Socio-Economic, Institutional and Climate Determinants of Green Microfinance: Evidence from a System GMM Panel Approach

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Abstract: *This study examines the socio-economic, institutional, and climate-related determinants of green microfinance in developing countries. Using a panel of 20 African countries over the period 2010–2025, the analysis applies a dynamic panel data model estimated through the two-step System Generalized Method of Moments estimator. The study contributes to the literature in two main ways. First, it introduces a rural climate vulnerability variable, CLIM_RURAL, constructed as the interaction between a climate shock index and the rural population share. Second, it employs a composite green_microfinance index that captures the multidimensional nature of green microfinance, including green loans, environmental policies, environmental screening, and awareness-raising activities. The empirical results show that rural climate vulnerability has a positive and highly significant effect on green microfinance, suggesting that climate shocks affecting rural populations increase the demand for green financial products. Institutional quality also exerts a positive and significant effect, indicating that stronger governance frameworks facilitate the development of inclusive green finance. By contrast, lagged poverty has a negative and weakly significant effect, while agriculture and income inequality do not show statistically significant effects. These findings suggest that green microfinance is driven by both climate adaptation needs and institutional capacity. The study highlights the importance of integrating climate-risk management into microfinance products, strengthening institutional quality, and reducing financial constraints for poor rural households in order to promote inclusive and sustainable green finance.*

Keywords: Green Microfinance; Rural Climate Vulnerability; Institutional Quality; Poverty; System Gmm; Developing Countries; Sustainable Finance.
JEL Classification: G21; O16; Q54; Q56; O13

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Introduction

In a context marked by the acceleration of climate change, increasing rural vulnerabilities, and persistent socio-economic inequalities, green finance has gained growing importance in sustainable development strategies. Developing countries are particularly exposed to this dual challenge: on the one hand, they need to strengthen financial inclusion among poor and rural populations; on the other hand, they must finance adaptation to climate shocks, particularly in agricultural and rural sectors that remain highly dependent on natural conditions.

Green microfinance has therefore emerged as an innovative instrument capable of reconciling financial inclusion, poverty reduction, and ecological transition. Unlike traditional microfinance, which primarily aims to improve access to credit for populations excluded from the formal banking system, green microfinance incorporates an environmental dimension by financing sustainable activities such as climate-smart agriculture, renewable energy, energy efficiency, water-saving irrigation, and climate adaptation technologies. It can thus serve as a potential lever for strengthening the resilience of vulnerable households while supporting more sustainable development pathways.

However, despite the growing interest in green finance, the empirical literature remains relatively limited when it comes to analysing the specific determinants of green microfinance in developing countries. Most existing studies focus either on green finance at the macroeconomic level or on traditional microfinance, without simultaneously integrating climate, rural, institutional, and socio-economic dimensions. Moreover, the indicators commonly used to measure green finance are often partial, generally limited to green loans or environmental policies, and do not fully capture the multidimensional nature of green microfinance.

This study is positioned within this perspective. Its originality rests mainly on two contributions. First, it proposes an innovative measure of rural climate vulnerability through the variable **CLIM_RURAL**, constructed as the interaction between a climate shock index and the share of the rural population. This variable goes beyond traditional aggregate climate measures by accounting not only for the intensity of climate shocks, but also for the actual exposure of rural populations. It therefore provides a more accurate way to capture the relationship between climate vulnerability and the demand for green financial products.

Second, this research employs a composite green microfinance index, referred to as **green_microfinance**, inspired by the **Green Index** approach and environmental performance assessment frameworks for microfinance institutions. This index is not limited to green loans, but incorporates several complementary dimensions, including green financial products, environmental policies, environmental loan screening, and awareness-raising activities for beneficiaries. This approach allows for a more comprehensive assessment of the environmental commitment of microfinance institutions.

Accordingly, the main objective of this study is to identify the socio-economic, institutional, and climate-related determinants of green microfinance in a sample of **20 countries** observed

over the period **2010–2025**, corresponding to a **16-year period**. To achieve this objective, the study employs a dynamic panel data model estimated using the **two-step System GMM method**, which makes it possible to control for endogeneity, unobserved individual heterogeneity, and the dynamic persistence of green microfinance.

The expected findings of this research help clarify the mechanisms through which climate shocks, institutional quality, poverty, agriculture, and income inequality influence the development of green microfinance. In this respect, the study contributes to the literature on inclusive sustainable finance by showing that green microfinance depends not only on economic conditions, but also on territorial climate vulnerability and institutional quality.

The remainder of the article is organized as follows. **Section 2** reviews the relevant literature. **Section 3** describes the methodology and data used in the empirical analysis. **Section 4** presents and discusses the main empirical results. Finally, **Section 5** concludes the study and provides policy implications.

Literature Review

2.1. Green Microfinance and Sustainable Development

Green microfinance represents an evolution of traditional microfinance, as it combines financial inclusion with environmental and social objectives. While conventional microfinance primarily aims to improve access to credit for poor populations, green microfinance also seeks to finance environmentally friendly activities, such as sustainable agriculture, renewable energy, energy efficiency, and climate adaptation.

In this perspective, Halouani (2025) shows that microfinance institutions can contribute to sustainable development when they integrate environmental and social objectives into their operations. Based on a panel of 30 microfinance institutions across nine countries over the period 2018–2023, the study finds that green loans and environmental risk management can reduce greenhouse gas emissions and strengthen women's empowerment.

Similarly, Abidi, Nsaibi, and Hussainey (2026) emphasize that green microfinance can enhance the resilience of vulnerable populations in Africa. Their study shows that, in a context marked by poverty, inequality, and climate shocks, green microfinance represents an important tool for improving access to essential services and supporting disadvantaged communities. This strand of literature confirms that green microfinance should not be considered merely as a financial instrument, but rather as a lever for sustainable development and social resilience.

2.2. Dimensions of Green Microfinance

The literature shows that green microfinance is a multidimensional concept. It is not limited to green loans, but also includes the environmental policies of microfinance institutions, the assessment of environmental risks associated with loans, and awareness-raising or training activities for beneficiaries.

The MIX–e-MFP report (2015), entitled *Assessing Green Microfinance: Qualitative and Quantitative Indicators*, identifies several indicators of the environmental performance of microfinance institutions, including green loans, formal environmental policies, environmental loan screening, and client training or awareness-raising activities.

Similarly, the **Green Index 3.0**, developed by e-MFP (2022), provides a framework for assessing the environmental performance of inclusive financial service providers. This framework is based on three main dimensions: clients' climate vulnerability, negative environmental impacts, and green economic opportunities. The CERISE/SPTF standards also incorporate an environmental dimension into the assessment of the social and environmental performance of inclusive finance institutions.

These methodological references justify the construction of a composite green microfinance index, especially when direct data on green microfinance activities are not fully available.

2.3. Green Loans as an Instrument of Green Microfinance

Green loans represent one of the main operational instruments of green microfinance. They refer to financing granted to activities with a positive environmental impact, such as solar energy, water-saving irrigation, organic farming, energy-efficient equipment, and sustainable natural resource management.

According to the MIX–e-MFP report (2015), green loans constitute a central quantitative indicator for measuring the environmental commitment of microfinance institutions. The report also emphasizes that data on green loans are among the easiest to track, although they remain limited and heterogeneous across institutions.

This approach justifies the use of a variable such as **Green_Loan_pct**, calculated as the ratio of green loans to total microfinance loans. This variable measures the share of the credit portfolio allocated to environmentally sustainable activities. It therefore constitutes an essential component of the green microfinance index proposed in this study.

Green_Loan_pct = Green_Loans / Total_Microfinance_Loans

2.4. Green Microfinance and Sustainable Agriculture

The relationship between green microfinance and sustainable agriculture is particularly important in developing countries, where a large share of poor households depends directly on the agricultural sector. Access to finance enables smallholder farmers to invest in sustainable agricultural technologies, such as drought-resistant seeds, water-saving irrigation systems, solar pumps, and agroecological practices.

The World Bank emphasizes that access to climate finance is essential to enable small farmers to adopt climate-smart agriculture and strengthen their resilience to climate shocks. In this perspective, Ansari, Ekta, Kumar, and Yadav (2025) show that green microfinance can serve as a bridge between rural development and sustainability. Their study indicates that green

microfinance enables rural communities to adopt renewable energy solutions, sustainable agricultural practices, and resource-efficient technologies.

Thus, green microfinance can transform rural finance into a tool for climate adaptation and agricultural modernization.

2.5. Agricultural Green Finance and Sustainable Agricultural Development

The literature on agricultural green finance shows that green financial instruments can improve sustainable agricultural development. Tong, Niu, Jiang, and Wang (2025) analyse the impact of agricultural green finance on green agricultural development in China using panel data covering 30 provinces over the period 2011–2021.

Their findings show that agricultural green finance significantly improves sustainable agricultural development, mainly through green technological innovation. This conclusion is particularly relevant for developing countries, as it suggests that green finance can support the adoption of cleaner and more productive agricultural technologies.

In the same vein, Benni (2024), in a report published by the FAO and GIZ, shows that inclusive green finance can support sustainable agriculture through financial products adapted to small producers, including green credit, climate insurance, and rural financing instruments. The report highlights the need to design financial services tailored to the needs of vulnerable farmers, taking into account climate risks, agricultural seasonality, and constraints on access to credit.

2.6. Green Microfinance and Poverty Reduction

Green microfinance can contribute to poverty reduction through several channels. First, it enables poor households to access financing for income-generating activities. Second, it reduces their vulnerability to climate shocks by supporting sustainable investments. Third, it strengthens beneficiaries' capacities through training and environmental awareness-raising.

In this perspective, Mujtaba et al. (2025) show that green microfinance contributes to poverty reduction and the development of sustainable livelihoods among rural households. Their study highlights several dimensions of impact, including income and asset creation, environmental sustainability, capacity building, and social empowerment.

Similarly, Abidi, Nsaibi, and Hussainey (2026) confirm that green microfinance can strengthen the resilience of vulnerable communities in Africa, particularly when populations are exposed to poverty, unemployment, inequality, and the effects of climate change. These findings support the hypothesis that green microfinance can act as a poverty reduction mechanism by improving the economic and environmental resilience of households.

Methodology

3.1. General Model

To identify the determinants of **green microfinance**, this study employs a dynamic panel data model estimated using the **two-step System Generalized Method of Moments** (**two-step System GMM**) estimator, developed by Arellano and Bover (1995) and Blundell and Bond (1998). This approach makes it possible to simultaneously control for the endogeneity of explanatory variables, unobserved individual heterogeneity, and the dynamic persistence of green microfinance over time.

The general specification of the model is written as follows:

$$\begin{aligned} \textbf{green\_microfinance}_{it} = {} & \alpha_0 + \delta\, \textbf{green\_microfinance}_{i,t-1} \\ & + \beta_1\, \textbf{poverty}_{i,t-1} + \beta_2\, \textbf{agriculture}_{it} \\ & + \beta_3\, \textbf{CLIM\_RURAL}_{it} + \beta_4\, \textbf{institutional\_quality}_{it} \\ & + \beta_5\, \textbf{income\_inequality}_{it} + \alpha_i + \varepsilon_{it} \end{aligned}$$

where **i** denotes the country and **t** denotes the year. The term α_i represents country-specific fixed effects, capturing unobserved heterogeneity across countries, such as institutional history, regulatory frameworks, financial development, and structural economic characteristics. The term ε_{it} denotes the idiosyncratic error term.

The lagged dependent variable, **green_microfinance_i,t−1**, is introduced to capture the dynamic persistence of green microfinance. Its coefficient, **δ**, measures the degree of inertia in the environmental performance of microfinance institutions over time. The explanatory variables include lagged poverty, the share of agriculture in GDP, rural climate vulnerability, institutional quality, and income inequality.

The use of the two-step System GMM estimator is particularly appropriate in this context because the model includes a lagged dependent variable and potential sources of endogeneity. In addition, the estimator combines equations in first differences and in levels, using appropriate lagged values of the variables as instruments. This improves estimation efficiency and helps address biases arising from simultaneity, omitted variables, and country-specific unobserved effects.

3.2. Data and Sample

This study relies on a panel of developing countries located mainly in North Africa and Sub-Saharan Africa, as well as other African economies characterized by high exposure to rural and climate-related vulnerabilities. The sample covers the period **2010–2025** and includes 20 countries: **Algeria, Morocco, Tunisia, Egypt, Mauritania, Benin, Cameroon, Congo, Côte d'Ivoire, Gabon, Ghana, Kenya, Nigeria, Uganda, the Democratic Republic of the Congo, Rwanda, Senegal, Tanzania, Chad, and Ethiopia**.

The selected countries share several structural characteristics that make them particularly relevant for the analysis of green microfinance. These include persistent rural poverty, strong dependence on agriculture, high exposure to climate shocks, and the gradual development of

microfinance institutions integrating environmental and sustainability-oriented practices. Accordingly, this sample provides a suitable empirical framework for examining how socio-economic, institutional, and climate-related determinants shape the development of **green microfinance** in contexts marked by environmental vulnerability and increasing demand for inclusive and sustainable financial services.

3.3. Estimated Model

Based on the results of the two-step System GMM estimation, the estimated empirical model is specified as follows:

$$\begin{aligned} \text{green\_microfinance}_{it} = {} & 0.5894 - 0.001048 \cdot \text{poverty}_{i,t-1} \\ & - 0.003508 \cdot \text{agriculture}_{it} \\ & + 0.000643 \cdot \text{CLIM\_RURAL}_{it} \\ & + 0.058577 \cdot \text{institutional\_quality}_{it} \\ & - 0.010240 \cdot \text{income\_inequality}_{it} \\ & + \alpha_i + \varepsilon_{it} \end{aligned}$$

3.4. Description of Variables

The following table presents the definition, measurement, data source, expected sign, statistical significance, and economic interpretation of each variable included in the empirical model.

Table 1. Description of Variables

Variable	Type	Measurement / Indicator	Expected Sign	Significance	Economic Description
green_microfinance	Dependent variable	Composite Green Index based on MIX/e-MFP, including green loans, environmental policies, environmental screening, and awareness-raising activities.	—	—	Measures the environmental performance of microfinance institutions. The index captures several dimensions of green microfinance, including green lending, environmental policies, environmental risk assessment, and client awareness activities.

pov (L1)	Explanatory variable lagged one period	Poverty rate (%) lagged by one period. Source: World Bank, PovcalNet / Poverty and Inequality Platform.	–	* p = 0.093	A high poverty rate in the previous period may reduce borrowers' repayment capacity and encourage microfinance institutions to restrict the supply of green credit. The lagged specification helps control for potential endogeneity.
agriculture	Explanatory variable	Share of agriculture in GDP (%). Source: World Bank, World Development Indicators (WDI).	+/–	ns p = 0.394	The share of agriculture reflects the importance of the rural sector in the economy. Its effect on green microfinance is ambiguous and may depend on the structure, productivity, and modernization level of the agricultural sector.
CLIM_RURAL	Explanatory variable	CLIM_RURAL = CLIM_shock_index × rural population share.	+	*** p = 0.004	Captures rural climate vulnerability. Deteriorating

		The CLIM_shock_index is a composite index based on temperature anomalies, precipitation deficits, and the number of extreme climate events.			climate conditions in rural areas may increase demand for green financial products, such as adaptation loans, agricultural insurance, renewable energy financing, and water-efficiency loans.
institutional_quality	Explanatory variable	Composite governance index based on the World Governance Indicators (WGI), calculated as the average of six governance dimensions, including control of corruption, rule of law, and government effectiveness. Scale: −2.5 to +2.5.	+	** p = 0.037	A strong institutional framework reduces transaction costs, protects property rights, improves contract enforcement, and strengthens trust in formal financial institutions, thereby promoting green microfinance development.
income_inequality	Explanatory variable	Gini index ranging from 0 to 100. Source: World Bank, PovcalNet /	–	ns p = 0.625	High income inequality may reduce poor

		Poverty and Inequality Platform, and WIID.			households' access to green credit while simultaneously increasing demand for alternative inclusive financial mechanisms. These opposing effects may explain the lack of statistical significance.

Note:
*** p < 0.01; ** p < 0.05; * p < 0.10; ns = not significant. Main data sources: World Bank databases, including WDI, WGI, and PovcalNet / Poverty and Inequality Platform; MIX Market / e-MFP Green Index; EM-DAT for extreme climate events; and ERA5/CRU for temperature anomalies and precipitation deficits.

Estimation Results

Table 2. Two-Step System GMM Estimation Results

Variable	Coefficient	Corrected Std. Error	t-statistic	P>|t|	95% CI Lower	95% CI Upper	Sig.
Poverty (L1)	−0.001048	0.0005903	−1.78	0.093	−0.0022881	0.0001922	*
Agriculture	−0.003508	0.0040189	−0.87	0.394	−0.011951	0.0049356	ns
Rural climate vulnerability	0.000643	0.0001939	3.32	0.004	0.000236	0.0010507	***
Institutional quality	0.058577	0.0259593	2.26	0.037	0.0040382	0.1131153	**
Income inequality	−0.010240	0.0206069	−0.50	0.625	−0.0535331	0.0330538	ns
Constant	0.589468	0.7204629	0.82	0.424	−0.9241686	2.1031040	ns

Note:
*** p < 0.01; ** p < 0.05; * p < 0.10; ns = not significant. Corrected standard errors are Windmeijer-corrected. F(5, 18) = 55.55; Prob > F = 0.000. Number of instruments = 17.

Table 3. Diagnostic Tests for the GMM Model

Test	Statistic	p-value	Decision
AR(1) — Arellano-Bond	z = −2.33	0.020	First-order autocorrelation is present, as expected
AR(2) — Arellano-Bond	z = 1.32	0.187	No second-order autocorrelation; condition validated
Hansen test	$\chi^2(11)$ = 17.42	0.096	Instruments are valid; H_0 is not rejected
Diff-Hansen — GMM levels	$\chi^2(6)$ = 1.06	0.983	Level instruments are exogenous
Diff-Hansen — L.pov agriculture	$\chi^2(3)$ = 0.60	0.896	Instruments are exogenous
Diff-Hansen — iv(institutional_quality)	$\chi^2(1)$ = 0.06	0.804	The instrument is exogenous

Note:
The Hansen test is the reference test for assessing instrument validity. The Sargan test is not robust to heteroskedasticity.

Diagnostic Interpretation
The two-step System GMM model is globally significant, as indicated by the Fisher statistic **F(5, 18) = 55.55** with **p < 0.001**. The number of instruments, **17**, is lower than the number of country groups, **20**, which satisfies the commonly recommended rule of thumb for avoiding instrument proliferation.

The Arellano-Bond tests confirm the presence of first-order autocorrelation, **AR(1): p = 0.020**, which is expected by construction in first-differenced residuals. More importantly, the absence of second-order autocorrelation, **AR(2): p = 0.187**, supports the consistency of the GMM estimator. The Hansen test, with **p = 0.096**, does not reject the null hypothesis of instrument validity, suggesting that the instruments used in the model are acceptable. In addition, the Difference-in-Hansen tests confirm the exogeneity of each subset of instruments.

Overall, these diagnostic tests support the validity of the two-step System GMM specification and indicate that the model is not affected by second-order serial correlation or invalid instruments.

Interpretation of the GMM Results

4.1. Lagged Poverty — pov (L1): β = −0.001048, p = 0.093, *
The coefficient of lagged poverty is negative and marginally significant at the 10% level. From an econometric perspective, the use of a one-period lag is justified for two main reasons. First, it helps control for the potential endogeneity between poverty and green microfinance, since a

contemporaneous relationship between these two variables could be affected by simultaneity bias. Second, it captures a delayed-effect mechanism, whereby poverty conditions in period *t−1* influence credit allocation decisions in period *t*. Within the System GMM framework, lagged levels and lagged differences of this variable are used as instruments, thereby improving the consistency of the estimation.

Building on this econometric interpretation, the negative coefficient also has an important economic meaning. A one-percentage-point increase in the poverty rate in the previous period reduces **green_microfinance** by **0.001048 units**. This result suggests that poverty represents a structural constraint on the development of green microfinance. High poverty levels reduce the perceived repayment capacity of potential borrowers, increase credit risk, and may encourage microfinance institutions to restrict the supply of green financial products, which are often considered riskier than conventional products. Moreover, households living in extreme poverty tend to prioritize immediate survival needs over long-term green investments.

This finding is consistent with previous empirical studies on microfinance outreach and poverty. Khandker (2005), in a pioneering panel-data study on Bangladesh, shows that poverty limits access to microcredit and that the poorest households are less likely to access formal financial products. Extending this argument to the environmental dimension of microfinance, Allet and Hudon (2013) confirm that microfinance institutions targeting the poorest populations tend to display weaker environmental performance, as priority is often given to immediate social impact rather than environmental criteria. Similarly, Awaworyi Churchill and Marr (2017) emphasize that poverty outreach and environmental performance may involve trade-offs, since profitability constraints can limit green investments in high-poverty contexts. Finally, Hermes et al. (2011) show that there is a trade-off between financial efficiency and depth of outreach in microfinance institutions, which may explain why poverty indirectly constrains the development of green microfinance.

Taken together, these results suggest that poverty does not only affect the demand side of green microfinance by limiting households' ability to invest in sustainable technologies; it also affects the supply side by increasing perceived credit risk for microfinance institutions. Therefore, reducing poverty-related financial constraints appears essential for expanding access to green microfinance products among vulnerable rural households.

4.2. Agriculture: β = −0.003508, p = 0.394, ns

The coefficient of the agriculture variable is negative but statistically non-significant (**p = 0.394**). From an econometric perspective, this result means that the null hypothesis of no effect of the agricultural share on **green_microfinance** cannot be rejected. The lack of statistical significance may be partly explained by the heterogeneity of agricultural structures across countries, which is only partially captured by country-specific effects, $\boldsymbol{\alpha_i}$. In addition, a potential partial multicollinearity with the rural climate vulnerability variable may reduce the precision of the estimated coefficient, since **CLIM_RURAL** itself incorporates the rural population share.

Beyond the econometric interpretation, this result also has an important economic implication. The absence of a significant effect suggests that the share of agriculture in GDP is not, by itself, a direct determinant of green microfinance once other socio-economic, institutional, and climate-related factors are controlled for. This finding may be explained by the coexistence of two opposing mechanisms. On the one hand, a larger agricultural sector may increase the demand for green financial products targeted at farmers, such as climate-adaptation loans, water-saving irrigation finance, solar equipment loans, and agricultural insurance. On the other hand, agricultural sectors in many developing countries remain largely informal, weakly modernized, and exposed to seasonal income fluctuations, which may limit farmers' access to formal financial services.

These two opposite effects may offset each other, resulting in a statistically non-significant net effect. In other words, agriculture can create a potential demand for green microfinance, but this demand does not automatically translate into effective access to green financial products. The ability of agriculture to stimulate green microfinance depends on additional conditions, such as the modernization of farming systems, the existence of rural financial infrastructure, institutional support, and the capacity of microfinance institutions to design products adapted to agricultural risks.

This interpretation is consistent with previous studies on agricultural finance and microfinance. Christen and Anderson (2001) show that in agriculture-dependent countries, access to formal microcredit remains constrained by informality, seasonality of income, and limited financial infrastructure. Similarly, Barnett et al. (2008) emphasize that agricultural financial products, particularly weather-indexed insurance, are difficult to scale up in developing countries because of moral hazard, adverse selection, basis risk, and weak institutional capacity. Cecchini and Madariaga (2011) also highlight that agricultural microfinance programmes require strong institutional support and complementary mechanisms in order to generate measurable developmental and environmental impacts.

Taken together, these findings suggest that the agricultural sector does not automatically promote the development of green microfinance. Rather, agriculture becomes a driver of green microfinance only when it is supported by appropriate institutions, climate-risk management tools, rural infrastructure, and financial products adapted to the specific needs of smallholder farmers. Therefore, the non-significant coefficient does not imply that agriculture is irrelevant; instead, it indicates that the agricultural share in GDP alone is insufficient to explain the development of green microfinance without considering the broader institutional and climate context.

4.3. Rural Climate Vulnerability — CLIM_RURAL: β = +0.000643, p = 0.004, ***

The variable **CLIM_RURAL** appears to be the most robust and statistically significant determinant in the model, with a p-value of **0.004**, indicating significance at the 1% level. From an econometric perspective, this result is particularly relevant because **CLIM_RURAL** is constructed as an interaction term between a climate shock index and the rural population share: CLIM_RURAL = CLIM_shock_index × rural_population_share

Since this variable is based on geophysical and demographic data, it is less likely to be affected by reverse causality than purely socio-economic indicators. This strengthens the reliability of the estimated coefficient and supports the relevance of including a rural climate vulnerability measure in the empirical specification.

Beyond its econometric relevance, the positive coefficient of **CLIM_RURAL** has a strong economic interpretation. A one-unit increase in the rural climate vulnerability index is associated with an increase of **0.000643 units** in **green_microfinance**. This result suggests the existence of a demand-driven climate adaptation mechanism. When rural populations are increasingly exposed to temperature shocks, precipitation deficits, and extreme climate events, their demand for green financial products tends to rise. These products may include agricultural adaptation loans, weather-indexed insurance, renewable energy financing, solar pump loans, water-saving irrigation loans, and other financial instruments designed to strengthen climate resilience.

This interpretation is particularly important because **CLIM_RURAL** does not merely capture the intensity of climate shocks. By interacting climate shocks with the rural population share, the variable also reflects the degree of social and territorial exposure to climate risks. In other words, the same climate shock may generate a stronger effect in countries where a larger share of the population lives in rural areas and depends directly on climate-sensitive activities, especially agriculture. Therefore, **CLIM_RURAL** provides a more precise measure of the contexts in which green microfinance is most likely to expand.

This finding is consistent with previous research on microfinance and climate adaptation. Agrawala and Carraro (2010), in an OECD report, identify microfinance as an important instrument for supporting climate change adaptation in developing countries, particularly by improving access to financial products for climate-exposed households. Similarly, Hammill et al. (2008) show that microfinance can strengthen the resilience of rural communities by facilitating access to adaptation technologies and risk-management instruments. These studies support the idea that climate vulnerability can increase the demand for financial services specifically designed to reduce environmental and livelihood risks.

More recent evidence also supports this mechanism. Arena et al. (2022), in a study published in *Business Strategy and the Environment*, document the vulnerability of microfinance borrowers to climate hazards and highlight how climate-related risks may increase credit risk and encourage the development of specific green financial products. In the same vein, the Climate Policy Initiative (2026) emphasizes that microfinance, because of its community-based structure and proximity to vulnerable households, can serve as a bridge between climate vulnerability and green growth in rural areas. Finally, Lal (2015) shows that in African countries, the combination of high climate vulnerability and strong rural dependence creates a structural demand for financial products adapted to smallholder farmers' needs.

Taken together, these results confirm that rural climate vulnerability is not only an environmental constraint but also a driver of green financial innovation. The positive and highly significant coefficient of **CLIM_RURAL** suggests that green microfinance develops more

strongly where climate shocks directly affect rural populations. Therefore, policies aiming to expand green microfinance should prioritize climate-vulnerable rural areas and promote financial instruments tailored to adaptation needs, such as green agricultural loans, climate insurance, renewable energy credit, and water-efficiency financing.

4.4. Institutional Quality: β = +0.058577, p = 0.037, **

The coefficient of **institutional quality** is positive and statistically significant at the 5% level, with a p-value of **0.037**. From an econometric perspective, this result suggests that institutional quality is a relevant determinant of **green_microfinance**. In the System GMM specification, this variable is instrumented by its contemporaneous value in the level equation, and the Difference-in-Hansen test confirms the exogeneity of this instrument, with $\chi^2(1) = 0.06$ and $p = 0.804$. Moreover, the use of Windmeijer-corrected standard errors ensures that the estimated standard error is robust to heteroskedasticity and small-sample bias. Since the World Governance Indicators tend to vary slowly over time, institutional quality can be considered a structural variable that is appropriately captured within the dynamic panel framework.

Building on this econometric evidence, the positive coefficient has a strong economic interpretation. A one-unit improvement in the institutional quality index is associated with an increase of approximately **0.059 units** in **green_microfinance**, making it the largest coefficient in absolute value among the statistically significant variables in the model. This result highlights the central role of institutions in the development of inclusive green finance. A strong institutional framework reduces transaction costs, protects property rights, improves contract enforcement, and strengthens trust in formal financial institutions. These conditions are essential for microfinance institutions to expand green financial products and integrate environmental criteria into their lending practices.

Furthermore, institutional quality affects both the supply and demand sides of green microfinance. On the supply side, better governance improves the ability of microfinance institutions to design, monitor, and enforce green lending contracts. It also facilitates the adoption of environmental screening mechanisms and reduces uncertainty for financial providers. On the demand side, stronger institutions increase borrowers' confidence in formal financial services and improve access to reliable and transparent financial products. Therefore, institutional quality does not merely support financial development in general; it specifically creates an enabling environment for the expansion of green and inclusive financial services.

This interpretation is consistent with the broader institutional economics literature. Acemoglu, Johnson, and Robinson (2001) argue that institutional quality is a fundamental determinant of long-term economic development because it secures property rights and reduces predatory behaviour. In the context of financial inclusion, Andrianaivo and Yartey (2010) show that strong institutions are a prerequisite for the development of financial markets in Africa. Similarly, Kendo and Tchakounte (2022) provide empirical evidence that institutional quality positively affects financial inclusion in Sub-Saharan Africa.

More specifically, in the field of green microfinance, Allet (2014) shows that microfinance institutions operating in favourable institutional environments are more likely to adopt formal

environmental policies and environmental screening mechanisms. This finding is further supported by Ahamed and Mallick (2019), who show that governance improves the capacity of financial institutions to provide inclusive and sustainable financial products. These studies reinforce the idea that green microfinance is not only driven by climate vulnerability or socio-economic needs, but also by the quality of the institutional environment in which microfinance institutions operate.

Taken together, these results suggest that institutional quality plays a strategic role in scaling up green microfinance. Strong institutions reduce uncertainty, improve contract enforcement, and encourage microfinance institutions to internalize environmental objectives. Therefore, policies aimed at promoting green microfinance should not focus only on financial products or climate adaptation needs, but should also strengthen governance, regulatory quality, transparency, and institutional capacity.

Synthesis of Results and Policy Implications

The results of the two-step System GMM model provide a clear hierarchy of the determinants of **green_microfinance**. Among the explanatory variables, **rural climate vulnerability** (**CLIM_RURAL**) and **institutional quality** (**institutional_quality**) emerge as the most robust and statistically significant drivers. This finding leads to a central conclusion: the demand for green microfinance is structurally driven by climate shocks affecting rural populations, while the supply and expansion of green microfinance are largely conditioned by the quality of the institutional framework.

In contrast, lagged poverty exerts a negative and marginally significant effect, suggesting that poverty remains a constraint on the development of green microfinance. This result is consistent with the traditional trade-off faced by microfinance institutions between social outreach and environmental performance. High poverty levels may reduce borrowers' repayment capacity and increase credit risk, thereby limiting the ability of microfinance institutions to expand green financial products. Meanwhile, agriculture and income inequality do not show statistically robust direct effects. This lack of significance may reflect the coexistence of opposing mechanisms that offset each other, as well as the partial capture of structural differences across countries by country-specific effects.

Taken together, these findings suggest that green microfinance development depends on the interaction between climate vulnerability, institutional capacity, and socio-economic constraints. Climate shocks create a growing need for adaptation-oriented financial products, particularly in rural areas. However, this demand can only be effectively transformed into access to green financial services when institutions are strong enough to support financial innovation, enforce contracts, reduce transaction costs, and promote trust in formal financial systems.

From a policy perspective, these results imply that public policies aimed at promoting green microfinance should be structured around three complementary priorities. First, climate adaptation mechanisms should be integrated into microfinance products targeted at vulnerable

rural populations. This includes green agricultural loans, climate-indexed insurance, renewable energy financing, water-efficient irrigation loans, and other instruments designed to strengthen household and agricultural resilience.

Second, governments and development partners should strengthen governance and institutional quality in order to create an enabling environment for inclusive green finance. Stronger institutions can encourage microfinance institutions to adopt environmental screening mechanisms, develop green lending standards, improve transparency, and integrate sustainability criteria into their lending operations.

Third, policies should reduce the financial constraints faced by poor households through guarantee schemes, targeted subsidies, concessional credit lines, and climate insurance mechanisms. Such instruments can reduce the perceived risk associated with green lending and improve access to green financial products for low-income and climate-vulnerable households. Overall, the results highlight that green microfinance cannot be promoted through financial instruments alone. Its expansion requires a coordinated strategy combining climate adaptation policies, institutional reforms, and inclusive financial mechanisms. In this sense, green microfinance should be viewed not only as a credit instrument, but also as a strategic tool for strengthening rural resilience, supporting sustainable agriculture, and advancing inclusive green development.

Conclusion

This study aimed to analyse the socio-economic, institutional, and climate-related determinants of green microfinance using a dynamic panel data model estimated through the two-step System GMM method. Based on a sample of **20 countries** observed over the period **2010–2025**, corresponding to a **16-year period**, the analysis identified the main factors that promote or constrain the development of inclusive green finance.

The empirical results first show that rural climate vulnerability, measured by the **CLIM_RURAL** variable, has a positive and highly significant effect on green microfinance. This finding represents one of the main contributions of the study. It indicates that climate shocks, when they strongly affect rural populations, stimulate the demand for green financial products designed to support adaptation and resilience. In other words, the more rural areas are exposed to climate risks, the greater the need for green financing, particularly to support sustainable agriculture, resource-efficient technologies, renewable energy, and climate insurance mechanisms.

Institutional quality also appears to be a key determinant of green microfinance development. Its positive and significant effect confirms that strong institutions play a decisive role in creating an enabling environment for sustainable finance. Better governance reduces credit risk, improves transparency, strengthens trust in financial institutions, and facilitates the integration of environmental criteria into microfinance practices.

By contrast, the socio-economic variables show more nuanced effects. Lagged poverty has a negative and weakly significant effect, suggesting that high poverty levels may limit access to green financial products due to solvency constraints, lack of collateral, and the priority given by poor households to immediate needs. Agriculture and income inequality, however, do not show statistically significant effects. This may be explained by the coexistence of opposing mechanisms or by the heterogeneity of economic structures across the countries studied.

The originality of this research lies in its dual methodological and empirical contribution. First, the construction of the **CLIM_RURAL** variable provides a more accurate measure of the real climate vulnerability of rural populations by combining the intensity of climate shocks with their social and territorial exposure. Second, the use of a composite **green_microfinance** index makes it possible to capture the multidimensional nature of green microfinance, going beyond the simple volume of green loans. These two contributions strengthen the relevance of the analysis and provide a better understanding of the dynamics of inclusive green finance in developing countries.

From a policy perspective, the results suggest the need to develop financial products specifically adapted to rural populations vulnerable to climate change. Microfinance institutions should integrate climate risks into their lending strategies and offer instruments such as green loans, climate insurance, credit guarantees, and financing for adaptation technologies. At the same time, strengthening institutional quality remains essential to ensure transparency, trust, and the effectiveness of green microfinance mechanisms.

Overall, this study shows that green microfinance can serve as a strategic tool for reconciling financial inclusion, climate resilience, and sustainable development. However, its expansion depends on the ability of countries to combine climate policies, institutional reforms, and inclusive financial mechanisms. Future research could extend this analysis by incorporating additional variables such as financial innovation, environmental regulation, digitalization of financial services, and regional differences in order to deepen the understanding of the determinants of green microfinance.

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