1 Robustness Check

(1) Endogeneity issues_Instrumental variables approach

To further mitigate endogeneity issues on research findings, this study refers to Li et al. (2020) research and utilizes company size as an instrumental variable for Two-Stage Least Squares (2SLS) estimation. Prior to estimation, this study conducted a weak instrument test with an F-statistic exceeding 10, indicating the absence of weak instrument problems and the effectiveness of the instrumental variables. Results from the instrumental variable estimation are presented in Table 1 column (1). The research findings demonstrate that the p-value of the Anderson Orthogonalized Matrix Cragg-Donald Wald F statistic is less than 0.1, rejecting the null hypothesis of instrument insufficiency. Additionally, the Cragg-Donald Wald F statistic value (9.4) exceeds the Stock-Yogo critical value (8.96), allowing rejection of the weak instrument hypothesis, affirming the appropriateness of instrumental variable selection. The regression coefficient of the core explanatory variable remains significantly positive, confirming the robustness of the study's conclusions.

Table 1 Endogeneity Test

	(1) IV CSP	(2) CNNM CSP	(3) NM CSP
DT	0.094**	0.025*	0.037***
	(0.060)	(0.015)	(0.011)
ROE	-0.217*	-0.651***	-0.556***
	(0.115)	(0.154)	(0.120)
CF	-0.025	-0.035	-0.002
	(0.081)	(0.113)	(0.080)
EPS	0.037	0.191***	0.119**
	(0.043)	(0.073)	(0.052)
AL	0.073	0.208	0.170**
	(0.085)	(0.127)	(0.085)
OIP	0.195***	0.230***	0.151*
	(0.056)	(0.084)	(0.078)
TAX	-0.036	-0.021	0.062
	(0.071)	(0.120)	(0.093)
_cons		1.284	1.135
		(1.041)	(0.736)
N	25740	15590	27980
r2	0.006	0.038	0.033

(2) Propensity score matching

We use propensity score matching (PSM) to address sample selection bias. Companies are divided into control and treatment groups based on the mean of their digital applications. Companies with digital levels higher than the mean are allocated to the treatment group, while the rest are in the control group. In this study, we further narrowed variable normalization bias by performing Caliper Nearest Neighbor Matching (CNNM) and Kernel Matching (NM). The assumptions of this study have been re-examined based on the matched samples. Moreover, regression results in columns (2) to (3) of Tables 1 indicate that the regression coefficient for DT remains significantly positive. These results suggest that matched samples do not alter the conclusions of this study and that the application of DT significantly enhances the efficiency of CSP. Therefore, it demonstrates the robustness of previous empirical findings when considering sample selection bias.

(3) System GMM and Differential GMM Methods

Based on the full sample, the dynamic system GMM and differential GMM methods were employed to test for potential endogeneity issues in the model. The empirical results are presented in Table 2. From left to right, the regressions include the effects of firm-level DT, SIC and SRC on CSP, using both differential GMM and system GMM techniques. From the regression results of the test statistic, the p-value of AR (2) for each model is above 0.1, indicating the absence of second-order autocorrelation. The p-value of the Hansen test was between 0.1 and 0.25, indicating a reasonable choice of instrumental variables. The results of the lagged one-period regressions of the explanatory variables are highly significant positive in all models, indicating that there is a significant time continuity in the amount of change in CSP.

Table 2 Endogeneity test results

	(1) CSP Differential GMM	(2) CSP System GMM	(3) CSP Differential GMM	(4) CSP System GMM	(5) CSP Differential GMM	(6) CSP System GMM
L.CSP	0.198***	0.097**	0.187***	-0.109***	0.200***	-0.069*
	(0.037)	(0.040)	(0.043)	(0.038)	(0.042)	(0.036)
DT	0.118***	0.211***				
	(0.037)	(0.043)				
L.DT	0.073**	-0.006				
	(0.037)	(0.042)				
SC_SIC			0.085**	0.168***		
			(0.037)	(0.042)		
L.SC_SIC			0.121***	-0.006		
			(0.037)	(0.041)		
SC_SRC					0.315***	0.161***
					(0.049)	(0.053)
L.SC_SRC					0.379***	0.132
					(0.103)	(0.081)
ROE	-0.145	-0.210	-0.030	-0.248	-0.160	-0.248**
	(0.208)	(0.148)	(0.206)	(0.157)	(0.201)	(0.124)
CF	0.399*	0.378	0.386*	0.401	0.172	0.073
	(0.223)	(0.287)	(0.230)	(0.288)	(0.197)	(0.098)
EPS	-0.211*	-0.071	-0.229*	-0.080	-0.123	0.016
	(0.115)	(0.073)	(0.122)	(0.075)	(0.121)	(0.062)
AL	-0.047	0.171	0.039	0.155	0.049	0.107
	(0.181)	(0.139)	(0.187)	(0.102)	(0.166)	(0.125)
OIP	-0.104	0.007	-0.130	0.050	-0.095	-0.027
	(0.169)	(0.192)	(0.169)	(0.132)	(0.159)	(0.194)
TAX	-0.028	0.099	0.150	0.212	-0.089	0.007
	(0.188)	(0.092)	(0.199)	(0.248)	(0.205)	(0.079)
_cons		-2.102		-2.396		0.428
		(1.640)		(1.585)		(0.855)
N	23400	23400	23400	23400	23400	23400
ar2	1.451	1.187	1.296	0.726	1.109	0.756
AR(1) P-value	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) P-value	0.147	0.235	0.195	0.468	0.268	0.450
Hansen test	0.213	0.141	0.129	0.153	0.255	0.273

Li, Y., Dai, J. & Cui, L. 2020. 'The impact of digital technologies on economic and environmental performance in the context of industry 4.0: A moderated mediation model.' *International Journal of Production Economics,* 229, 107777.