activities, with a supplementary integrated environmental strategy to protect planet Earth’s ecology **(Nath et al,.2014)**. The transformation in the banking industry is clear and bold, not only from an environmental perspective. But also from a tech one, indeed, financial technology, is helping to reshape the new face of the industry. The covid-19 pandemic and the uncertainty of the global economy proved that the need for adaptation and anticipation became a crucial matter in financial activities more than ever. The banking industry approach and business model must shift from a passive framework to a proactive one, to answer its customers’ needs, the change is imminent, and the fifth revolution is bordering on and cannot be ignored anymore (Nicoletti, 2021). Customer demands and expectations have grown exponentially over the years. In a time of persistent change, and the availability of a great range of options in which loyalty is no more evident, financial institutions must develop beyond their core products and services to maintain and expand their market shares **(Mehdiabadi et al,.2022)**. a report by the investment association annual survey shows that in 2021 70% of the UK public want their money to be channeled in a way that makes a difference in society’s well-being or the planet’s ecology, Data proved that 49% out of the £9.4 trillion in the UK assets were adopting the ESG in 2020 **(The Investment Association, 2021)**.

In a highly competitive environment, rigidity is no longer supported, to survive, banks must embrace change, adopt innovative technologies, or team up with startups and other institutions operating in financial technology. All these transformations must cooperate along with keeping ‘Green’ as the emblematic coloration of the banking industry framework and its business model. To respond to the national and international calls for climate resilience and developing smart-low carbon solutions to fund new investments and sustain economic growth, fintech can play the role of the infrastructure to foster environmental sustainability. Fintech-led banks must adapt to the needs of their customers, without customers, there are no banking activities, and there rise another problem, which is access to finance. Financial inclusion is a key driver to attaining sustainable development goals, where financial inclusion is more seen as a process and fintech as an infrastructure to help achieve SDGs goals. Investigations show that there is a huge gap in financing sustainability worldwide, according to **(Fuessler et al. ,2018),** it exists an average need of 3.5 trillion USD per year to be supplied to the energy sector until 2050 to attain the two degrees goal of the Paris Agreement. Therefore, it is essential to look for diversified sources to fill the capital gap needed worldwide, Dorfleitner and Braun (2019) report that fintech applications assist access to capital for green projects, they can increase the investor base involving small investors and private capital and provide new forms or mechanisms of financing. In this regard, the UK government is putting massive plans to kick start a green industrial revolution, where greening the financial system is an integrated strategy within the big picture of achieving clean economic growth. In September 2021 the UK government raised 10 billion USD to fund sustainable projects via the selling of the largest green sovereign bond worldwide **(HM Treasury, 2021).**

Our study aims to draw essential guidance to policymakers in the UK, it is an attempt to assess fintech and financial inclusion as an integrated framework to achieve environmental sustainability in the kingdom and therefore, contribute to leveling up the Net-zero plan of the government through digitalization and a financially inclusive environment. By examining the relationship between FinTech, financial inclusion, and environmental sustainability, this paper offers valuable contributions in several key aspects where it provides a comprehensive analysis using the Bayesian var method that fills a research gap in understanding their interconnection, which to the best of our knowledge is the first attempt taking the UK as a sample. In addition, our findings have practical implications for policymakers and industry stakeholders offering guidance in the field of FinTech adoption aligned with environmental goals.

The rest of our research is organized as follows. Section 2 features a review of the existing related literature. Section 3 represents the data and methodology. Section 4 showcases the results and empirical analysis. Section 5 presents the discussion of the empirical findings where we delve deeper into the implications of the results, exploring their economic significance. Finally, section 6 concludes.

2. literature review:

The fintech term despite gaining major importance the past recent years, has existed a long time ago. The term was first used in the early 1990s and referred to the “Financial Services Technology Consortium”, a project initiated by Citigroup to facilitate technological cooperation efforts. There are many different definitions of fintech among academics. An investigation by Zavolokina et al. (2016) delves into how Fintech terminology is used in science journals, including renowned newspapers and reports of research companies. Their study found 38 distinct definitions, containing “the application of IT in finance, start-ups, services, technologies, and companies in the financial sector as the top 5 meanings”.

Leong and Sung (2018) define Fintech as “any new concepts that improve financial service operations through the provision of technology solutions tailored to specific company conditions”. Fintech is a fundamental pillar to achieve financial development, inclusive financial system, social cohesion, and subsequent sustainable development, through building a setup for a novel digital financial network (Vergara and Agudo, 2021). When the question of environmental sustainability is addressed, evidence shows that fintech can be a key element to bridge the gap between the availability of funding and green project and promote renewable infrastructure to sustain clean-economic growth (Knuth, 2018). Schletz et al. (2020) argue that innovation in financial services through fintech can diminish the existing market barriers and enhances energy efficiency intermediations.

The existing literature has shown that the digitalization of financial services and the adoption of fintech by banking institutions empowered financial inclusion in emerging countries where the traditional bank-based financial system is immature (Yoshino et al,. 2020).

Olayini (2017) defines financial inclusion as a situation where a considerable segment of the population has access to financial services. A study by Sun and Zhang (2023) analyses the effect of banking activity and financial inclusion on the net-zero carbon footprint for 30 provinces in China for the period of 2000–2020, using the GMM model, the authors found that financial inclusion supports sustainability and decarbonization in China.

However, further research is required when assessing the interaction between fintech and financial inclusion in empowering the sustainability of countries. Concerning the effect of financial inclusion on climate change and sustainability, we find different arguments among economists. In theory, the effect of an inclusive financial system and the environment can be both positive and negative. Indeed, growing financial inclusion can lead to enhancing the sustainable environment and reducing the effect of climate change, by financially empowering the vulnerable portion of society, who are likely to be financially excluded.

Via financial inclusion, there is a more accessible, affordable, and sustainable range of financial products and services, which will be cost-energy effective (Le et al,.2020). Shahbaz et al. (2013) utilized the carbon emission function to explore the impact of financial development on CO_2 emissions, the study's results show that financial development enables investors to implement environment-friendly technology and reduces CO_2 production.

On the other hand, financial inclusion boosts economic growth and manufacturing activities, leading to more CO2 emissions. Zhang (2011) assessed the effect of financial development on CO2 emissions in China for the period 1980 to 2009, the study observed that China's financial development triggers the increase in CO2 emissions. Related findings were found in India by Shahbaz et al. (2015), using the Vector Error Correction Model (VECM) from 1970 to 2012, the authors argue that financial development has a positive impact on CO2 emissions in India. Also, easy, and affordable access to finance will increase the purchasing power of consumers and enable them to afford energy-intensive goods such as automobiles, which will increase the pollution level in the environment (Frankel and Romer,1999).

To the best of our knowledge, this study is the first to assess the interconnectedness of fintech and financial inclusion as an integrated framework to support the clean energy transition in the UK, this empirical study focuses on analyzing the dynamic relationship between our variables in a time of uncertainty. The uniqueness of the Bayesian var model adopted allows for drawing assumptions based on the available theory.

3. Data and methodology :

3.1. Data and variables:

Envisioning a scenario where banking embraces green practices, this section explores the effect of fintech on financial inclusion and environmental sustainability in the United Kingdom using several variables presented in table (). The data were sourced from renowned databases including Eikon, UK Department for Business, Energy and Industrial Strategy, and the World Bank. The selected timeframe for data collection spans from 1998 to 2022.

Table (1): Study's variables

groups	Variables	description	Source
Financial inclusion	**F-inclusion**	an index for financial inclusion focusing on two dimensions: supply and demand.	Calculated based on data extracted from the Eikon database
Fintech	**ATM**	the number of Automated Teller Machines	Eikon database

	Mobile banking	the total transaction volume or activity conducted through mobile banking services	World Bank
Environmental sustainability	**CO2**	The level of carbon dioxide (CO2) emission measured in metric tons	World Bank
	Bioenergy	Load factor of electricity from solar photovoltaics	UK Department for Business, Energy, and Industrial Strategy
Growth	**GDP**	Gross domestic product	IMF

Source: by the authors

Financial Inclusion measured the extent of financial accessibility and utilization by individuals and businesses. The number of ATMs and the prevalence of mobile banking were considered key indicators of fintech and technological advancements in the banking sector. Additionally, CO2 emissions were incorporated as a vital metric to gauge the carbon footprint in the UK, and bioenergy production was utilized as an indicator of renewable energy sources and sustainable practices. Finally, GDP allows for an assessment of how financial inclusion, fintech, and sustainable practices may influence economic growth and overall prosperity.

In this research, we create a financial inclusion index employing an innovative non-parametric approach, widely recognized in the literature for developing composite indices with equal weights. This methodology has been previously applied to construct indices related to well-being, such as the human development index **(Anand and Sen, 1994)**, as well as financial inclusion indices **(Park & Mercado Jr, 2018)** and **(Sha'ban et al., 2020)**. To achieve this, we follow a structured three-step process:

i. **In the first step of the process, we gather data on various indicators related to the supply and demand aspects of financial inclusion.**

To determine the financial inclusion index, we must consider factors from both the demand and supply perspectives. On the demand side, it refers to the financial needs of the population and their efforts to access finance, while on the supply side, it pertains to the actions taken by financial institutions to enable the population's access to finance **(Ongeta, 2019).**

Table (2): the indicators of financial inclusion index

Financial inclusion index	
Financial inclusion demand	**Financial inclusion supply**

• Number of bank branches • Number of ATMs	• Bank deposits • domestic credit to the private sector

Source: by the authors

These components (presented in table …) are non-substitutable **(Casadio Tarabusi & Guarini, 2013)**, which means that they cannot be interchanged or compensated for each other where a low value of bank branches cannot be balanced with a high number of ATMs and vice versa. The same principle applies to domestic credit to the private sector and bank deposits.

To maintain simplicity and ensure a clear and transparent approach, this study adopts a simple aggregation method **(Saisana & Tarantola, 2002)** employing a straightforward mathematical function.

ii. **Once the data is collected, we proceed with the normalization and weighting of the indicators.**

To guarantee equal weighting of the four indicators, we use the standardization approach of normalization. This process brings our indicators to the same variance and allows us to attribute equal weights.

The following rules are utilized to normalize our variables:

- **The supply side:**

$$FS_{i,t} = \frac{FSi,t - Min(FSi)}{Max(FSi) - Min(FSi)} \quad \text{….. (01)}$$

- **The demand side** $$FD_{i,t} = \frac{FDi,t - Min(FDi)}{Max(FDi) - Min(FDi)} \quad \text{…. (02)}$$

Where:

- $\boldsymbol{FS_{i,t}}$ represents the value of indicator "i" within the Supply dimension at time t. the values **Min(FSi)** and **Max(FSi)** correspond to the minimum and maximum values respectively, of the indicator "i" from the Supply dimension throughout the sample period.
- Likewise**,** $\boldsymbol{FD_{i,t}}$ refers to the value of indicator "i" from the Demand dimension in time t, Min **(FDi)** and Max **(FDi)** stand for the minimum and maximum values respectively of the indicator "i" from the Demand dimension throughout the sample period.

iii. **In the final step, we construct the financial inclusion index**

To consolidate our two-dimensional indexes into a comprehensive measure of financial inclusion, we employ the geometric mean as our aggregation method. This approach allows us to effectively combine the diverse dimensions and calculate a composite index that captures the essence of financial inclusion.

3.2. Methodology:

To examine the relationship between fintech, financial inclusion, and environmental sustainability and to understand the dynamic relationships between these variables over time and how changes in one variable impact the others, this study adopts a Bayesian vector autoregressive (VAR) model. Given the limited length of our dataset, the Bayesian VAR approach is the most suitable for this study because it provides a robust and flexible framework that accounts for the small sample size by incorporating prior knowledge, regularizing the estimation, and enabling the quantification of uncertainty **(Tsagkanos et al., 2022).**

According to **(Ciccarelli & Rebucci, 2003)** and **(Tsagkanos et al., 2022) ,** let the VAR model:

$$Y_t = X_t\beta + \varepsilon_t \ldots (3)$$

Where:

- Y_t is a $n \times 1$ vector of endogenous variables.
- ε_t is a $n \times 1$ vector of error terms that explains the random disturbances, identically and normally distributed with variance - covariance matrix $\Sigma, \varepsilon_t \sim$ IIN $(0, \Sigma)$.
- X_t is a matrix n $\times$ nk and represents the set of independent variables.
- β is $nk \times 1$ and represents the coefficients that assess the relationship between variables.

The Bayesian prior and posterior distribution rules of the parameters $p(\beta, \Sigma)$ are respectively as follows:

$$L\langle Y \mid \beta, \Sigma\rangle \emptyset |\Sigma|^{-\mathbb{T}_2} \exp\left\{-\frac{1}{2}\sum_t (Y_t - X_t\beta)'\Sigma^{-1}(Y_t - X_t\beta)\right\} \ldots (4)$$

$$p\langle \beta, \Sigma \mid Y\rangle = \frac{p(\beta,\Sigma) LY|\beta,\Sigma\rangle}{p(Y)} \sigma p(\beta, \Sigma) L\langle Y \mid \beta, \Sigma\rangle \ldots (5)$$

Given $p\langle \beta, \Sigma \mid Y\rangle$, the marginal posterior distributions conditional on the data, $p\langle \Sigma \mid Y\rangle$ and $p\langle \beta \mid Y\rangle$ can be obtained by integrating out β and Σ from $p\langle \beta, \Sigma \mid Y\rangle$ respectively.

Incorporating prior distributions of the parameters in Bayesian analysis is a common practice to strengthen the robustness and reliability of inferences about their true value. In the Bayesian VAR context, various priors have been used in the literature such as Litterman/Minnesota prior, Normal-Wishart prior, Sims-Zha normal-Wishart prior and Sims-Zha normal-flat **(Evans & Alenoghena, 2017).** In this study, we employ the Minnesota prior introduced by **(Litterman, 1986)** due to its favorable characteristics where it assumes that Σt, the covariance matrix, is known, which simplifies the process of prior elicitation and posterior computation.

4. Results and empirical analysis:

4.1 Unit root test:

To assess the stationarity properties of the variables under study, we have used the Augmented Dickey-Fuller (ADF) test which is commonly used in the literature. This test aims to determine whether a variable follows a unit root process, indicating its stationarity or non-stationarity.

Table (3): ADF unit root test results

variables	ADF without Constant & Trend		
	Level	**1^{st} difference**	**Decision**
F-inclusion	*0.4190*	*0.0213*	I (1)
ATM	*0.3551*	*0.0149*	I (1)
Mobile banking	*0.9919*	*0.0018*	I (1)
CO2	*0.0065*	*0.4533*	I (0)
Bioenergy	*0.6509*	*0.0194*	I (1)
GDP	*0.0001*	*0.0000*	I (0)

Note: *significance level of 5%*

Source: data processing

Based on the results presented in **table (3)**, we can observe that F-inclusion, along with ATM, mobile banking, and bioenergy are integrated in order which implies that these variables are non-stationary at level and requires differencing to achieve stationarity. On the other hand, CO2 and GDP are integrated of order 0 suggesting that these variables are stationary in their level.

1. **Johansen cointegration test:**

The Johansen cointegration test can be seen as a multivariate generalization of the augmented Dickey-Fuller test where it examines the linear combination of variables **(Dwyer, 2015)**. It considers both the trace and the maximum eigenvalue tests to evaluate the maximum rank of cointegration. **Table (4)** indicates that no-cointegration exists among variables which suggests that these variables do not exhibit a long-term relationship.

Table (4): Johansen cointegration results

Johansen test

Hypothesized	Eigenvalue	Trace statistics	Probabilities
None	*0.913123*	*57.7458*	*0.0593*
At most one	*0.797433*	*70.5509*	*0.1986*
At most two	*0.724177*	*64.82718*	*0.1235*
At most three	*0.600580*	*35.20326*	*0.5830*

Source: data processing

4.2 Bayesian VAR estimation:

The next step is to estimate the Bayesian VAR model taking into account the prior information and the specific characteristics of the data. Estimation results provide us with different insights into the relationships and dynamics among the variables under study.

Table (5) reveals that there is a negative and significant effect of fintech, represented by both ATM and mobile banking, on financial inclusion. Additionally, CO2 emissions have a negative and significant impact on fintech adoption, while bioenergy production does not show a significant effect. GDP also has a positive and significant impact on financial inclusion, fintech adoption (ATM), and CO2 emissions.

Furthermore, the results indicate a negative and significant relationship between financial inclusion and ATM usage, while financial inclusion has a positive and significant effect on mobile banking adoption. Interestingly, both CO2 emissions and bioenergy production have a positive and significant impact on ATM usage, while their effects on mobile banking are negative and non-significant. furthermore, there is a negative and significant impact of financial inclusion, ATM usage, mobile banking adoption, and bioenergy production on CO2 emissions.

Finally, the analysis reveals the existence of a significant positive effect of financial inclusion on GDP while the other variables such as ATM usage, mobile banking adoption, and bioenergy production do not have a significant impact on GDP.

Table (5): Bayesian var estimation results

Bayesian VAR estimates						
	F_inclusion	**ATM**	**Mobile banking**	**CO2**	**Bioenergy**	**GDP**
F_inclusion	*0.940579* *(0.01527)*	*-0.455130* *(3.64083)*	*3.069672* *(0.0360)*	*-0.230368* *(0.03573)*	*1.877301* *(3.64630)*	*1.894417* *(0.03763)*
ATM	*-0.000391* *(0.00140)*	*0.953438* *(0.06851)*	*0.094149* *(0.24250)*	*-0.000610* *(0.01022)*	*-0.004810* *(0.06825)*	*-0.064354* *(0.12180)*
Mobile banking	*-0.000343* *(0.00049)*	*-0.023544* *(0.02382)*	*0.975059* *(0.08546)*	*-0.001591* *(0.00358)*	*0.003506* *(0.02387)*	*-0.003439* *(0.04260)*

CO2	*0.004223* *(0.01038)*	*0.611573* *(0.00485)*	*-0.187980* *(1.80053)*	*1.020280* *(0.07623)*	*-0.120805* *(0.50604)*	*0.436152* *(0.00296)*
Bioenergy	*-0.001329* *(0.00186)*	*0.008028* *(0.02041)*	*-0.046774* *(0.32199)*	*-0.002493* *(0.01357)*	*0.943675* *(0.09136)*	*-0.000120* *(0.16171)*
GDP	*4.90E-05* *(0.00056)*	*-0.001202* *(0.02744)*	*-0.003385* *(0.09774)*	*0.000747* *(0.00412)*	*0.001083* *(0.02750)*	*0.004368* *(0.04958)*
R-squared	*0.945512*	*0.973026*	*0.962146*	*0.975514*	*0.862051*	*0.957491*
F-statistic	*14.46064*	*30.06019*	*21.18088*	*33.19919*	*5.207528*	*9.420279*

Source: data processing

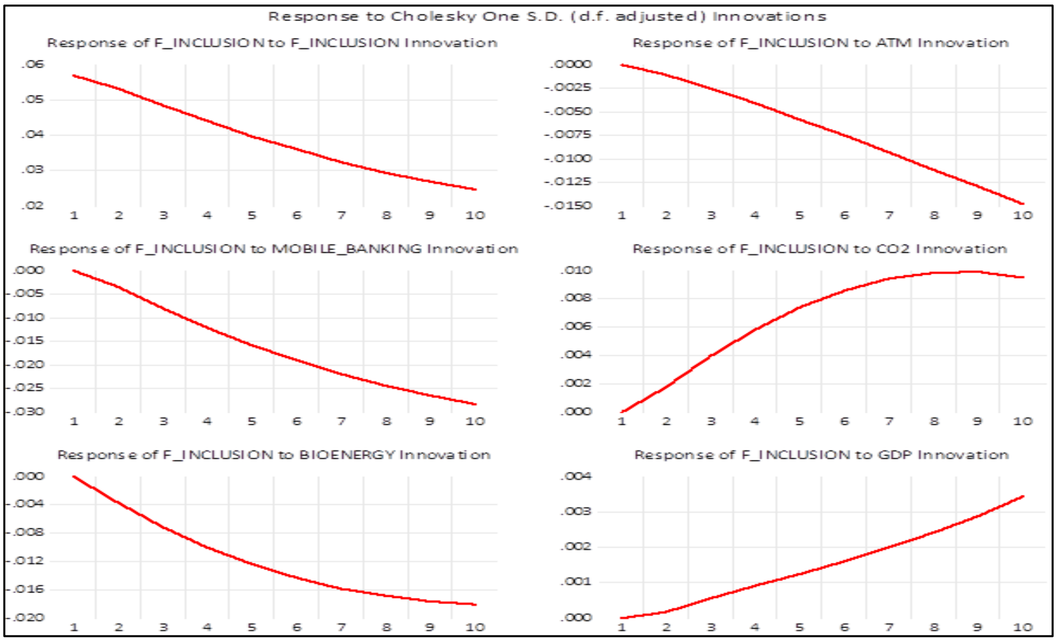
4.3 Impulse responses functions IRF:

To analyze how shocks or innovations in one variable spread through the system and impact the other variables over time, impulse response functions (IRFs) were generated. The IRFs in a Bayesian analysis framework differ in several ways where these last are estimated based on the posterior distribution of the parameters taking into consideration the uncertainty associated with the estimation process.

The results of the IRFs analysis are visually presented through four figures, showing the response of different variables of interest.

Figure 1, depicts the response of financial inclusion to shocks or innovations within the system. This figure provides insights into how financial inclusion reacts and adjusts to various stimuli. Shocks in the fintech variables lead to a decrease in the level of financial inclusion in the short term. In addition, financial inclusion reacts positively and anticipates a positive response to CO2 emission shock and a negative response to bioenergy production. Lastly, the positive response of financial inclusion to GDP shocks implies that an increase in economic growth stimulates higher levels of financial inclusion in the short term.

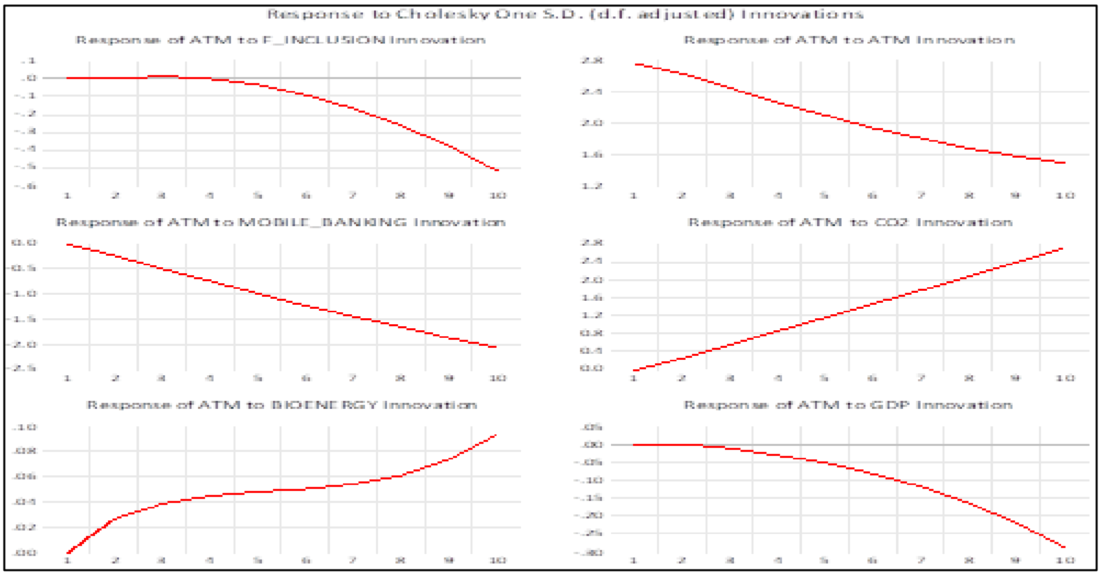
Figure 01: Response of F-inclusion



Source: data processing

Figures 2 and **3** picture the response of fintech, representing the response of both ATM and mobile banking to shocks respectively. Results in **Figure 2** showcase a negative response of ATMs to financial inclusion. Similarly, ATM responds negatively to mobile banking shocks in addition to a positive response of ATM to both environmental sustainability factors, CO_2 emissions, and bioenergy production.

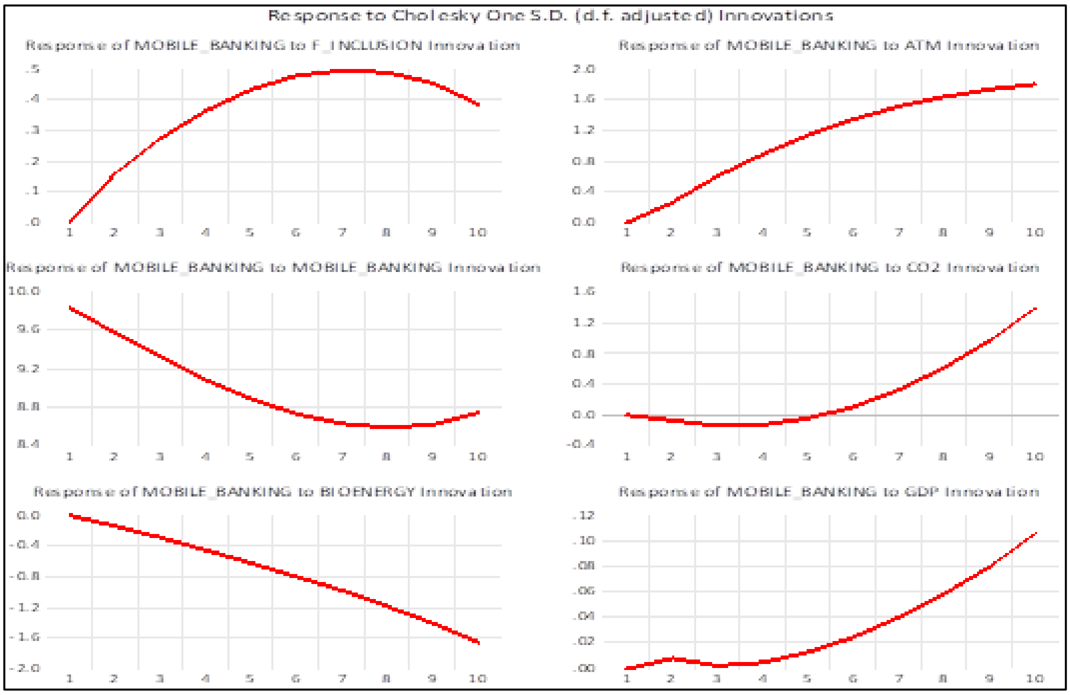
Figure 2: the response of ATM



Source: data processing

Figure 03 displays the response of mobile banking to various shocks. It shows a positive response to financial inclusion and ATM shocks, indicating that increases in these variables lead to greater mobile banking adoption. In response to CO_2 shocks, there is an initial negative impact followed by a subsequent positive effect at t=5. Bioenergy shocks result in a negative response, while GDP shocks elicit a positive response.

Figure 03: the response of mobile banking

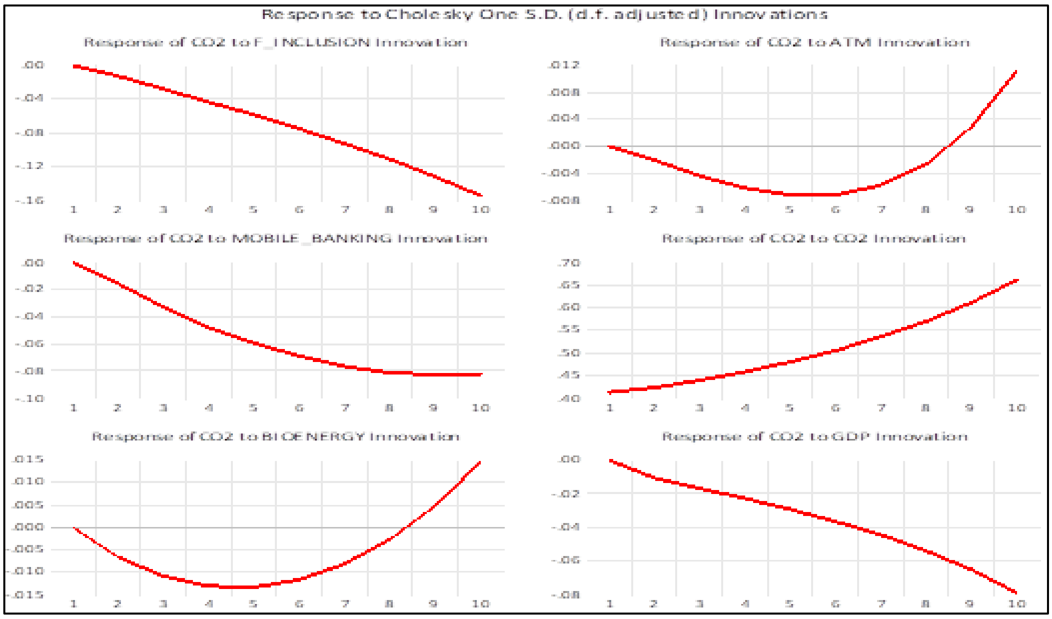


Source: data processing

Moving on to **Figures 4** and **5**, we explore the response of environmental sustainability variables, including CO2 emissions and bioenergy production, to system shocks.

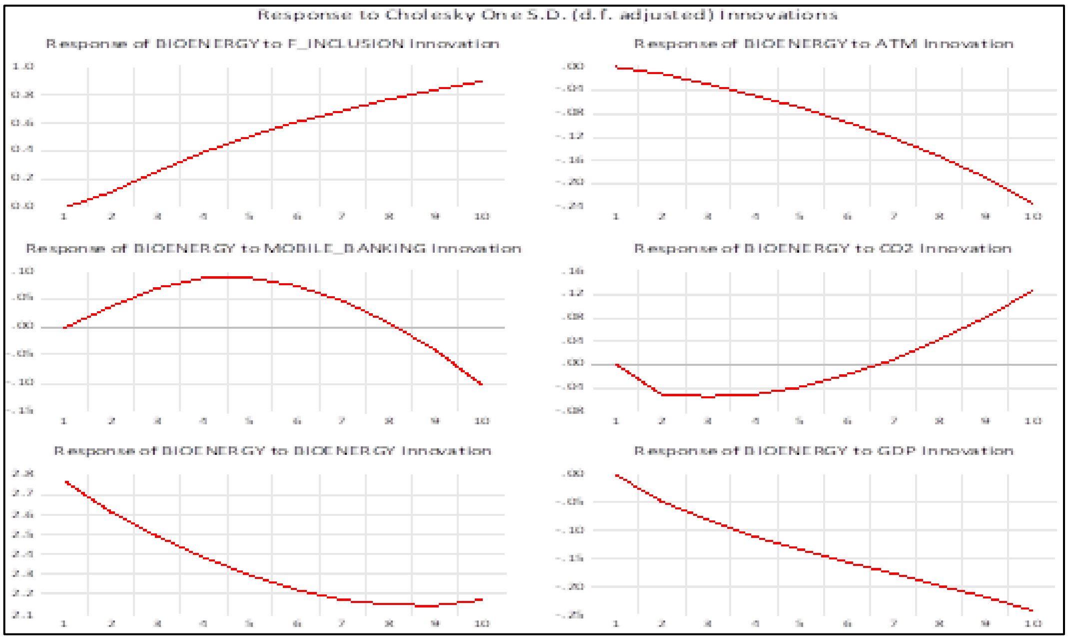
Figure 04, shows that CO2 emissions respond negatively to shocks in financial inclusion, ATM, mobile banking, and GDP. In addition, there is a negative response followed by a subsequent positive response at t=8 until the end of the period for both ATM and bioenergy shocks. While in **Figure 05**, bioenergy production shows a positive response to financial inclusion shocks and a negative response to ATM shocks. In addition to a positive response followed by a subsequent negative response at t=8 for mobile banking shocks. Additionally, CO2 shocks result in a negative response followed by a subsequent positive response at t=6.5.

Figure 04: the response of CO2 emissions



Source: data processing

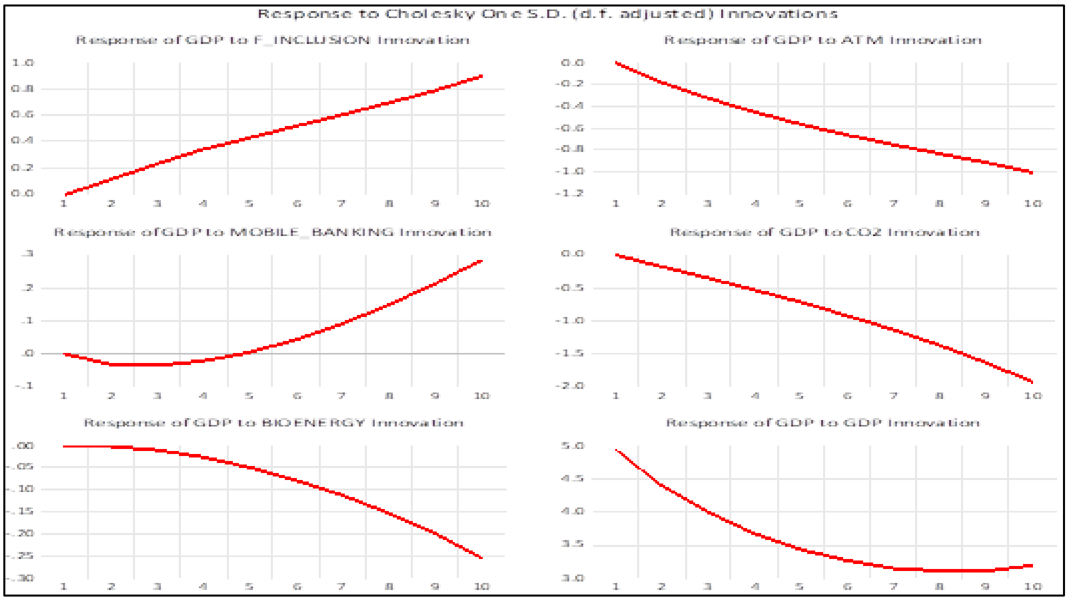
Figure 05 : Bioenergy response



Source: data processing

figure 6 presents the response of GDP to shocks. Results highlight that GDP exhibits a positive response to shocks in financial inclusion and a negative response to shocks in ATM while a negative response is followed by a positive response to shocks in mobile banking. Additionally, GDP shows a negative response to both environmental sustainability variables and CO2 shocks.

Figure 06: the response to GDP



Source: data processing

4.4 Granger causality Wald tests

In addition to the aforementioned tests, this study adds another layer of analysis by conducting a Granger causality test to strengthen and complement the previous results through the examination of the causal relationship among financial inclusion, fintech, and environmental sustainability. By assessing the Wald test, we can determine whether one variable can be said to Granger-cause another variable **(Shukur & Mantalos, 2000).**

The findings are summarized in **table (6)** based on the table in Annex 01**.**

Table (6): Granger causality test results

Variable		**p-value**	**Decision**
The causal relationship between fintech and financial inclusion			
ATM F-inclusion	F-inclusion ATM	0.206 0.966	there is no causal relationship between ATM and financial inclusion in either direction. However, a multidirectional causal relationship exists between financial inclusion and mobile banking
Mobile banking F-inclusion	F-inclusion Mobile banking	0.042 0.003	
The causal relationship between financial inclusion and environmental sustainability			
CO2 F-inclusion	F-inclusion CO2	0.014 0.033	A multidirectional causal relationship between financial inclusion and CO2 emissions. Additionally, there is evidence of a one-directional causal relationship between bioenergy production and financial inclusion
Bioenergy F-inclusion	F-inclusion Bioenergy	0.001 0.185	
The causal relationship between Fintech and environmental sustainability			

ATM Mobile banking	CO_2 CO_2	0.667 0.005	no causal relationship between ATM and CO_2 emissions. However, a causal relationship exists between ATM and bioenergy. mobile banking shows a causal relationship with both CO_2 emissions and bioenergy production
ATM Mobile banking	Bioenergy Bioenergy	0.040 0.046	

Source: authors' analysis based on data processing

5. Discussion:

This paper endeavors to empirically assess whether financial inclusion affects the environmental performance through the adoption of financial technology. The case of the United Kingdom provides an interesting context to examine the effect of fintech being the second-largest destination for fintech investment globally, after the United States. **(international trade administration, 2022).** The empirical findings supported our hypothesized effect, implying that Fintech has the potential to support green finance and enhance the sustainability of financial institutions and environmental performance. Overall, results confirm that financial technology contributed to expanding financial inclusion within the country especially when using mobile banking apps and online payment platforms, where it helps to incur lower transaction costs, overcome barriers, offer diverse services, and expands access to financial services for individuals who are underserved or unbanked without the need for physical bank branches. However, regarding the negative relationship between ATMs and financial inclusion, we must note that even though ATMs play an important role in providing convenient and accessible cash withdrawal services and offering extended banking hours (24/7), it also faces limitations and have a few negative aspects in terms of limited geographical reach, high costs, lack of banking services. These findings align with **(Arner et al., 2020; Nurohman et al., 2021; Zetzsche et al., 2019).** Moreover, in the context of environmental sustainability, the UK has made significant efforts to switch toward a low-carbon economy by reducing gas emissions and promoting renewable energy sources, and the integration of FinTech involves various aspects. Indeed, results highlighted the significant role of financial inclusion, facilitated by fintech in promoting environmental sustainability in several ways. First, ATMs and mobile banking reduce CO_2 emission through paperless transaction which leads to a reduction in paper production and ultimately decrease associated CO_2 emissions, and convenient access to financial services without the need for physical branch visits which reduces CO_2 emissions from transportation. In addition, given the positive effect of ATMs and mobile banking on bioenergy production, these last not only provide financial support but also promote green investment. ATM and mobile banking services facilitate financial transactions, loan applications, and investment opportunities related to renewable energy projects. Several studies supported these results such as **(Gunn & Stanley, 2018; Liu et al., 2022; Toumi et al., 2023).**

In conclusion, the relationship between financial inclusion, FinTech, and environmental sustainability in the UK signifies a convergence of efforts towards a more inclusive and environmentally conscious financial ecosystem. By leveraging technology and promoting financial inclusion, the UK can advance both financial access and environmental sustainability, fostering a greener and more inclusive economy **(Mhlanga, 2022)**.

6. conclusion:

Accessible and affordable finance is a key pillar of a sustainable, contemporary, industrialized nation. Empirical studies proved decarbonization to be an effective tool to pave the way for clean economic growth and attempt to reach the UK's net zero carbon footprint goals. This study aims to quantify the effect of fintech on financial inclusion and sustainability in the United Kingdom, using a Bayesian Vector Auto-Regressive approach for the period from 1998 to 2022. In an era of a continuously globalized world, the degradation of ecological resources is making climate change matter at the center of policymakers' strategies and agendas worldwide.

In the Energy White Paper, published in December 2020, the UK government set out critical points aiming to lower carbon power, the UK predicts the energy sector to become dominant by low-carbon solutions by 2050. However, the focus on reducing CO2 gas emissions as a cost-effective tool for greening the economy requires a strong financial system to channel the capital flow toward sustainable, ecology-friendly investments. Our finding suggests that fintech frameworks as an infrastructure to support the sustainable development of the UK must be integrated with the implementation of financial inclusion as a process to empower the sustainability goals. The econometric study results show that the shocks in CO2 emission respond negatively to financial inclusion and fintech adoptions, which indicates robust evidence of the requirement of developing a digitalized inclusive financial system to sustain the transition to net-zero carbon. In addition, the positive response of the Bioenergy variable to the stimuli of fintech and financial inclusion indicates the efficiency of inclusive digital financial platforming promoting the renewable energy industry in the UK. Overall, the Implementation of the digital green banking industry can help foster access to affordable funds for renewable energy projects.

The state should adjust the governmental strategies to the local needs, developing action plans that fit the current financial and environmental requirement of the UK's real economic situations. When we Evoque the term “real” we refer to the real geographical disparities on the ground, which act as a barrier to financial inclusion, and hence, refrain the access to green finance for all. Indeed, financial exclusion is stopping the financial system from supporting the achievement of net-zero goals to its fullest potential. The policymakers should consider teaming up with the private sector, especially startups operating in technology to create a novel framework tailored to the need of the diverse population of the UK. The unbanked portion of society might consider adopting sustainable energy solutions if the ease and affordability of “Green” is featured. When embedding finance in the society, considering the well-being of the people when designing a solution that sustains economic growth without harming mother nature, the government is pushing away the fake “green” from finance or more known as greenwashing, and therefore, keeping the authentic ethicality of the green banking industry.

Further studies could delve into this matter and take a step further in assessing the determinant of true human centric green finance on a country level.

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