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A study of digital transformation and MSMEs performance from a spatial perspective: Evidence from China

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Abstract

Aim/purpose – Not only have micro, small, and medium enterprises (MSMEs) been regarded as a driving force of the national economy, but they have also become important in promoting innovation and entrepreneurship. In general, today's MSMEs face problems, such as high business costs, insufficient innovation, and inadequate management capabilities, that have all forced the digital transformation of MSMEs. However, in existing studies, the impact of digital transformation on performance is controversial, and the subjects are generally listed companies. In this paper, we have decided to use micro business survey data and analyze them from a spatial perspective to explore how MSMEs' digital transformation plays a role in influencing performance and the path of its effect.

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Design/methodology/approach – We use a sampling method with a dual directory--regional sampling frame to investigate MSMEs in Ningbo City, Zhejiang Province, China and then delve into the impact of digital transformation on enterprise performance from a spatial perspective by the spatial weighted logit model.
Findings – Hierarchical analysis shows that there is a large room for improvement in the Digital transformation of enterprises. The digitalization level of an enterprise has a positive impact on performance. While from a spatial perspective, the digitalization level of neighboring enterprises has a negative impact on the performance of the enterprise. Path analysis shows that the digital transformation of enterprises can increase innovation, reduce costs, and improve the performance of enterprises.
Originality/value – We provide an empirical basis for vigorously promoting the digital transformation of enterprises, jointly building digital parks, and improving enterprise performance by reducing costs and improving efficiency. At the same time, it provides relevant suggestions for digital transformation for manufacturing MSMEs that are hesitant to see or are at a loss in the digital transformation and helps manufacturing MSMEs to achieve cost reduction and increase efficiency.

Keywords: MSMEs, digital transformation, double sampling frame, performance analysis.
JEL Classification: C13, C81, M30, O33.

1. Introduction

Micro, small, and medium enterprises (MSMEs) is a collective term for small businesses, micro-enterprises, cottage industries, and individual entrepreneurs (Gu, 2022), and these businesses are considered a driver of the national economy (Winarsih et al., 2020). According to the United Nations, MSMEs account for roughly 95% of business enterprises and 60% of employment globally (UNCTAD, 2022). By the end of 2020, the number of MSME households accounted for 95.68% of China's market entities, reaching a total of 130 million, accounting for 70% of employment, 62.98% of business revenue, 53.46% of total profit, and a steady increase in economic contribution (National Bureau of Statistics, 2022). This demonstrates how MSMEs are crucial for fostering economic growth and job creation (Yoshino & Taghizadeh-Hesary, 2016). With the development of "Industry 4.0" in the post-epidemic period, more fierce competition among enterprises has developed, intensifying the pressure on their survival and growth (Lahane et al., 2021). MSMEs are more vulnerable than large enterprises (Winarsih et al., 2020; Zhang et al., 2022). MSMEs generally face significant challenges like rising labor costs, transaction costs year over year, limited access to business information, insufficient technological capabilities (Chouki et al., 2022; Prasanna et al., 2019), and particularly, issues arising from capacity constraints related to knowledge, innovation, and creativity (Moscalu et al., 2020).

With the rapid development of digital technologies, such as the IoT (Internet of Things), cloud computing, big data, and artificial intelligence and their full integration with the national economy, new economic dynamics are developing rapidly (Soto-Acosta, 2020). Digital technologies, digital innovation, and digitization are fundamentally changing business processes, products, services, and relationships (Chatterjee et al., 2022; Karimi & Walter, 2015; Thathsarani & Jianguo, 2022), and driving enterprises to transform their business practices and employees' mindsets, forcing them to restructure for survival (Borah et al., 2022; Hartl & Hess, 2017). Digital transformation (DT) has emerged as a new approach for many enterprises to gain a competitive advantage in the context of intense and dynamic market competition (Chen et al., 2021; Rupeika-Apoga et al., 2022; Teng et al., 2022). The IDC 2020 study (Gillen et al., 2020) showed that 67% of Global 1000 enterprises have digital transformation as a core strategy of consensus, reaching 50% of the Top 1000 Chinese enterprises. The majority of nations have recently focused more on how MSMEs can assist in development. Governments and their combined private sectors at all levels have started to support the growth of MSMEs while striving for several benefits. Globally, the National Financial Inclusion Strategy (NFIS), the Small Business Consultant and Support Provide (2018), and Tax Administration 3.0: Digital Transformation of Tax Administration (OECD Forum on Tax Administration, 2020) have been promulgated. China has also promulgated the Special Action Plan for Digital Empowerment of SMEs, the Plan on Opinions on Supporting the Healthy Development of New Industries and New Models to Activate the Consumer Market and Drive the Expansion of Employment and a series of other policies to promote digital transformation of enterprises. At the same time, governments at all levels are actively responding to the call to further accelerate the digital transformation of enterprises.

However, there is still debate over how enterprise digital transformation affects enterprise performance. On the one hand, digital transformation promotes the rationalization of production operations as well as improves asset utilization and innovation; this, in turn, enhances enterprise performance (Thathsarani, 2022). According to research by Mikalef and Pateli (2017), who used data from 274 worldwide enterprises, the adoption of digital technology encourages enterprise market reaction agility and indirectly boosts enterprise performance. On the other hand, after examining how well digital transformation has performed in the banking industry and, despite the enormous investment in digital transformation, Ekata (2012) concluded that its contribution to enterprise economic de-

velopment is really quite small. Hajli et al. (2015) found that only some enterprises benefited from digital transformation; most enterprises did not actually improve their performance. Nasiri et al. (2020) found that relying only on the digital transformation of enterprises does not improve the performance of enterprises.

It can be seen that, whether through case studies or empirical research, the academic community has not yet reached a consensus on the impact of digital transformation on enterprise performance. Additionally, there is a lack of extensive experimental data to test the effects of digital transformation or analyze the impact mechanism, making it crucial to resolve the enterprise digital transformation conundrum. The spatial dimension is rarely studied. With this study, based on the spatial perspective, we contribute to using survey data to explore the impact of digital transformation on enterprise performance in MSMEs. We further reveal the mechanism of digital transformation on enterprise financial performance from the two dimensions of R&D investment and operating cost. Through this study, we help further enrich the theories related to enterprise digital transformation and improve the transformation performance, and optimize the transformation path for MSMEs that are currently in digital transformation or have not yet implemented digital transformation. For MSMEs that are undergoing or have not yet begun digital transformation, it can also offer some insights into enhancing transformation performance and optimizing the transformation path. It has therefore important practical significance for the promotion of further high-quality development of the digital economy.

Our paper is structured as follows. First, we conduct a literature review outlining the direct impact of firms' digital transformation on performance, while discussing the spatial spillovers of firms' digital transformation. We then argue for the importance of spatial perspectives on the ability to innovate and reduce costs in improving firm performance by narrowing our discussion to evidence around the path of technological innovation and cost reduction in improving performance. The evidence around MSMEs drives our research hypothesis. We then provide insights into our research methodology and key findings and explore the relationship between digital transformation and the performance of MSMEs through spatial weighted logit model analysis. The results section is followed by a discussion of our findings and a concluding statement setting out the practical recommendations of our work.

2. Literature review and hypotheses

The development of MSMEs faces problems such as high operating costs and lack of innovation capacity; to break through the dilemma, digital transformation has thus become a must for MSMEs (Matarazzo et al., 2021). Digital transformation refers to the process of changing the physical attributes of an enterprise through digital technology (Vial, 2019). It is an enterprise change driven by information systems, including business process improvement, organizational structure change, and business model innovation, all of which bring unique creative capabilities to the enterprise (Mikalef & Pateli, 2017). In addition, from the perspective of organizational change, the digital transformation of enterprises enables organizations to respond efficiently to gain competitive advantage, thus promoting organizational innovation (Hess et al., 2016; Vial, 2019) and providing impetus for enterprise performance improvement. In summary, digital transformation by enterprises using digital technologies to restructure and optimize their production processes and organizational structures cannot only reduce costs but also improve efficiency and ultimately enhance enterprise performance. Based on this, the following hypotheses are proposed in this study. In conclusion, businesses that undergo digital transformation by reorganizing and optimizing their organizational structures and manufacturing processes can decrease costs, increase efficiency, and ultimately improve business performance. These lead to the following hypotheses being put up for this investigation.

H1: Digital transformation of enterprises has a positive impact on enterprise performance.

The environment in which an enterprise is located has an impact on the development and performance of the firm. According to the spillover effect, when an enterprise performs a certain activity, it not only generates the expected benefits of the activity but also has an impact on both people and society outside the enterprise (Henderson, 2020; Lieberman & Asaba, 2006). The presence of different interactions between similarly situated and interacting groups in a given area, such as competition, learning, and imitation. Particularly in an atmosphere of uncertainty and ambiguity, it can significantly affect an enterprise's productivity and, to a certain extent, promote convergent behavior (Chen & Ma, 2017). The neighboring enterprises have a high degree of digital transformation, which has brought many advantages to the enterprises, such as efficiency improvement, innovation ability, data-driven decision-making, improving customer experience, and integrating Business ecosystem, so that the neighboring enterprises with

Digital transformation occupy an advantageous position in the competition, grasp the limited market resources, and thus reduce the performance of the enterprise (Haefner & Sternberg, 2020; Pan et al., 2022). Based on this, we propose the following hypothesis.

H2: Digital transformation of neighboring enterprises has a negative impact on enterprise performance.

According to IT capability theory, and looking at it from a resource-based viewpoint, digital transformation, as a unique resource input, can help enterprises integrate organizational resources and form digital capabilities which, in turn, can enhance the innovation capability and overall performance of enterprises (Bharadwaj, 2000). Dasilva (2018) suggested that, in the process of digital transformation, enterprises will complete digital integration by stimulating the vitality of both information technology data platform construction and business integration, as well as driving business innovation and increasing R&D investment. These actions will maximize the "multiplier" creation effect and therefore, the incremental value of the enterprise. Not only can digital transformation improve physical enterprise performance by enhancing innovation capabilities (Nambisan et al., 2019), but a good internal learning environment and a close external network spirit of cooperation can also strengthen the contribution of digital transformation to enterprise performance (Cetindamar Kozanoglu & Abedin, 2021; Garmann-Johnsen et al., 2020). Therefore, getting enterprises to improve their performance through digital transformation is the key pathway to digital innovation capability formation and ultimately, to performance improvement.

On the other hand, digital transformation reduces production costs and improves the economic efficiency of enterprises by empowering the controllability of production processes and the modularization and flexibility of production models (Moeuf et al., 2018). The application of AI, IoT, big data, and other technologies can help enterprises achieve optimal resource allocation and unified management of each segment (Sharma & Shastri, 2020). Enterprises can also use digital business models to reverse the production side from the demand side and gradually realize modular and flexible production through smart manufacturing (Büchi et al., 2018). As a result, enterprises can allocate production factors based on real-time access to market information, quickly plan production, reduce production costs, and improve enterprise economic efficiency. At the same time, digital transformation accelerates the frequency of internal and external information interaction and reduces not only information search, bargaining, and contracting costs, but also performance monitoring costs in the enterprise trans-

action process. In this way, transaction costs are reduced (Karagiannaki et al., 2017), and enterprise performance is improved. Based on this, we propose the following hypotheses.

H3a: Digital transformation affects enterprise performance through the innovation path.

H3b: Digital transformation affects enterprise performance through the cost path.

3. Research methodology

3.1. Data collection

Ningbo, China is dominated by the manufacturing industry. At present, China's digital transformation is also dominated by the manufacturing industry. We use a questionnaire to investigate the digital transformation of MSMEs, with the questionnaire digital transformation status and effectiveness. In the module of digital transformation comprising three modules: basic information, digital transformation intention, transformation status quo and effectiveness, we set questions looking at various aspects of enterprise operation.

For data collection, we focused on Ningbo City in Zhejiang Province as the research site. Ningbo is a key industrial city in Eastern China with a large number of MSMEs and a wide range of industries. The survey targeted all MSMEs in the Ningbo Industrial Park. Due to the low threshold of establishment and the large number of MSMEs, as well as the rapid changes in registration and cancellations and the incomplete and untimely updating of the enterprise directory database, we adopt a double sampling frame of directory-region design. This method both avoids single sampling frame errors and ensures not only the full coverage of the target total but also that the sample structure is consistent with the overall structure. To form the original directory database, we first use web crawlers to capture basic information on Ningbo MSMEs and use circular isometric sampling with registered capital as the auxiliary variable for the enterprises in the directory sampling frame. We then use ΠPS sampling by the village for the enterprises in the regional sampling frame, with the overlapping part determined according to the directory sampling frame. The research was conducted from July 20, 2021, to August 20, 2021, with 253 questionnaires distributed and 147 valid questionnaires returned.

3.2. Variables

Enterprise performance: In this study, enterprise net profit (Margin) is used as an indicator of enterprise performance.

Key independent Variables: In terms of the areas and dimensions focused on by quantitative research, the current literature on the impact of digital transformation on enterprise performance from the perspective of econometric models mainly focuses on the macro and regional levels; enterprise-level research is relatively rare (Storey, 1994). Considering the characteristics of MSMEs and the limitations of the data collected by the questionnaire, we refer to scholars such as Lassnig et al. (2021), Mikhridinova et al. (2021), Tiwasing et al. (2022), as well as reports, such as *Discovering new momentum: How China's manufacturing industry can win the digital economy* (Accenture, 2017), and other. Planning, production, sale, and management are primary indicators, while 15 secondary and 40 tertiary indicators are selected for measurement. In this study, hierarchical analysis is applied to determine the weights, with results obtained shown in Table 1.

Table 1. Enterprise digital transformation indicators and weights

Primary indicators	Secondary indicators	Weight	Tertiary indicators	Weight
1	*2*	*3*	*4*	*5*
A1 Planning 0.36	B11 Top design of digital strategy	0.17	C111 Digital system construction	0.13
			C112 Digital transformation mode	0.04
	B12 Digital importance	0.09	C121 Digital construction fund investment	0.09
	B13 Digital ecological layout	0.07	C131 Collaborative digitalization of industrial chain business	0.05
			C132 Enterprise service coverage	0.01
			C133 Digital business scale	0.02
	B14 Network interconnection construction	0.03	C141 Equipment digitization level	0.02
			C142 Equipment networking degree	0.01
A2 Production 0.23	B21 Digitization of R&D process	0.08	C211 Digitalization of research and development tools	0.01
			C212 Digitization of R&D management process	0.05
			C213 Digitization of product management	0.02
			C221 Supplier management digitalization	0.003
	B22 Procurement digitization	0.03	C222 Procurement process digitization	0.01
			C223 Procurement monitoring digitization	0.02

Table 1 cont.

1	*2*	*3*	*4*	*5*
	B23 Logistics digitization	0.02	C231 Digital application of in-plant physical transportation	0.001
			C232 Digitization of logistics distribution capacity	0.004
			C233 Warehouse digitization	0.01
	B24 Digitization of production and manufacturing	0.10	C241 Digitization of manufacturing process	0.03
			C242 Collaboration level of production equipment	0.01
			C243 Digitization of production monitoring	0.06
A3 Sale 0.13	B31 Operation digitization	0.07	C311 Digital level of market research	0.05
			C312 Digital level of sales management	0.02
	B32 Transaction digitization	0.02	C321 Digital level of customer experience	0.01
			C322 Construction and application of e-commerce platform	0.003
	B33 After-sale service	0.04	C331 Digital level of customer relationship management	0.04
A4 Management 0.28	B41 Enterprise culture	0.07	C411 Enterprise spirit	0.03
			C412 Entrepreneurship	0.01
			C413 Employee workflow digitization	0.005
			C414 Innovation and transformation of enterprise business model	0.01
			C415 Management system reform	0.01
	B42 Financial digitization	0.03	C421 Degree of financial information terms	0.01
			C422 Digital financial sharing	0.002
			C423 Financial data analysis	0.02
	B43 Digitalization of human resource management	0.02	C431 Human resource management software application	0.004
			C432 Digital quality of employees	0.02
	B44 Digital performance	0.15	C441 Market response speed	0.03
			C442 R&D efficiency	0.02
			C443 Production efficiency	0.02
			C444 Management and decision-making efficiency	0.07
			C445 Information transmission efficiency	0.01

The subsequent comprehensive evaluation used the hierarchical analysis method to measure the digitization level of individual enterprises (*DE*). Relevant indicator descriptions of the data presented in this study are presented in Table 2. The enterprise digitization level scores ranged from 44.10 to 91.30, with the

majority of enterprises scoring around 60 with a standard deviation of 9.24. The average digital level score of transformed enterprises was 70.85, while the average digital level score of enterprises without digital transformation was 55.51. **The results show that the overall digital level of MSMEs is medium to high, indicating not only that there is more room for improvement in digital transformation, but that there are also differences among enterprises.**

Intermediary variables: The mediated path variables are comprised of two possible dimensions: (1) Innovation capability (*RD*); enterprise R&D investment measures the elevated product quality of the enterprise and is the innovation path; (2) Cost of sales (*Cost*); the operating cost of enterprises measures decreases in cost and is the cost path.

Control variables: To enhance the rationality of the constructed model, the following control variables are selected in this study: (1) enterprise size (*Size*), using the natural logarithm of the enterprise's total assets; (2) establishment length (*Time*), the current year – establishment year; (3) enterprise production number (*People*), using the number of enterprise production personnel; (4) asset and liability ratio (*Lev*), using the ratio of enterprise liabilities to enterprise assets; (5) industry type (*Industry*), the industry in which the enterprise produces products; (6) total tax revenue (*Tax*), as expressed by the total tax revenue of the year; (7) sales expense (*Sale*), as expressed by the total sales expenses of the year.

Table 2. Variable specification and descriptive statistical

Variable type	Variables	N	Mean	Std. Dev.	Min	Max
Dependent variable	Margin	147	396.52	676.52	0	3500
Independent variables	DE	147	60.22	8.75	44.10	91.30
	NerDE	147	1053.35	1160.27	41.6	2766.4
Intermediary variables	RD	147	9075.32	14566.24	15	120000
	Cost	147	7442.14	12834.09	15	45000
Control variables	Size	147	7.82	1.71	4.317	11.513
	Time	147	14.19	7.84	0	36
	People	147	94.21	118.32	0	895
	Lev	147	0.200	0.18	0.002	1.450
	Industry	147	–	–	1	7
	Tax	147	141.49	155.50	2.5	500
	Sale	147	1449.72	10144.50	5	120000

3.3. Methods

When making decisions, enterprises are influenced by other enterprises in the same industry at the same time (Chen & Ma, 2017), which infers that there is a certain clustering effect in the digital transformation of MSMEs. As a consequence, the Moran test is applied to further verify this. The weights are set based on the neighboring distance, and the weights of each enterprise located in the same park or uniform village are set to 1, with the rest set to 0. The matrix is normalized and further tested for spatial auto-correlation by Moran's index (I). The formula of Moran's I is.

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_{i=0}^{n} z_i^2} \quad (1)$$

Where, z_i is the deviation of the attribute of element *i* from its mean (X_i – X), $W_{i,j}$ is the spatial weight between elements *i* and *j*, *n* is the sum of elements, and S_0 is the aggregation of all spatial weights. The results show that Ningbo Xidian enterprises have a high positive spatial correlation (Moran's I = 0.031, p = 0.043), indicating that enterprises with a higher degree of digital transformation are clustered around the same digital type of enterprises. That is to say, enterprises with high levels of transformation are surrounded by enterprises with high levels of transformation, while enterprises with low levels of transformation are surrounded by enterprises with low levels of transformation.

To test the impact of digital transformation on the transformation performance of MSMEs and the transformation path, the *Spatial weighted logit* model was developed for observation under conditions of limited data indicators:

$$margin_i = C + \partial_1 \times DE_i + \partial_2 \times nerDE_i + \gamma_1 \times \text{Size}_i + \gamma_2 \times Time_i + \gamma_3 \times People_i + \gamma_4 \times Lev_i + \gamma_5 \times Industry_i + \gamma_6 \times Tax_i + \gamma_7 \times Sale_i \quad (2)$$

$nerDE_i$ is the digitalization level of the neighboring enterprises of the *i*th enterprise, and $control_{j,i}$ is the control variable; C is a constant term.

$$Z_i = C + \beta_1 \times nerDE_i + \beta_2 \times DE_i + \sum_j \gamma_j \times control_{j,i} \quad (3)$$

$$margin_i = C + \beta_1 Z_i + \beta_2 \times nerDE_i + \beta_3 \times DE_i + \sum_j \gamma_j \times control_{j,i} \quad (4)$$

In the equation, Z_i is the potential transformation path variable of the *i*th enterprise, (3) and (4) are used to determine whether the Z variable is the intermediate path for the digital transformation of MSMEs to promote enterprise performance improvement based on the establishment of Equation (2).

4. Research results

4.1. Baseline regression model

Table 3 investigates the impact of the digitalization level of this enterprise and adjacent enterprises on the performance of this enterprise under different control variables. The third and fourth columns verify whether there is a spatial effect of digital transformation in MSMEs. Among them, the first and third columns are the results of adding the core independent variables. In the first column, the digitalization level of the enterprise (*DE*) has a significant positive relationship with performance, H1 is verified. In the third column, the digitalization level of neighboring enterprises (*NerDE*) has a significant negative relationship, with significance at the 1% level, H2 is thus verified.

Table 3. The impact of the enterprise digitalization level and the digitalization level of neighboring enterprises, on enterprise performance

Dependent variable	**Margin**			
DE	43.01***	14.25**	35.06***	12.43**
	(5.083)	(5.671)	(5.648)	(5.685)
NerDE			–0.130***	–0.0831*
			(0.0445)	(0.0421)
Size		0.0147***		0.0169***
		(0.00424)		(0.00434)
Time		8.863*		8.624
		(5.304)		(5.248)
People		0.445**		0.391*
		(0.214)		(0.214)
Lev		-0.176*		-0.588*
		(44.56)		(48.77)
Industry		57.64***		52.42***
		(17.87)		(17.87)
Tax		1.086***		1.012***
		(0.363)		(0.362)
Sale		0.00761*		0.00724*
		(0.0044)		(0.00435)
_cons	–2197.8***	-882.4**	–1581.1***	–360.8
	(310.1)	(364.9)	(368.3)	(447.3)
R^2	0.340	0.602	0.379	0.613
adj. R^2	0.335	0.578	0.370	0.587

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The regression results in the second and fourth columns of the data after adding all control variables are investigated. Although the regression coefficients are reduced, which may be due to the absorption by the added control variables, the addition of control variables does not affect the positive relationship between the digital level of enterprises and performance, the same as previous research results (Do et al., 2022; Zhai et al., 2022); the negative relationship between the digital level of adjacent enterprises and performance is still significant at the 5% level (Haefner & Sternberg, 2020; Pan et al., 2022). This result further indicates that not only can enterprise digital transformation drive enterprises to achieve higher performance but the spatial clustering effect of enterprises is also verified. Among the control variables, enterprise size (*Size*), duration of establishment (*Time*), number of productive people (*People*), industry type (*Industry*), total tax revenue for the year (*Tax*), and cost of sales (*Sale*) are all significantly and positively correlated with performance, but asset and liability ratio (*Lev*) is significantly and negatively correlated with performance.

4.2. Path analysis

The previous section verifies that there is a positive impact of digital transformation on the performance of MSMEs, and this section explores the path through which digital transformation has an impact on the performance of MSMEs.

Table 4. Intermediary effect test

Intermediary variable	R&D investment		Operating cost	
	bootstrap test	sgmediation test	bootstrap test	sgmediation test
Sobel		22.22***		11.99***
		(4.005)		(3.137)
Indirect effect	24.25***	21.22***	11.99**	11.99***
	(7.154)	(4.005)	(5.635)	(3.137)
Direct effect	18.76**	18.04***	27.27***	27.26***
	(5.867)	(5.264)	(6.379)	(5.328)

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

According to the theoretical analysis, digital transformation can have an impact on the R&D investment and operating cost of enterprises, thus, the mediating effect model is used to verify. The mediating variables are looked at from two dimensions: innovation and cost. First, R&D investment is selected as the mediating variable for analysis, while the Sobel and Bootstrap tests are conduct-

ed on the mediating variables. Results are shown in Table 4. The results are all significant, indicating that R&D investment has a mediating effect on the impact of digital transformation on enterprise performance.

Table 5. The impact of the enterprise digitalization level and the digitalization level of neighboring enterprises, on the innovation path

Dependent variable	RD	Margin	Margin
DE	683.1***		14.38***
	(136.8)		(5.403)
NerDE	–1.425*		–0.0858**
	(1.020)		(0.0373)
RD		0.0262***	0.0199***
		(0.00291)	(0.00313)
Time	302.0**	11.74**	8.165
	(141.0)	(5.443)	(5.197)
People	6.794	0.362	0.382*
	(5.818)	(0.224)	(0.212)
Industry	–306.4	51.03***	45.55**
	(491.2)	(18.76)	(17.83)
Sale	0.694***	0.00152	0.00286
	(0.107)	(0.00469)	(0.00445)
_cons	–35159.6***	–137.4	–783.6**
	(9008.4)	(106.0)	(344.6)
R^2	0.531	0.545	0.603
adj. R^2	0.510	0.528	0.581

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5 demonstrates the effect of enterprise digitalization level on its R&D investment; the results show that the digitalization level of neighboring enterprises has a significant negative effect on a company's enterprise R&D investment when controlling for corresponding variables. The third column under the combined effects regression indicates that the digital transformation of neighboring firms has a negative effect on the performance of their firms and is achieved through R&D investment. It is consistent with H3a, which indicates that there is a spatial spillover effect of digital transformation among enterprises and, due to the competitive relationship among enterprises, the higher the digitalization level of neighboring enterprises, the greater the negative effect on the R&D investment of an enterprise.

Table 6. The impact of the enterprise digitalization level and the digitalization level of neighboring enterprises, on the cost path

Dependent variable	Cost	Margin	Margin
DE	–223.1*		27.72***
	(130.9)		(5.721)
NerDE	3.856***		–0.110**
	(0.976)		(0.0446)
Cost		–0.0106***	–0.00998*
		(0.00387)	(0.00374)
Time	–12.07	23.49***	14.15**
	(134.8)	(6.481)	(5.830)
People	6.726	0.157	0.253
	(5.565)	(0.275)	(0.242)
Industry	–182.0	39.46*	39.28*
	(469.8)	(23.15)	(20.33)
Sale	0.0277	0.0239***	0.0167***
	(0.102)	(0.00485)	(0.00443)
_cons	18429.8**	7.720	–1463.6***
	(8616.4)	(139.8)	(378.9)
R^2	0.330	0.309	0.530
adj. R^2	0.294	0.283	0.502

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Analysis of the results in Table 6, controls for four variables: the length of time the enterprise has been established *(Time)*, the number of people the enterprise produces (*People*), the type of industry (*Industry*), and the cost of sales (*Sale*). The results in the first column indicate that the digitization level of an enterprise has a significant negative effect on the operating cost of the enterprise and the digitization level of neighboring enterprises has a positive effect on the operating cost of an enterprise. The second column shows that enterprise operating cost has a significant negative effect on enterprise performance, and that the higher the enterprise operating cost is, the lower the performance of this enterprise. Therefore, considering the combined effect, the third column shows that the digital transformation of neighboring MSMEs can affect the performance of an enterprise by affecting the enterprise operating cost, which is consistent with H3b.

The results of the verification of the two potential paths in the spatial perspective are significant, indicating that the level of digitization of neighboring firms affects the performance of an enterprise through two paths: R&D investment and operating cost.

4.3. Robustness test

To verify the robustness of the results of the factors influencing the performance of enterprise digital transformation, the explanatory variable enterprise digitalization level is re-measured by the *Entropy method* (Jiang, 2014; Xu et al., 2018). A new adjacent enterprise digitalization level index is then obtained, and both baseline regression and path analysis are conducted again. As shown in Table 7, after replacing the explanatory variables with the index measured by the *Entropy method*, the results are consistent with the benchmark regression results of the impact of digital transformation on enterprise performance, indicating the robustness of the results.

Table 7. The impact of the enterprise digitalization level and the digitalization level of neighboring enterprises (Entropy method) on enterprise performance

Dependent variable	Margin			
DEWM	23.47***	7.870**	20.21***	8.331***
	(2.959)	(3.106)	(2.864)	(3.043)
NerDEWM			–0.441***	–0.239***
			(0.0977)	(0.0905)
Size		0.0143***		0.0156***
		(0.00424)		(0.00418)
Time		9.624*		8.082
		(5.311)		(5.227)
People		0.474**		0.385*
		(0.2146)		(0.2126)
Lev		–14.18*		–49.81*
		(44.12)		(45.20)
Industry		58.52***		53.51***
		(17.86)		(17.57)
Tax		1.125***		1.006***
		(0.361)		(0.356)
Sale		0.00769*		0.00736*
		(0.00439)		(0.00429)
_cons	–332.4***	–305.8	–43.32	90.51
	(103.4)	(289.3)	(116.1)	(320.1)
R^2	0.312	0.602	0.400	0.622
adj. R^2	0.307	0.578	0.312	0.593

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Similarly, the explanatory variable adjacent enterprise digitization level is replaced with the value measured by the *Entropy method*, and path analysis is performed as a robustness check. The results indicate that the digitalization level of neighboring enterprises has a negative effect on the performance of this enterprise, controlling for variables such as enterprise size (*Size*). The higher the digitalization level of neighboring enterprises is, the lower the R&D investment and the higher the operating cost of this enterprise. Therefore, considering the combined effect, the digital transformation of neighboring MSMEs can affect an enterprise's performance by influencing its R&D investment and operating costs. This effect has been verified once again.

Table 8. The impact of the enterprise digitalization level and the digitalization level of neighboring enterprises (Entropy method) on the innovation path

Dependent variable	RD	Margin	Margin
DEWM	389.3***		9.352***
	(70.58)		(2.802)
NerDEWM	–5.101**		–0.266***
	(2.308)		(0.0842)
RD		0.0262***	0.0192***
		(0.00291)	(0.00310)
Time	315.3**	11.74**	7.733
	(141.4)	(5.443)	(5.163)
People	6.383	0.362	0.370*
	(5.863)	(0.224)	(0.211)
Industry	–269.3	51.03***	46.83***
	(488.1)	(18.76)	(17.51)
Sale	0.690***	0.00152	0.00285
	(0.107)	(0.00469)	(0.00437)
_cons	–5613.5	–137.4	–177.1
	(3783.6)	(106.0)	(136.7)
R^2	0.533	0.545	0.614
adj. R^2	0.512	0.528	0.593

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 9. The impact of the enterprise digitalization level and the digitalization level of neighboring enterprises, (Entropy method) on the cost path

Dependent variable	Cost	Margin	Margin
DEWM	–177.2**		16.52***
	(70.03)		(2.938)
NerDEWM	6.992***		–0.352***
	(2.290)		(0.0971)
Cost		–0.0106***	–0.00179*
		(0.0039)	(0.00354)
Time	–34.52	23.489***	13.74**
	(140.3)	(6.481)	(5.754)
People	6.857	0.1568	0.260
	(5.817)	(0.2748)	(0.240)
Industry	–307.7	39.46**	41.10**
	(484.3)	(23.148)	(19.88)
Sale	0.0388	0.0239***	0.0162***
	(0.106)	(0.0049)	(0.00433)
_cons	12271.4***	7.72	–263.1
	(3753.9)	(139.7)	(159.9)
R^2	0.167	0.309	0.502
adj. R^2	0.130	0.283	0.476

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5. Discussion

In this paper, China Ningbo MSMEs were analyzed as the research object through the questionnaire survey from the perspective of space to explore the influence of enterprise digital transformation on enterprise performance. This is a powerful supplement to the digital transformation of existing enterprise research systems. To some extent, this study enriches the existing research content and also provides a reference for China MSMEs' digital transformation.

The results mainly reveal two points: first, the digital transformation of MSMEs in Ningbo, China can have a positive impact on the performance of the adjacent enterprises can have a negative impact on the enterprise. The research on related listed companies has also reached the same conclusion (Do et al., 2022; Guo & Xu, 2021). However, the current level of digital transformation of MSMEs is generally low, and there are still great opportunities for improvement. Second, digital transformation can have a positive impact on the performance of enterprises through business revenue and product innovation, which is consistent with previous research (Wang, 2023; Zhai et al., 2022). Compared with the ex-

isting research results, this paper presents the same from the point of common ground. The current Chinese MSMEs are in the digital transformation development stage and the digital degree of difference is obvious (Wang, 2023). The difference is that this paper by constructing the space matrix from the perspective of MSMEs' digital transformation on the enterprise performance, to some extent, enriches the research content and the enterprise data analysis from a more microscopic perspective. All this contributes to the reliability of the research results.

This study, of course, has some deficiencies, mainly in the main data from China's manufacturing city of Ningbo. Because China is a manufacturing power and manufacturing is one of the pillar industries of China's economy, regional restrictions will lead to the universality of the research results. The empirical research for the rest of the world needs further updated data for specific analysis. In addition, we propose some research questions that can further promote the digital transformation of MSMEs. First, does the transformation of different digital technology applications have a different impact on enterprise performance? Second, are the digital transformation paths of MSMEs in different industries and of different sizes different? Third, how do the different application scenarios of SMEs digital transformation affect their financial performance?

6. Conclusions

Taking 147 MSMEs as samples, we study the impact of digital transformation on enterprise performance and intermediary process from the perspective of space, which provides a basis for the subsequent promotion of digital transformation of MSMEs to achieve cost reduction and efficiency increase. The findings reveal that: (1) there is still much room for improvement in the current transformation of MSMEs, and there are gaps between businesses; the government should actively develop a communication platform for digital transformation, promote the development of relevant technical personnel, and actively assist enterprises in carrying out digital transformation (Teng et al., 2022); enterprises themselves need to adopt a new mindset and more aggressively innovate and experiment; (2) a spatial regression model is utilized to determine that enterprise performance is significantly improved as a result of digital transformation and that the higher the degree of digitalization of neighboring enterprises, the worse the performance of a particular enterprise; because of the significant cluster effect among enterprises, the government can both transform the

existing park and guide MSMEs to cooperate and develop digital transformation, building digital workshops together to achieve cost reductions and efficiency; (3) path analysis found that digital transformation can help enterprises improve their performance in many ways: first, the innovation path – increasing enterprise R&D investment, second, the cost path – reducing enterprise operating costs. This also requires us to promote the enterprise digital transformation when paying attention to the enterprise space spillover effect, through cooperation between the park, building enterprise digital workshops, and digital communication experience to promote enterprise digital transformation, and at the same time should also encourage enterprises to improve through digital transformation innovation ability to increase enterprise performance, and promote the development of enterprises (Haefner et al., 2020).

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