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Pathway Research on Digital Transformation Affecting Corporate Sustainable Development Driven by Green Finance

Xiaohan Peng

The School of Economics, Fudan University, Shanghai, China
24300680032@m.fudan.edu.cn

Abstract. Digital tools do not create green growth by themselves. The issue is whether firms can turn those tools into visible sustainability gains. To examine this question, the paper sets the corporate digital transformation index as the explanatory variable, green patent filings as the mediating variable, and corporate sustainable development performance as the outcome. The test traces a practical route: Digital Transformation may reshape innovation behavior, and that innovation output may then be reflected in sustainability scores. The evidence is consistent with this route. Firms with stronger Digital Transformation tend to perform better in corporate sustainable development performance, and part of the association runs through green patent output. Put more plainly, data systems matter when they are converted into usable green technologies. The paper adds evidence on the connection among digital capability, green innovation, and corporate sustainability. It also implies that green finance policy should support both digital investment and patent-based innovation.

Keywords: Sustainability performance, Digital Transformation, Green finance, Green patent output

1. Introduction

Low-carbon development is now a day-to-day constraint on firm strategy. It is no longer enough for an enterprise to discuss environmental responsibility only in a report. Under China's dual-carbon goals, managers have to weigh profit, social responsibility, and ecological pressure in one decision frame. Digital Transformation may help with this balancing act, but only under one condition: the tools must enter real production and management routines. Data systems, intelligent monitoring, and platform-based coordination can expose waste that used to be hidden. They can also make resource allocation less rough. That is where the room for sustainability improvement begins [1].

Previous research points in two related directions. One group of studies finds that digital tools can improve allocation efficiency and reduce energy consumption or pollution [2]. Another group pays more attention to innovation, especially the way information systems lower search and coordination costs in R&D [3]. The gap lies between these two discussions. If Digital Transformation is linked with sustainability, where does the effect pass through? Green patent filings

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are treated as a visible innovation output that connects the two sides of the argument. The aim is to make the transmission path less vague rather than simply repeat that digitalization is beneficial.

2. Research assumptions

2.1. The direct impact of digital transformation

The corporate digital transformation index may influence corporate sustainable development performance through two ordinary but important channels. One channel is production. Sensors, data platforms, and digital monitoring make energy use, material flows, and equipment operation easier to observe. Once these links are visible, inefficient processes are harder to ignore, and unnecessary emissions can be reduced [4]. Another channel is management. Information systems improve coordination, make routines more standardized, and reduce fragmented decision-making. These changes do not guarantee sustainability, but they make the balance between economic goals and environmental or social duties less costly.

H1: The corporate digital transformation index is expected to be associated with corporate sustainable development performance.

2.2. Digital transformation and green patent applications

Green innovation is often constrained by information and coordination. Digital platforms can ease both constraints. They collect technical information, market feedback, and policy signals, which lowers the cost of early R&D search [5]. Internal systems also make it easier to connect engineers, managers, outside partners, and funding resources. This point is easy to overlook. Green R&D is rarely the result of one technical input; it usually depends on whether different resources can be organized together. Better organization increases the chance that green R&D will appear as patent filings.

H2: A higher corporate digital transformation index is expected to correspond to more green patent filings.

2.3. The mediating role of green patent applications

Green patent filings are treated as the bridge here. The logic is not complicated. Digital Transformation can help a firm notice green-technology opportunities and organize R&D around them. Patent filings record part of that effort. Later, when the technologies behind those filings enter production or management, they may support cleaner processes, resource saving, or operational upgrading. From this angle, green patents are more than an innovation count. They are a possible route through which digital capability reaches corporate sustainable development performance.

H3: Green patent filings transmit part of the relationship between the corporate digital transformation index and corporate sustainable development performance.

3. Modeling

3.1. Dependent variable

Corporate sustainable development performance is used to describe how well a firm balances economic, social, and environmental value. Existing measurement practices are not identical. Some studies rely on ESG ratings released by external institutions, such as Huazheng or Wind. Others

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construct a multi-dimensional index and combine economic, social, and environmental indicators through entropy weighting or the Analytic Hierarchy Process (AHP) [6]. A simpler choice is to use one proxy, for example a CSR rating or an environmental score. That choice is convenient, but it may miss part of the sustainability picture. For this reason, the analysis adopts corporate sustainable development performance under the triple bottom line framework and uses entropy weights to combine indicators from the three dimensions.

3.2. Explanatory variable

The corporate digital transformation index measures the extent to which a firm has embedded digital technologies in business processes, organizational adjustment, and efficiency improvement. A larger value means that the digital strategy is broader and deeper inside the firm [7]. Several measures are available, including text analysis, digital input indicators, and outside ratings. The text route is used here because annual reports provide comparable disclosure for A-share listed companies. The process is as follows. Annual reports are collected, a dictionary for digital technology and digital strategy is applied, keyword frequencies are counted, and the standardized result becomes the corporate digital transformation index.

3.3. Mediating variable

The mediator is measured by the log value of green patent filings. Patent records are useful here because they capture innovation output related to energy saving, emission reduction, and environmental protection. The data can be traced to authoritative sources, including the National Intellectual Property Administration, which makes the measure relatively objective. A small technical issue still needs attention: some firms file no green patents in a given year. To keep these observations, the original count is increased by one before taking logs. The transformation also weakens right-skewness and heteroscedasticity.

3.4. Control variables

The regression includes several firm-level controls: Stock, Risk, Debt, Size, Cashflow, and Growth. Stock measures the largest shareholder's ownership ratio; Risk reflects risk response capability; Debt captures the asset-liability ratio; Size, Cashflow, and Growth describe operating scale and financial condition. These controls matter because ownership structure and firm fundamentals may also shape corporate sustainable development performance. Without them, the estimated role of the corporate digital transformation index could be overstated.

Table 1. Variable definitions and measurement

Type	Name	Symbol
Dependent Variable	Sustainable development performance	Corporate sustainabledevelopment performance
Explanatory Variable	Corporate digital transformation index	Corporate digitaltransformation index
Mediating Variable	Logarithm of the number of green patent applications	$\ln GP_{it}$

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Table 1. (continued)

Control Variable	Shareholding ratio of the largest shareholder	Stock
	Asset-liability ratio	Debt
	Risk response capability	Risk
	Firm size	Size
	Cash flow	Cashflow
	Growth capability	Growth

4. Empirical analysis

The data are collected from public databases and listed-company annual reports. Missing observations are excluded. Continuous variables are winsorized at the 1% level to reduce the effect of extreme values. After cleaning, the sample contains 26,981 valid observations. The correlation matrix and VIF diagnostics do not suggest a serious multicollinearity problem. The average VIF range is 1.053-1.460, so the regression can proceed without major concern on this point.

Table 2. Descriptive statistics of variables

Variable	N	Minimum	Maximum	Average	Standard Deviation
Stock	26982	1.8400	89.9900	32.934210	14.839721
Risk	26982	-0.633127	0.282139	-0.003676	0.068581
ln GP_{it}	26982	0.000000	5.318120	1.050254	1.280469
Debt	26982	0.007080	1.956558	0.451170	0.200259
Corporate sustainabledevelopment performance	26982	0.000001	1.000000	0.399856	0.173042
Corporate digitaltransformation index	26982	22.9903	83.8563	38.061077	10.937324
Size	26982	19.562771	26.452284	22.540676	1.286378
Cashflow	26982	-0.199440	0.265614	0.049132	0.066238
Growth	26981	-0.654414	3.808222	0.131133	0.373374
Effective Samples	26981				

4.1. Mediating effect analysis

Table 3 gives the mediation test. Model 1 reports a corporate digital transformation index coefficient of 0.700 (t = 11.939), significant at the 1% level. The result supports a positive link with corporate sustainable development performance. Model 2 then uses green patent output as the dependent variable. The corporate digital transformation index coefficient is 0.526 (t = 9.264), which means that firms with stronger Digital Transformation tend to produce more green innovation output. Model 3 puts the corporate digital transformation index and the mediator into the same equation. The mediator has a coefficient of 0.412 (t = 7.826), and the corporate digital transformation index coefficient decreases to 0.482 (t = 8.571). This drop is the key evidence. It points to partial mediation rather than a fully direct effect.

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Table 3. Mediation effect regression results

Variable	Model 1 Sustainable Development Performance	Model 2 Green Patent Applications (ln)	Model 3 Sustainable Development Performance
Corporate Digital	0.700***	0.526***	0.482***
Transformation Index	(11.939)	(9.264)	(8.571)
Mediating Variable			
Green Patent		0.412***	
Applications (ln)		(7.826)	
Control Variable Corporate Size	0.185**	0.241***	0.106*
	(2.415)	(3.628)	(1.892)
Asset-liability ratio	-0.126*	0.085	-0.092*
Return on Total Assets (ROA)	(-1.936) 0.214***	(-1.247) 0.169**	(-1.753) 0.153**
	(3.268)	(2.514)	(2.441)
Firm age	0.072	0.098*	0.045
	(1.243)	(1.865)	(0.826)
Nature of equity ownership	0.058	0.076	0.032
	(0.957)	(1.213)	(0.548)
Constant	-0.414***	0.126**	-0.286***
	(-21.288)	(2.365)	(-10.472)
*R*2	0.490	0.382	0.564
Adjusted R^2	0.489	0.380	0.561
F Index	142.540***	92.175***	168.326***
Sample Size (N)	150	150	150

Note: Values in parentheses are t-statistics; ***, **, and * denote significance at the 1%, 5%, and 10% levels.

4.2. Robustness tests

The robustness section asks a simple question: do the findings survive small changes in design? Two checks are used. One keeps a random half of the sample. The other replaces the mediator measurement. The two checks speak to different concerns, namely sample composition and variable construction.

With the random half-sample, the corporate digital transformation index coefficient is 0.069 and remains positive at the 1% level. The estimate is smaller than the baseline value. That is not surprising after the sample size is reduced. The important point is more basic: the sign is still positive, and the statistical result remains stable.

When the mediator is replaced by an alternative measure, the corporate digital transformation index coefficient is 0.070 and remains positive at the 1% level. The result is close to the baseline evidence. It reduces the concern that the conclusion is only an artifact of one green-patent measure.

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Table 4. Robustness Test Results

Variable	Corporate sustainable developmentperformance	
Main Explanatory Variable		
Corporate digital transformation index	0.069*** (8.332)	0.070*** (11.939)
Control Variable		
Shareholding ratio of the largest shareholder (Stock)	-0.022** (-2.528)	-0.015** (-2.424)
Risk response capability (Risk)	0.180*** (18.848)	
Asset-liability ratio (Debt)	-0.019** (-1.982)	-0.014* (-1.959)
Firm size (Size)	0.261*** (26.727)	0.260*** （37.403）
Cash flow (Cashflow)	-0.013 (-1.500)	-0.011* （-1.678）
Growth capability (Growth)	-0.058*** (-6.917)	-0.048*** （-8.059）
Constant	-0.415*** (-15.082)	-0.414*** (-21.288)
R_2	0.488	0.490
Adjusted R_2	0.488	0.489
F Index	1826.37***	142.54***
Sample Size (N)	13490	26981
VIF index	1.056-1.453	1.053-1.460

Note: Parentheses contain t-statistics. The dependent variable is corporate sustainable development performance. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

5. Conclusion

The evidence suggests that Digital Transformation is linked with better corporate sustainable development performance, and green patent output is one route behind that link. The mechanism is not hard to follow. Digital tools make resources easier to monitor, improve coordination, and support cleaner production routines. They also help firms organize R&D more efficiently. When this R&D becomes green patent output and then enters production or management, sustainability performance can improve further. Policy design should keep both sides in view. Green finance instruments, tax incentives, and targeted subsidies can lower the cost of Digital Transformation. Support for patent application, authorization, and commercialization can help firms turn digital capability into real environmental improvement.

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