UNLOCKING ENVIRONMENTAL INNOVATION: DO BIGTECH AND FINTECH CREDIT EASE FINANCIAL CONSTRAINTS?

ĐỔI MỚI SÁNG TẠO VÌ MÔI TRƯỜNG: LIỆU TÍN DỤNG TỪ BIGTECH VÀ FINTECH LÀM GIẢM KHÓ KHĂN TÀI CHÍNH?

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ABSTRACT

This study examines the impact of financial constraints on firms' environmental innovation, with a particular focus on the moderating role of alternative financing. Using cross-country data from 2013 to 2019, we find that a one-standard-deviation increase in financial constraints (measured by KZ_index) is associated with a 6.9% decline in environmental innovation. However, BigTech credit significantly mitigates this effect, offsetting nearly 39% of the adverse impact, whereas FinTech credit shows no comparable influence. These findings highlight the importance of financial capacity in supporting environmental innovation and suggest that BigTech credit may serve as an effective enabler of sustainable investment.

Keywords: Financial constraints; BigTech; FinTech; Environmental innovation.

TÓM TẮT

Nghiên cứu này xem xét tác động của khó khăn tài chính đối với hoạt động đổi mới sáng tạo vì môi trường của doanh nghiệp, với việc tập trung vào vai trò điều tiết của các kênh tài chính thay thế. Sử dụng dữ liệu đa quốc gia trong giai đoạn 2013-2019, tác giả tìm thấy rằng khi các khó khăn tài chính (đo lường bằng chỉ số KZ_index) tăng thêm một độ lệch chuẩn thì chỉ số đổi mới sáng tạo vì môi trường giảm 6,9%. Tuy nhiên, tín dụng từ các công ty BigTech có khả năng làm giảm đáng kể tác động này, bù đắp gần 39% ảnh hưởng tiêu cực, trong khi tín dụng từ các công ty FinTech không cho thấy tác động tương tự. Những phát hiện này nhấn mạnh tầm quan trọng của năng lực tài chính trong việc hỗ trợ hoạt động đổi mới sáng tạo vì môi trường, đồng thời đề xuất rằng tài trợ từ các công ty BigTech có thể đóng vai trò như một công cụ hiệu quả thúc đẩy đầu tư bền vững.

Từ khóa: Khó khăn tài chính; BigTech; FinTech; Đổi mới sáng tạo vì môi trường.

1. Introduction

Financial constraints refer to limitations on a firm's ability to access external funding for investments, especially those characterized by high uncertainty, long-term horizons, and substantial capital requirements. Environmental innovation, by its nature, often demands significant upfront investment and is associated with uncertain returns, making it particularly vulnerable to financial limitations. While previous studies have emphasized the role of regulatory pressure and technological capabilities as key drivers of green innovation (De Marchi, 2012; Do, 2024; Jing et al, 2024; Kim et al., 2021; Wang and Li, 2022), financial capacity remains a critical yet underexplored

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determinant. Firms often encounter significant barriers in accessing traditional financing channels, thereby hindering their ability to invest in sustainable technologies and processes. In recent years, a large number of studies have focused on the role of financing constraints on green innovation (Li et al., 2024). Traditional lenders often perceive green projects as risky, with high information asymmetry, low collateral value, and long payback periods, which constrain access to external finance (Hottenrott and Peters, 2012; Zhang and Vigne, 2021). Evidence further indicates that financially constrained firms invest significantly less in R&D and clean technologies (Andersen, 2017; Nanda and Rhodes-Kropf, 2017; Zhang and Jin, 2021). As a result, financial frictions remain a key barrier to firms' environmental innovation (Ghisetti et al., 2017; Xu and Kim, 2022).

In this context, the emergence of BigTech and FinTech firms introduces alternative financing options that may alleviate such financial constraints (Hodula, 2022; Li and Pegoraro, 2022; Thakor, 2020). BigTech firms - large tech companies with diverse business models and extensive user bases - are increasingly offering financial services through integrated digital ecosystems (Cornelli et al., 2023). Their strong capital base and vast data access enhance credit risk assessment and support long-term investments, including environmental innovation, as part of integrated sustainability strategies. Meanwhile, FinTech companies, focused on digital financial services, use data analytics, machine learning, and platform-based lending models to lower transaction costs and expand credit access, particularly for underserved firms (Cornelli et al., 2023). These alternative financial channels have the potential to mitigate the adverse effects of financial constraints, thereby enabling a broader range of firms to pursue environmental innovation initiatives.

Under information asymmetry theory, traditional lenders and investors often lack sufficient information to accurately assess the long-term profitability and risks of green projects, leading to adverse selection and moral hazard that amplify financing constraints (Chen et al., 2024; Ling et al., 2021). The development of FinTech helps alleviate these frictions by leveraging big data analytics, machine learning, and blockchain technologies to improve credit evaluation, enhance transparency, and strengthen the matching efficiency between capital supply and demand, thereby stimulating firms' environmental R&D and investment in clean production (Li et al., 2023; Trotta et al., 2024). Specifically, intelligent risk control systems built on big data and IoT technologies play a pivotal role in mitigating information asymmetry in the evaluation of green projects. (Wang et al., 2025). Moreover, FinTech credit platforms exhibit advanced data processing and risk-screening capabilities that help correct credit mismatches and broaden financing channels for innovation-oriented firms (Li et al., 2024; Liu et al., 2023; Wang et al., 2024; Zhou et al., 2022). Consistent with dynamic capability theory, FinTech strengthens firms' ability to generate and implement environmental technological innovation by improving the efficiency and effectiveness of innovation processes through deep data integration, algorithmic coordination, and seamless system connectivity (Tian et al., 2023; Wang et al., 2025). Therefore, FinTech and BigTech financing not only serve as external enablers that alleviate financing constraints but also act as internal capability enhancers, strengthening firms' ability to integrate technological and financial resources for sustainable innovation.

This study investigates how financial constraints affect firms' investment in environmental innovation and the role of BigTech and FinTech credit in shaping this relationship. Using a cross-national dataset from 2013 to 2019, the analysis finds that a one-standard-deviation increase in financial constraints is associated with a 6.9% decline in the environmental innovation index. These findings support that financially constrained firms, which have limited internal cash flow and restricted access to external capital, are less capable of undertaking green innovation activities.

Furthermore, our results indicate that BigTech credit mitigates the adverse impact of financial constraints on green innovation, whereas FinTech credit does not. Our finding is robust when we (i) exclude firms from Japan and the United States, which together account for a large proportion of the sample, and (ii) use GMM estimation. Specifically, a one-standard-deviation increase in BigTech credit offsets approximately 39% of the negative effect of financial constraints on green innovation. This might be because BigTechs typically possess greater financial resources, more extensive user networks, and access to vast datasets that enhance credit risk assessment and facilitate long-term financing (Frost et al., 2019; Kowalewski and Pisany, 2022; Stulz, 2019). These advantages, therefore, enable them to support financially constrained firms engaged in capital-intensive, high-risk innovation projects, such as green technologies (Gao et al., 2024; Prado and Bauer, 2022). In contrast, FinTech credit is often delivered through peer-to-peer or alternative lending platforms, focusing on short-term, smaller-scale financing (Cornelli et al., 2024; Sheng, 2021). As a result, it may lack the capacity or risk tolerance to fund long-term environmental innovation.

This paper makes several contributions to existing literature. First, it provides empirical evidence on the impact of financial constraints on firms' investment decisions, thereby enriching the literature on corporate finance and investment behavior (Bond and Meghir, 1994; Campello et al., 2010; Denis and Sibilkov, 2010; Hoberg and Maksimovic, 2015; Hoegl et al., 2008; Xu and Kim, 2022). Second, our paper advances the literature on environmental innovation by highlighting financial capacity as a key driver influencing firms' engagement in environmental innovation (De Marchi, 2012; Do, 2024; Kim et al., 2021; Wang and Li, 2022). Third, this study adds to research on the growing roles of BigTech and FinTech in finance (e.g., Frost et al., 2019; Girardone et al., 2024; and others). Particularly, it offers empirical insights into how BigTech and FinTech credit differently influence the relationship between financial constraints and environmental innovation. Consistent with previous studies (Kowalewski and Pisany, 2022; Stulz, 2019), our results suggest that BigTech credit—unlike FinTech—is likely to substitute for traditional bank financing in supporting innovation, largely due to BigTech's unique advantages, such as access to vast alternative data and advanced analytics that traditional banks struggle to replicate. This substitution effect is driven by BigTech's ability to leverage digital footprints and integrated platforms to offer scalable, data-driven lending solutions, particularly for projects that require long-term investment and risk tolerance.

The remainder of this paper is structured as follows. Section 2 presents a detailed description of the datasets employed in the analysis and explains the methodology adopted to examine the relationship of interest. Section 3 reports the main empirical findings, followed by robustness checks to ensure the reliability and consistency of the results.

Section 4 concludes the paper by summarizing the key insights, discussing their broader implications, and suggesting possible avenues for future research.

2. Data, sample and methodology

2.1. Data and sample

Table 1. Descriptive statistics

	Mean	Std. Dev	1st quartile	Median	3rd quartile
ENV_INNO	1.766	1.942	0.000	0.000	3.932
KZ_INDEX	0.140	1.454	-0.376	0.341	0.958
BIGTECH	0.342	0.797	0.000	0.015	0.251
FINTECH	0.641	0.751	0.011	0.173	1.232
SIZE	23.082	2.833	21.045	22.650	24.682
LEV	0.246	0.188	0.096	0.231	0.356
ROA	0.046	0.122	0.024	0.055	0.094
MB	3.390	4.798	1.212	2.179	4.015
TANG	0.275	0.229	0.090	0.212	0.407
R&D	0.026	0.062	0.000	0.000	0.022
LIQUIDITY	0.444	0.223	0.271	0.431	0.599
GDPG	0.026	0.017	0.016	0.022	0.029
INFT	0.019	0.015	0.010	0.018	0.024
CORRUPT	1.119	0.801	0.861	1.340	1.730

This table presents descriptive statistics for the main variables.

We conduct our analysis using firm-level data from 2013 to 2019 sourced from Worldscope. The dependent variable is defined as the natural logarithm of one plus the environmental innovation score, obtained from the Thomson Reuters ASSET4 database, which is widely used as a proxy for firms' eco-innovation activities (Meles et al., 2023; Rajesh, 2020). We measure financial constraints using the Kaplan and Zingales (1997) index. The KZ Index is a composite indicator that captures the extent to which a firm faces difficulties in obtaining external finance, with higher values indicating greater financial constraints. The KZ index is defined as $-1.002 \times$ Cash Flow $+ 0.283 \times$ Tobin's Q $+ 3.139 \times$ Debt $- 39.368 \times$ Dividends $- 1.315 \times$ Cash Holdings. This formula is widely adopted in the literature as a firm-level proxy for financial constraints (Cleary, 1999; Baker et al., 2003; Lamont et al., 2001). Following prior studies (Cornelli et al., 2023; Hodula, 2022; Kowalewski and Pisany, 2022), we measure BigTech and FinTech credit as the total country-level volume of each, scaled by country's population (in USD), using Cornelli et al. (2020) 's novel database. Our final sample comprises 5,617 firms, resulting in 25,271 firm-year observations across 36 economies. All variable definitions are given in Appendix A. Appendix B presents sample composition by country.

Descriptive statistics are reported in Table 1. The average level of environmental innovation (ENV_INNO) is 1.766 with low variation (SD = 1.942). The Kaplan-Zingales Index (KZ_INDEX) has a mean of 0.140, suggesting generally low financial constraints. Regarding alternative credit sources, 34.2% of firms use BigTech credit (BIGTECH), while 64.1% utilize FinTech credit (FINTECH), with notable variation in adoption levels of these new financing channels. Table 2 presents low correlation coefficients, suggesting minimal multicollinearity concerns.

Table 2. Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) ENV_INNO	1						
(2) KZ_INDEX	-0.021*	1					
(3) BIGTECH	0.049*		1				
(4) FINTECH	-0.143*	0.120*	0.094*	1			
(5) SIZE	0.302*	0.035*	0.323*	-0.358*	1		
(6) LEV	0.043*	0.521*	-0.067*	0.041*	0.098*	1	
(7) ROA	0.108*	-0.361*	0.037*	-0.109*	0.173*	-0.074*	1

Variables	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(8) MB	1						
(9) TANG	-0.147*	1					
(10) R&D	0.201*	-0.255*	1				
(11) LIQUIDITY	0.162*	-0.536*	0.366*	1			
(12) GDPG	0.039*	-0.001	-0.044*	0.069*	1		
(13) INFT	0.001	0.001	-0.064*	0.011	0.178*	1	
(14) CORRUPT	0.002	-0.026*	0.088*	-0.081*	-0.512*	-0.456*	1

*This table shows the correlation matrix of the key variables. *indicates that the correlation is significant at least at the 1% level.*

2.2. Methodology

To explore the relationship between financial constraints and firms' environmental innovation, we run the following regression:

$$ENV\_INNO_{i,j,t} = \alpha + \beta_1 CONSTRAINTS_{i,j,t} + \beta_2 X_{i,j,t} + \varepsilon_{i,j,t} \quad (1)$$

Where i, j and t indicate firm, country and year, respectively. ENV_INNO is the natural logarithm of one plus the environmental product innovation score (0-100), with 100 representing the highest level of environmental innovation. CONSTRAINTS represents financial constraints, measured by the KZ_index (Kaplan and Zingales, 1997). $X_{i,j,t}$ is a vector of control variables: firm size (SIZE), leverage (LEV), return on assets (ROA), market-to-book ratio (MB), tangibility (TANG), R&D expenses (R&D), liquidity (LIQ), annual GDP growth (GDPG), annual inflation rate (INFT) and control of corruption (CORRUPT). The model includes industry, time and country fixed effects.

3. Results

3.1. Baseline results

Table 3 shows our baseline results to examine the link between financial constraints and environmental innovation.

Financial constraints exhibit negative and statistically significant coefficients (−0.047 and −0.076) across two specifications, both with and without time, industry, and country fixed effects, indicating an adverse relationship with environmental innovation. Specifically, a one-standard-deviation increase in the KZ_index is associated with a 3.9% (= −0.047 × 1.454 / 1.766) to 6.3% (= −0.076 × 1.454 / 1.766) reduction in ENV_INNO. These results suggest that financially constrained firms, facing limited internal cash flows and restricted access to external financing, struggle to undertake green initiatives. This finding is consistent with Brown et al (2012), who

emphasize the crucial role of external equity in supporting R&D and innovation activities. Among the control variables, firm size, leverage, and liquidity are positively associated with environmental innovation, whereas asset tangibility and annual GDP growth display negative associations, aligning with prior literature.

Table 3. Financial constraints and green innovation

Dep. Var. =	ENV_INNO	
	[1]	[2]
KZ_INDEX	-0.047**	-0.076***
	(0.018)	(0.015)
SIZE	0.243***	0.414***
	(0.010)	(0.015)
LEV	0.864***	0.237*
	(0.144)	(0.123)
ROA	1.009***	-0.072
	(0.177)	(0.135)
MB	-0.013***	0.007**
	(0.004)	(0.003)
TANG	-0.508***	-0.310**
	(0.125)	(0.138)
R&D	-0.578	1.433***
	(0.418)	(0.409)
LIQUIDITY	0.831***	0.383***
	(0.136)	(0.125)
GDPG	-4.382***	-2.381*
	(1.454)	(1.422)
INFT	-2.884**	-0.479
	(1.450)	(0.797)
CORRUPT	0.412***	0.033
	(0.039)	(0.134)
Year FE	NO	YES
Industry FE	NO	YES
Country FE	NO	YES
Number of observations	25,371	25,371
R-squared	0.143	0.470

*This table reports the baseline OLS regression results for the impact of financial constraints on green innovation. ENV_INNO is the environmental product innovation score. KZ_INDEX is the Kaplan and Zingales (1997) 's index, which is defined as −1.002 × Cash flow + 0.283 × Tobin's q + 3.139 × Debt - 39.368 × Dividends - 1.315 × Cash holdings. All variables are defined in Appendix A. Standard errors are robust to heteroskedasticity and are clustered at the firm level. ***, **, or * next to the coefficients indicate significance at the 1%, 5%, and 10% levels, respectively.*

3.2. The role of BigTech and FinTech credit

Financially constrained firms often face difficulties in generating cash flow and securing traditional financing (Campello et al., 2010; Denis and Sibilkov, 2010; Hoberg and Maksimovic, 2015; Korajczyk and Levy, 2003). As a result, they are more likely to seek BigTech or FinTech credit as alternative funding sources for their investment and growth opportunities. BigTech firms are large, non-financial corporations that offer financial services as part of a broader portfolio. Their broad and diversified user base enables them to deliver low-cost and non-rival services (Cornelli et al., 2023; Frost et al., 2019). Moreover, with substantial financial resources, BigTech firms can support long-term investments, including capital-intensive environmental innovations that require considerable time and capital, often aligning credit services with broader sustainability strategies. Therefore, the adverse effects of financial constraints on environmental innovation are expected to be less severe in countries where alternative credit sources are more widely available.

While BigTech firms offer financial services alongside non-financial core activities, FinTech companies focus mainly on financial services. FinTech credit, provided through decentralized platforms to match individual lenders with borrowers (Cornelli et al., 2023), leverages advanced data analytics and algorithms to reduce search and transaction costs, improve risk assessment, and accelerate loan processing (Buchak et al., 2018; Fuster et al., 2019; Stulz, 2019). These efficiencies allow FinTech firms to offer more competitive rates, exert downward pressure on lending costs, improve transparency, and reduce capital costs (Allen et al., 2021; Anagnostopoulos, 2018; Girardone et al., 2024; Stulz, 2019; Thakor, 2020). Consequently, like BigTech, FinTech credit is anticipated to help ease financial constraints on firms pursuing environmental innovation.

To examine this hypothesis, we extend Equation (1) by incorporating alternative credit and its interaction with financial constraints:

$$ENV\_INNO_{i,j,t} = \alpha + \beta_1 CONSTRAINTS_{i,j,t} + \beta_2 ALT\_CREDIT_{j,t} \times CONSTRAINTS_{i,j,t} + \beta_3 ALT\_FIN_{j,t} + \beta_4 X_{i,j,t} + \varepsilon_{i,j,t} \quad (2)$$

Where $ALT\_CREDIT_{j,t}$ is the volume of alternative credit (i.e., BIGTECH or FINTECH) for country j in year t. $X_{i,j,t}$ is the vector of control variables discussed in section 2.2.

Tables 4 presents the regression estimates of how alternative credit influences the relationship between financial constraints and environmental innovation. The two measures of alternative credit are as follows. BIGTECH, measured at the country level, is defined as the volume of credit provided by large technology firms, normalized by country's population in USD (Cornelli et al., 2023) and is reported in column (1). FINTECH refers to the size of the FinTech sector (e.g., peer-to-peer (P2P) or marketplace lending to consumers, businesses or for property; balance sheet lending to consumers, businesses or for property; invoice trading; debt-based securities and mini-bonds; financing flow) scaled by country's population in USD (Cornelli et al., 2020) and is reported in column (2).

Table 4. The role of BigTech and FinTech credit

Dep. Var. =	ENV_INNO	
	[1]	[2]
KZ_INDEX	-0.084***	-0.077***
	(0.016)	(0.018)
KZ_INDEX × BIGTECH	0.042***	
	(0.015)	
BIGTECH	0.080***	
	(0.029)	
KZ_INDEX × FINTECH		0.001
		(0.014)
FINTECH		-0.073***
		(0.028)
SIZE	0.414***	0.414***
	(0.015)	(0.015)
LEV	0.227*	0.236*
	(0.123)	(0.123)
ROA	-0.073	-0.081
	(0.135)	(0.135)
MB	0.006*	0.007**
	(0.003)	(0.003)
TANG	-0.309**	-0.309**
	(0.138)	(0.138)
R&D	1.422***	1.437***
	(0.409)	(0.409)
LIQUIDITY	0.388***	0.382***
	(0.125)	(0.125)
GDPG	-2.072	-2.002
	(1.425)	(1.448)
INFT	0.036	0.141
	(0.823)	(0.794)
CORRUPT	-0.024	0.010
	(0.133)	(0.135)
Country FE	YES	YES
Industry FE	YES	YES
Year FE	YES	YES
Number of observations	25,371	25,371
R-squared	0.470	0.470

This table reports the baseline OLS regression results for the impact of financial constraints on green innovation, conditional on BigTech and FinTech credit. ENV_INNO is the environmental

*product innovation score. KZ_INDEX is the Kaplan and Zingales (1997) 's index, which is defined as −1.002 × Cash flow + 0.283 × Tobin's q + 3.139 × Debt - 39.368 × Dividends - 1.315 × Cash holdings. BIGTECH is defined as the volume of BigTech credit divided by country population (Cornelli et al., 2020). FINTECH is defined as the volume of FinTech credit divided by country population (Cornelli et al., 2020). All variables are defined in Appendix A. Standard errors are robust to heteroskedasticity and are clustered at the firm level. ***, **, or * next to the coefficients indicate significance at the 1%, 5%, and 10% levels, respectively.*

Table 4, column (1), confirms the adverse effect of financial constraints on environmental innovation, showing a negative coefficient of −0.084 when BigTech credit is used as an alternative financing source. As expected, the interaction terms BIGTECH × CONSTRAINTS are positive and statistically significant. Specifically, the coefficient for KZ_INDEX × BIGTECH (0.042) indicates that a one-standard-deviation increase in BIGTECH (0.797) reduces the negative impact of KZ_INDEX on innovation by 3.3% (= 0.042 × 0.797 × 100). Given the direct effect of KZ_INDEX (−0.084), this offset represents approximately 39% of the adverse effect. This finding highlights the economically meaningful role of BigTech credit in mitigating the detrimental effects of financial constraints on environmental innovation, particularly in markets where BigTech financing is more accessible.

Column (2) shows that financial constraints continue to exert a negative impact on environmental innovation. However, the positive, though statistically insignificant, coefficients for the interaction terms suggest that the mitigating role of FinTech credit in this relationship is less clear. Interestingly, the standalone FINTECH coefficient is −0.073 and significant. This likely reflects the nature of FinTech firms, which tend to specialize in platform-based lending and focus on short-term financing rather than long-term, capital-intensive projects (Cornelli et al., 2024; Sheng, 2021). Combined with the earlier results, this suggests that financially constrained firms prefer BigTech companies over FinTech firms when seeking alternative financing for new opportunities, particularly for long-term innovation initiatives.

3.3. Additional analysis

3.3.1. Alternative samples

To verify that our findings are not driven by firms from the United States and Japan - which represent 31.8% and 9.6% of the sample, respectively - we exclude these countries and re-estimate the models.

Table 5 presents robustness tests excluding the United States (columns 1-3) and Japan (columns 4-6) to ensure that results are not driven by these major economies. Across all specifications, the coefficients on KZ_INDEX remain negative and statistically significant, confirming the adverse effect of financial constraints on environmental innovation. The interaction term KZ_INDEX × BIGTECH remains positive and significant in both subsamples, while the main effect of BIGTECH is also positive and significant, indicating that BigTech credit continues to mitigate the negative impact of financial constraints. In contrast, the interaction terms involving FINTECH remain statistically insignificant, and the standalone FINTECH coefficient is negative and significant only in column (6). These consistent patterns reinforce the main findings and suggest that the mitigating role of BigTech credit is robust to the exclusion of large economies.

Table 5. Alternative samples

Dep. Var. =	ENV_INNO					
	Exclude the United States			Exclude Japan		
	[1]	[2]	[3]	[4]	[5]	[6]
KZ_INDEX	-0.081***	-0.088***	-0.085***	-0.077***	-0.083***	-0.083***
	(0.018)	(0.019)	(0.020)	(0.015)	(0.016)	(0.018)
KZ_INDEX×BIGTECH		0.031**			0.035**	
		(0.015)			(0.014)	
BIGTECH		0.071**			0.081***	
		(0.030)			(0.030)	
KZ_INDEX×FINTECH			0.016			0.010
			(0.023)			(0.014)
FINTECH			-0.063			-0.076***
			(0.039)			(0.029)
CONTROLS	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Number of observations	17,253	17,253	17,253	22,910	22,910	22,910
R-squared	0.479	0.479	0.479	0.458	0.458	0.458

*This table reports the regression results on the impact of financial constraints on green innovation, conditional on BigTech and FinTech credit, for subsamples excluding Japan and the United States. KZ_INDEX is the Kaplan and Zingales (1997) 's index, which is defined as −1.002 × Cash flow + 0.283 × Tobin's q + 3.139 × Debt - 39.368 × Dividends - 1.315 × Cash holdings. BIGTECH is defined as the volume of BigTech credit divided by country population (Cornelli et al., 2020). FINTECH is defined as the volume of FinTech credit divided by country population (Cornelli et al., 2020). All variables are defined in Appendix A. Standard errors are robust to heteroskedasticity and are clustered at the firm level. ***, **, or * next to the coefficients indicate significance at the 1%, 5%, and 10% levels, respectively.*

3.3.2. Alternative regression method

To address the endogeneity concern, we adopt the Blundell and Bond (1998) two-step system generalized method of moments (GMM) estimation to identify the impact of financial constraints on green innovation and the role of BigTech and FinTech in this relationship.

Table 6 reports the robustness checks based on the GMM estimation to address potential endogeneity issues. The coefficient of KZ_INDEX remains negative and statistically significant, confirming the detrimental effect of financial constraints on environmental innovation. The interaction term KZ_INDEX × BIGTECH remains positive and significant, indicating that BigTech credit consistently mitigates the adverse impact of financial constraints. In contrast, the interaction term involving FINTECH variable remains insignificant. Overall, these consistent results confirm that the mitigating influence of BigTech credit is robust across estimation methods.

Table 6. Alternative regression method

Dep. Var. =	ENV_INNO		
	[1]	[2]	[3]
L.ENV_INNO	0.905***	0.926***	0.924***
	(0.020)	(0.012)	(0.016)
KZ_INDEX	-0.585***	-0.253**	-0.225*
	(0.184)	(0.113)	(0.119)
KZ_INDEX × BIGTECH		0.286**	
		(0.144)	
BIGTECH		0.019	
		(0.018)	
KZ_INDEX × FINTECH			0.007
			(0.150)
FINTECH			0.062
			(0.043)
CONTROLS	YES	YES	YES
AR (1) test (p−value)	0.000	0.000	0.000
AR (2) test (p−value)	0.546	0.930	0.916
Hansen test of overid. restrictions	0.158	0.210	0.250
Difference-in-Hansen tests of exogeneity	0.370	0.150	0.172
Observations	19,826	19,826	19,826

*This table reports the GMM regression results for the impact of financial constraints on green innovation, conditional on BigTech and FinTech credit. All variables are defined in Appendix A. ***, **, or * next to the coefficients indicate significance at the 1%, 5%, and 10% levels, respectively.*

4. Conclusion

This study shows that financial constraints significantly hinder firms' environmental innovation, particularly for long-term and high-risk tolerance projects. While BigTech credit appears to mitigate these financing barriers, FinTech credit does not demonstrate a comparable moderating effect. These findings underscore the pivotal role of financial capacity in enabling firms to pursue green innovation and highlight BigTech as a potentially important facilitator of sustainable investment.

Our results suggest that regulators and governments may consider fostering partnerships between BigTech firms and traditional financial institutions to broaden access to credit for firms engaging in environmentally oriented innovation. In addition, the limited effectiveness of FinTech credit underscores the need to strengthen regulatory frameworks and risk assessment mechanisms in the FinTech sector to support long-term, capital-intensive projects better. For corporate managers, the evidence emphasizes the importance of aligning alternative financing strategies with green innovation goals, particularly in contexts where financial constraints are most binding. Further exploration of the interactions among traditional bank lending, government subsidies, and alternative financing channels could provide a more comprehensive understanding of the financing ecosystem driving the green transition.

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APPENDIX A: VARIABLE DEFINITION

Variable	*Definition*	*Source*
ENV_INNO	Firm-level environmental innovation measure. The natural logarithm of 1 plus the environmental product innovation score. The score ranges from 0 to 100, with 100 indicating the highest level of environmental innovation.	Asset4
BIGTECH	The volume of BigTech credit is divided by country population (in USD).	Cornelli et al. (2020)
FINTECH	FinTech-driven and loan-based business models, i.e., peer-to-peer (P2P) or marketplace lending to consumers, businesses, or for property; balance sheet lending to consumers, businesses, or for property; invoice trading; debt-based securities and mini-bonds; financing flow divided by country population (in USD).	Cornelli et al. (2020)
KZ_INDEX	Firm-level financial constraint measure. The Kaplan and Zingales (1997)'s index is defined as −1.002 × Cash flow + 0.283 × Tobin's q + 3.139 × Debt - 39.368 × Dividends - 1.315 × Cash holdings.	Worldscope
SIZE	Logarithm of total assets.	Worldscope
LEV	Total debts divided by total assets.	Worldscope
ROA	Earnings before interest and taxes as a proportion of total assets.	Worldscope
MB	Book liabilities plus market value of equity divided by book value of total assets.	Worldscope
TANG	Net property, plant, and equipment scaled by total assets.	Worldscope
R&D	R&D expenses divided by total assets.	Worldscope
LIQUIDITY	Total current assets divided by total assets.	Worldscope
GDPG	Annual GDP growth.	World Bank
INFT	Annual inflation rate	World Bank
CORRUPT	Control of corruption	World Bank

APPENDIX B: SAMPLE DISTRIBUTION

#	Country	ISO	No. of Firms	No. of Observations	ENV_INNO	KZ_INDEX	BIGTECH	FINTECH
1	Australia	AUS	241	1,261	0.867	-0.502	0.000	0.183
2	Austria	AUT	23	100	2.707	0.041	0.000	0.006
3	Belgium	BEL	32	152	2.556	-0.063	0.000	0.035
4	Brazil	BRA	75	370	1.200	0.237	0.004	0.020
5	Canada	CAN	246	1,184	1.197	0.331	0.000	0.076
6	Switzerland	CHE	121	493	2.310	-0.506	0.000	0.030
7	Chile	CHL	22	121	1.215	0.182	0.000	0.054
8	China	CHN	741	2,189	1.366	-0.014	2.098	1.266
9	Germany	DEU	171	676	2.649	0.057	0.000	0.039
10	Denmark	DNK	38	175	2.155	-0.319	0.000	0.084
11	Spain	ESP	47	226	2.747	0.300	0.000	0.024
12	Finland	FIN	46	179	3.208	-0.711	0.000	0.177
13	France	FRA	130	617	2.910	0.272	0.020	0.089
14	United Kingdom	GBR	292	1,466	1.768	-0.513	0.012	1.057
15	Hong Kong	HKG	104	571	1.836	-0.022	0.000	0.002
16	Indonesia	IDN	36	213	1.183	-0.971	0.013	0.033
17	India	IND	111	544	2.189	-0.005	0.001	0.003
18	Ireland	IRL	37	207	2.136	0.433	0.000	0.070
19	Israel	ISR	25	96	1.185	0.086	0.000	0.200
20	Italy	ITA	61	217	2.296	0.106	0.000	0.031
21	Japan	JPN	397	2,437	2.821	0.119	1.193	0.051
22	Korea	KOR	128	701	2.472	0.538	0.777	0.123
23	Mexico	MEX	40	226	1.353	0.112	0.001	0.010
24	Malaysia	MYS	53	282	1.521	-0.589	0.034	0.014
25	Netherlands	NLD	53	252	2.690	0.237	0.000	0.248
26	Norway	NOR	47	168	2.372	-0.163	0.000	0.023
27	New Zealand	NZL	34	156	0.732	-0.284	0.000	0.326
28	Philippines	PHL	14	82	1.609	0.516	0.001	0.007
29	Poland	POL	22	108	1.646	0.297	0.000	0.024
30	Russia	RUS	27	167	0.757	-0.497	0.136	0.005
31	Singapore	SGP	49	211	1.550	-0.214	0.008	0.426
32	Sweden	SWE	144	457	2.422	0.016	0.000	0.075
33	Thailand	THA	72	250	1.876	-0.188	0.034	0.000
34	Turkey	TUR	51	200	2.316	-0.029	0.000	0.000
35	United States	USA	1805	8,085	1.456	0.566	0.073	1.353
36	South Africa	ZAF	82	532	1.374	-0.487	0.000	0.002
	Total		5,617	25,371				

This table presents the number of firms, the number of firm-year observations, and the means of ENV_INNO, KZ_INDEX, BIGTECH, and FINTECH for each economy. The sample consists of 5,617 firms (i.e., 25,371 firm-year observations) across 36 economies from 2013 to 2019.