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What Is Necessary for Digital Transformation of Large Manufacturing Companies? A Necessary Condition Analysis

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Abstract: Digital transformation is of significant importance to the sustainable development of manufacturing companies and the construction of the digital economy. However, this major change is often hindered by numerous complex antecedents. What are the key factors in the digital transformation of manufacturing companies, and what is their relative importance? Accordingly, this paper identifies the key factors for digital transformation in large manufacturing companies from the "Ability–Motivation–Opportunity" (AMO) perspective. This study uses a necessary condition analysis (NCA) to conduct a necessity causality study on data collected from 67 listed Chinese manufacturing companies between 2016 and 2020. The results show that the digital transformation of large manufacturing companies is influenced by four necessary conditions: managerial myopia, industry concentration (very large effect), dynamic capabilities, and industrial digitalization (large effect). Managerial myopia and industry concentration have a negative necessary impact on digital transformation. The types of conditions and the level of bottlenecks required at different stages of digital transformation vary significantly. This study reveals the necessary causal relationships between organizational abilities, motivation, external opportunities, and digital transformation, providing empirical evidence to promote the digital transformation practices of manufacturing companies.

Keywords: large manufacturing companies; AMO; digital transformation; necessary condition analysis

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1. Introduction

The digital transformation of large manufacturing companies has already become an inevitable requirement for the sustainable development of the manufacturing industry [1], but successful digital transformation faces many difficulties. These companies are systematically crucial for the national economy and have even more important responsibilities for constructing the digital economy. Despite their focus on digital strategies and substantial investments, which surpass those of smaller enterprises and for which they have dedicated teams for digital transformation, their efforts have yet to materialize fully into tangible outcomes. A study released by Accenture's "2022 China Enterprise Digital Transformation Index" (https://www.accenture.cn/cn-zh/insights/strategy/china-digital-transformation-index-2022 accessed on 16 April 2024) revealed that only 17% of enterprises can transform digital investment into business performance. Therefore, what factors constrain the digital transformation of large manufacturing companies?

Scholars attempt to explore the influencing factors of digital transformation from different perspectives, which can be summarized into the following two types: (1) The determinism perspective emphasizes that external pressures compel enterprises to undergo digital transformation, including factors such as network embedding, market competition, and environmental uncertainty [2–5]. (2) The voluntarism perspective highlights proactive decisions and actions within organizations, including internal factors like the

entrepreneurial orientation of employees and leadership [6–9]. However, the conclusions drawn from different perspectives can vary greatly due to differences in the factors involved and research methodologies. In response to this phenomenon, Rajagopalan and Spreitzer [10] pointed out that integrating different theoretical perspectives can help us fully understand the complexity of change and alleviate inconsistencies between research results. Therefore, research has begun to explore the complex causal relationships between multidimensional factors and organizational change from a configurational perspective [11], such as introducing the "Technology–Organization–Environment" (TOE) framework. Although the TOE framework can explain complex managerial phenomena and their causes, it is widely used to explain organizations' technology integration and adoption behavior [12]. Digital transformation, as a broader and longer-term strategic initiative, does not halt at the application level of digital technology but is more about internal organizational changes under the influence of digital technology. This process is also influenced by external digital ecosystems and competitive environments.

The AMO theory perspective has dialectical characteristics in order to thoroughly contemplate and reshape digital transformation. The AMO theory effectively merges the opposing perspectives of determinism and voluntarism, weaving together organizational abilities, motivation, and external opportunities into three cohesive dimensions. This synthesis offers a fresh perspective on understanding digital transformation [13,14]. First, from the perspective of organizational abilities, digital transformation requires enterprises to have sufficient idle resources to cope with the risk of transformation failure and the ability to flexibly allocate resources to adapt to the continuously changing external environment [15,16]. Second, from the perspective of organizational motivation, digital transformation, as a systematic strategic change, is driven by the top manager team, and the most fundamental motivation does not come from the information department but from the top management [6]. Whether executives are willing to adjust the organization's strategic actions actively is crucial for digital transformation because managers pursuing short-term benefits are often reluctant to make strategic changes for long-term goals, nor are they willing to affect the relationship of interests due to change; therefore, the time domain of the executives themselves should not be ignored [17]. In addition, executives' motivation to overcome organizational inertia to drive strategic change is also affected by exogenous conditions such as pay gaps within the firm [18]. Finally, from the perspective of external opportunities, the digital transformation of enterprises is influenced by industry competition and digital ecology [19]. The intensity of industrial competition is an essential motivation for enterprises to break through organizational boundaries and use digital technology to overcome time and space constraints to broaden access to resources and improve their resource utilization efficiency [20]. The degree of development of the digital ecosystem also determines the magnitude of spillover effects from upstream and downstream industry chains [4].

Based on the above background, this study introduces the more dialectically characterized AMO (Ability–Motivation–Opportunity) theory to construct an analytical framework to explore the constraints of digital transformation in large companies. According to Hanelt et al. [21], this paper posits that it is the interaction between organizational constraints, change agents, and pre-existing environmental conditions that drive strategic change [22]. The AMO theory effectively integrates the seemingly opposing perspectives of determinism and voluntarism, suggesting that the interaction between ability, motivation, and opportunity can comprehensively explain and help us understand the actions taken during digital transformation [13,14,23,24]. This study aims to identify the key antecedents of digital transformation based on the AMO theoretical framework from the perspective of theoretical rigor and relevance. At the same time, this study realizes that in such a complex management activity as digital transformation, practitioners cannot design, manage, and control all the factors simultaneously. Therefore, identifying the most influential factors and determining the relative importance of each factor are also valuable practical requirements.

In summary, this paper adopts necessary condition analysis (NCA), a suitable research method, to perform an analysis of the necessary conditions. The key value of the logic of necessity lies in identifying the factors that have a crucial restricting effect on the outcome [25]. As the two-factor theory describes, while motivational elements contribute to job satisfaction, the lack of hygiene factors will invariably result in the absence of job satisfaction. Fulfilling such health factors is necessary to achieve the outcome and deserves primary attention [26]. Specifically, this paper identifies the necessary conditions and their effect sizes through the necessary conditions in kind. It makes a judgment on the primary and secondary relationships of the conditions through the necessary conditions to identify the bottleneck level, and provides the order and threshold of the emergence of the necessary conditions as the level of digital transformation increases [24]. The contributions are as follows. We find the key factors constraining large manufacturing companies' digital transformation by revealing the causality between organizational ability, organizational motivation, external opportunities, and digital transformation, effectively addressing the limitations of regression analyses that focus solely on sufficiency causality. These insights enable managers to strategically allocate resources in alignment with digital transformation needs, thereby preventing blind conformity in the digital transformation initiatives of enterprises.

2. Theoretical Background and Hypotheses

2.1. Organizational Ability and Digital Transformation

The organizational ability refers to the knowledge, skills, and resources required to accomplish a specific goal or behavior [13]. This study uses the conditions of organizational slack and dynamic capability to portray the organizational ability dimension.

Organizational slack refers to additional resources beyond the minimum required for an organization to sustain operations [27], which can be flexibly transformed and called upon. Organizational slack provides a critical buffer in the face of market uncertainty or unforeseen events by enhancing an enterprise's risk-taking capacity, which is particularly significant in digital transformation. Digital transformation is a complex strategic change that involves technology refresh, business model innovation, and corporate culture reform [28] and is usually accompanied by a high degree of uncertainty and the risk of potential failure. Organizational slack serves as an important buffer, providing companies with the necessary resources to support them while exploring new technologies and markets and effectively reducing the stress caused by change failure. In addition, organizational slack allows firms to explore growth and innovation. The degree of organizational slack reflects a company's willingness to invest in higher-risk activities with uncertain returns. Companies with more slack resources are more likely to explore new business opportunities or invest in advanced production technologies [29], significantly increasing the likelihood of digital transformation success without sacrificing day-to-day operations. Consequently, we propose the following hypothesis:

Hypothesis 1 (H1): *A high level of organizational slack is necessary for a high level of digital transformation in manufacturing companies.*

The dynamic capability is an enterprise's ability to integrate, build, and reconfigure internal and external resources to respond to a rapidly changing market environment [30], including the three core capabilities of sensing, seizing, and transforming [31]. Dynamic capabilities help enterprises accelerate the implementation of strategic change decisions, meet customer needs through continuous innovation, and make it easier for organizations to adapt to new technologies and changing markets. Specifically, companies with dynamic capabilities can identify external opportunities and challenges through continuous environmental scanning, increasing the sensitivity and responsiveness to emerging technology trends, changing consumer behavior, and competitive dynamics [32]. These companies can capitalize on perceived opportunities and execute transformative actions through

strategic investments and innovation in business models [32]. Especially for the evolving strategic change in digital transformation, a dynamic capability enables organizations to flexibly adjust or reconfigure their resource allocation to support continuous innovation and adaptive change and to cope with the uncertainties arising from the change process effectively [33]. Thus, the role of dynamic capability in digital transformation is not only to enhance the adaptability and flexibility of an organization but, more importantly, to promote continuous innovation and long-term development. In summary, this study proposes the following hypothesis:

Hypothesis 2 (H2): *A high level of dynamic capability is necessary to achieve a high level of digital transformation in manufacturing companies.*

2.2. Organizational Motivation and Digital Transformation

Organizational motivation refers to the driving force that can stimulate specific behaviors of executives, which usually includes intrinsic drivers such as interest and desire as well as extrinsic drivers such as rewards and penalties [13], for which this paper introduces the two conditions of managerial myopia and pay gaps.

Managerial myopia refers to the tendency of managers to focus on benefits that can be instantly satisfied in the present rather than investing in risky actions that cause costs in the short term and pay off in the long term [34]. Top managers are the strategic decision-makers of the company, and their time orientation determines the organization's future strategic direction [35]. Time orientation refers to a manager's subjective perception, preference, and insight of time in the strategic decision-making process, which can be divided into long- and short-term orientations. Top managers with a long-term orientation have a longer time horizon, are highly concerned about the company's long-term development [36], and tend to make more comprehensive and creative strategic decisions [37]. Executives with a long-term perspective are pivotal, particularly during strategic changes like digital transformation, which are characterized by their extended duration, systemic nature, and inherent uncertainty. Given that digital transformation involves significant resource investments, lengthy payback periods, and significant opportunity costs [28], it is imperative for managers to possess both the foresight and patience to sustain such change. Long-term-oriented managers are good at maintaining their strategic focus during the change process, adeptly navigating the myriad challenges and obstacles to successfully drive digital transformation. Accordingly, we propose the following hypothesis:

Hypothesis 3 (H3): *Low-level managerial myopia is necessary for high-level digital transformation of manufacturing companies.*

Pay gaps, defined as the disparity in compensation levels between top managers and employees, plays a significant role in strategy implementation. According to tournament theory, a significant pay gap can effectively boost top managers' motivation to innovate and change [38], which is crucial for digital transformation and other strategic change. Particularly, in the context of increasing technological sophistication and scale, a differentiated compensation system provides top executives with significant financial incentives to commit to long-term goals [39], thus fueling the organization's long-term growth. In addition, according to the managerial power theory, the pay gap can reflect the power and status of management in an organization [38]. A wider pay gap implies that top managers have more control over high-value resources. This power gives executives more flexibility and autonomy to promote innovation and strategic change, thus effectively promoting organizational digital transformation. Moreover, social comparison and equity theories suggest that executives form perceptions of fairness by comparing their compensation with that of others. Excessive compensation may enhance these perceptions of fairness, thereby motivating them to exert greater effort towards change [40]. In summary, we propose the following hypothesis:

Hypothesis 4 (H4): *A high-level pay gap is necessary for high-level digital transformation of manufacturing companies.*

2.3. External Opportunities and Digital Transformation

External opportunities are defined as situational factors that either encourage or restrict organizational behaviors [13]. To thoroughly examine the opportunities and challenges faced by organizations in dynamic environments, this study incorporates an analysis of industry concentration and industrial digitalization.

Industry concentration is an important indicator of the degree of competition and monopoly in a market. A high industry concentration indicates a more monopolistic market [41], where dominant firms can become digital leaders in the industry because they have more resources and capacity to invest in digital technology innovation. These companies can use their strong demonstration effect to provide a template or standard for other companies to transform, thus promoting the digitalization process of the entire industry. However, it should be noted that high industry concentration is not necessarily conducive to digital transformation. In a monopoly market, the monopolist may lose the incentive to change due to the lack of competition, thus missing the opportunities brought by digitalization and ultimately posing a threat to the long-term competitiveness of the enterprise. In contrast, in industries with a low concentration, there are a large number of competitors [42], and the huge competitive pressure in the market forces enterprises to increase their sensitivity to external competitors and changes in the market environment, which can effectively stimulate the motivation of the organization to actively seek digital transformation and to build a sustainable competitive advantage by improving operational efficiency, enhancing innovation capability, and optimizing the customer experience. Consequently, we propose the following two hypotheses:

Hypothesis 5 (H5): *High-level industry concentration is necessary for the high-level digital transformation of manufacturing companies.*

Hypothesis 6 (H6): *Low-level industry concentration is necessary for the high-level digital transformation of manufacturing companies.*

Industrial digitalization indicates the degree of integration of an industry with the digital economy, which reflects the level of development of the industry's digital ecosystem and reveals the industry's maturity in digital technology application. From a pressure perspective, organizations often feel the urgency of undergoing digital transformation in response to the requirements of upstream and downstream partners and changes in market demand. This backward pressure from other links in the industry chain prompts enterprises to take active action to adapt to the synergistic demands of industry chain digitalization [4]. In addition, because of the industry chain spillover effect of enterprise digital transformation, the higher the level of industrial digitalization, the more conducive it is to increase the feasibility and success rate of individual enterprises' digital transformations [43]. As the level of industrial digitalization increases, upstream and downstream enterprises can work more closely with each other, which is conducive to constructing efficient digital ecosystems and sharing platforms [5]. This supports the effective reduction in information acquisition costs and information asymmetry among enterprises in the industry [44,45]. It helps enterprises solve the problems of "not daring to change" and "not knowing how to change" during digital transformation. In summary, we propose the following hypothesis:

Hypothesis 7 (H7): *High-level industrial digitalization is necessary for high-level digital transformation of manufacturing companies.*

The research hypotheses are presented in Figure 1.

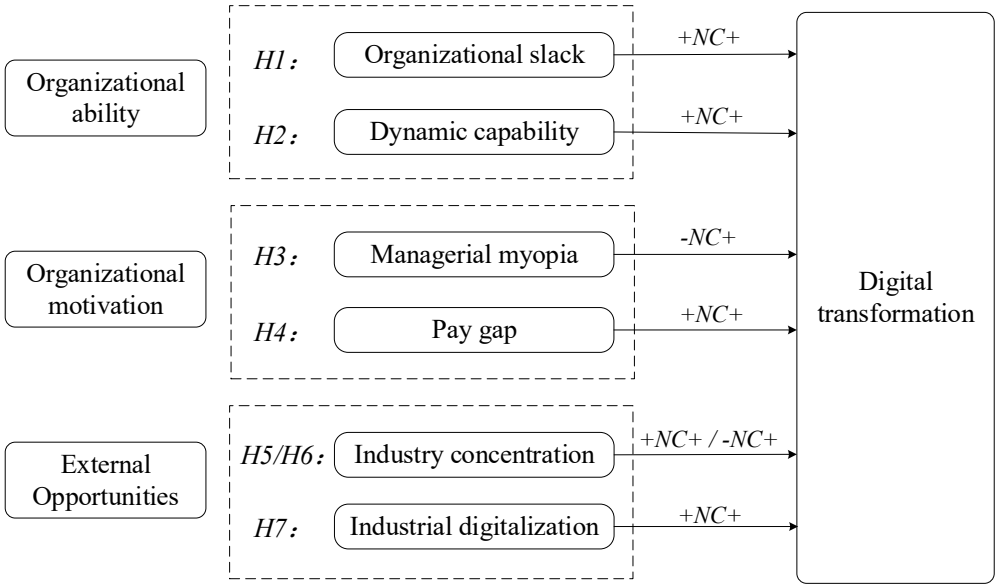


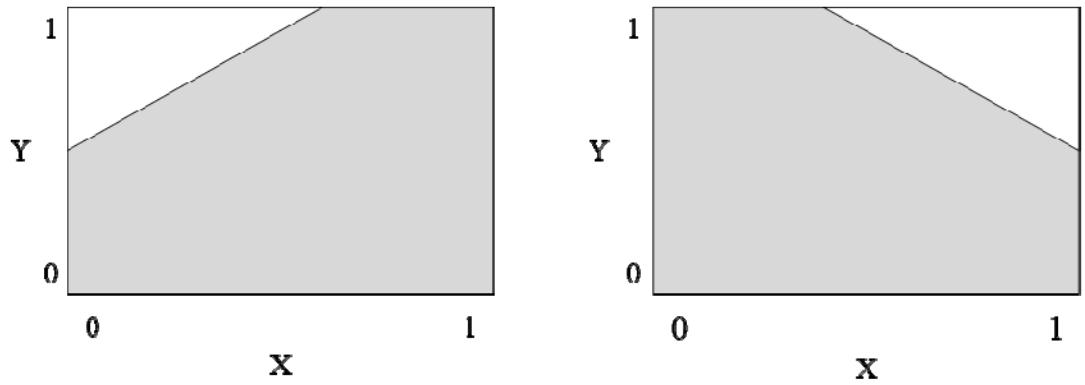
Figure 1. Research hypotheses. (Note: "NC" stands for necessary condition; "+NC+" means that high level of X is necessary for high level of Y; "−NC+" means that low level of X is necessary for high level of Y).

3. Empirical Analysis

3.1. Research Methodology

The necessary condition analysis (NCA) method is an emerging tool for necessity causality inference, dedicated to identifying necessary conditions that are decisive constraints on an outcome. Necessity causality proposes that "when a condition does not occur, the outcome does not occur" [24]. In detail, we can use the R package NCA to conduct the necessary condition analysis to identify whether each antecedent condition is necessary for the outcome (https://bookdown.org/ncabook/advanced_nca2/ accessed on 16 April 2024). The NCA has the following two advantages. First, the NCA can directly analyze reliable and valid original datasets. Second, the NCA can not only effectively identify the necessary conditions for the outcome but can also further determine to what extent these conditions are necessary for the outcome [24], i.e., the effect size of the necessary conditions, also known as the bottleneck level.

When applying the NCA method, the scatter plot of the data is first plotted in a Cartesian coordinate system to assess the impact of the necessity of a particular antecedent condition by identifying the ceiling region. Ceiling lines can be plotted by a ceiling envelope (CE) if X or Y are discrete variables or when the scatter boundaries are irregular, or by ceiling regression (CR) if X and Y are continuous or multilevel discrete variables. The location of the blank area above the ceiling line (Ceiling Zone) Indicates the direction of the necessity causation [24]. Suppose the Ceiling Zone is in the upper left corner. In that case, it indicates that high levels of X are necessary for high levels of Y, that is, a positive (+NC+) necessity relationship (as shown in Figure 2a). If the ceiling region is in the upper right corner, it indicates that low levels of X are necessary for high levels of Y, that is, a negative (−NC+) necessity relationship (as shown in Figure 2b). The ceiling area's size further reflects the necessity of causality's magnitude. The larger the area of the ceiling region, the larger the effect size, that is, the higher the level of necessity of X for Y. In the NCA, the necessity is subject to two criteria: the effect size d $\geq$ 0.1 [24] and passing a significance test ($p < 0.05$) [46].



High-level X is a necessary condition for high-level Y. Low-level X is a necessary condition for high-level Y.

(**a**) (**b**)

Figure 2. The positive and negative necessity relationship.

Based on the above characteristics, this study uses the NCA method to unfold the analysis of necessary conditions more intuitively using the original dataset. Given that the main variables in this study are all continuous variables, the CR method was chosen to plot the scatter plot between each antecedent condition and the results, and analyze the necessary conditions in kind and in degree. The necessary condition in kind refers to the process of recognizing the direction of the necessity effect and the magnitude of the effect of each antecedent condition, which is determined by the amount of effect of each antecedent condition, the *p*-value, and the corner position of the ceiling area in the scatterplot. The necessary condition in degree could further identify the minimum threshold level of each antecedent condition.

According to previous research hypotheses, only hypotheses H3 and H6 in this study correspond to the negative necessity relationships. That is, low levels of managerial myopia and industry concentration are necessary for high levels of digital transformation, so the identified ceiling region will be located in the upper right corner, while all the other hypotheses correspond to positive necessity relationships; therefore, the upper left corner is chosen as the ceiling region for the necessity analysis.

3.2. Data

Given the focus on digital transformation in large manufacturing companies, we selected the top 100 revenue-generating companies listed on the A-share main board from 2016 to 2020. These companies play a critical role in bridging upstream and downstream sectors, essential for promoting sustainable growth within industrial chains. Their substantial influence on technological innovation and ecosystem development positions them at the heart of this study. Additionally, a close examination of their digital transformation initiatives offers valuable, specific insights and strategic recommendations. These insights are vital for advancing these enterprises as leaders in national innovation, transformation, and contributing to economic progress.

The sample selection process was as follows. Only companies that consistently generated revenue over the five-year period were included. Companies with substantial missing data were excluded. Ultimately, this approach resulted in a balanced set of 335 data samples from 67 qualified manufacturing companies. The data include investment figures in hardware and software for digital transformation, sourced from the financial report notes in the WIND database (https://www.wind.com.cn/portal/zh/EDB/index.html accessed on 8 January 2024). Data concerning other variables were gathered from the China Stock Market and Accounting Research Database (CSMAR) (https://data.csmar.com/ accessed on 8 January 2024).

3.3. Variable Measurement

3.3.1. Outcome Variable

Digital transformation (*Digital*). The level of digital transformation is quantified through specific metrics, notably, (i) Digital Investment Intensity. Drawing on Ho et al. [47], we use the proportion of digital software and hardware investments to total assets to measure companies' real digital investment level. Digital software investment is the annual summary of the intangible assets related to digital transformation, and digital hardware investment is the annual summary of the fixed assets related to digital transformation. (ii) Digital Technology Adoption. This paper adopts the word frequency of keywords related to "digitalization", such as artificial intelligence, blockchain, cloud computing, and big data, in the text of annual reports to measure the level of digital technology application of companies. The keywords are captured in the "Management Discussion and Analysis" (MD&A) section of the annual reports of listed companies and the frequency of the relevant words in the MD&A section is counted to obtain the number of keywords for the underlying digital technology and the use of digital technology. Finally, the entropy weighting method is used to assign weights to four secondary indicators, namely, digital software investment, digital hardware investment, underlying digital technology, and digital technology utilization, to obtain the digital transformation level of companies.

3.3.2. Antecedent Condition

Organizational slack (*Slack*). This study, drawing on Bourgeois [48], employs a financial data-based measurement approach to assess organizational slack. Specifically, it calculates the average values of three key financial ratios: the current ratio, equity-to-debt ratio, and expense-to-income ratio. These metrics collectively provide a comprehensive measure of the organizational slack. Specifically, the current ratio (current assets divided by current liabilities) indicates a firm's capability to cover short-term obligations with its current assets. The equity-to-debt ratio (owner equity divided by total liabilities) assesses a firm's long-term solvency. The expense-to-income ratio (selling and administrative expenses divided by operating income) reflects the degree of financial cushion or slack an organization has.

Dynamic capability (*Dynamic*). This study comprehensively measures the dynamic capability in three dimensions: absorptive capacity, adaptive capacity, and innovative capacity [33]. The absorptive capacity is measured by the intensity of the enterprise's R&D expenditures, that is, the proportion of R&D expenditures to operating revenues. The adaptive capacity is measured by the coefficients of variation of the company's intensity of R&D expenditure, capital expenditure, and advertising expenditure to reflect the flexibility of the enterprise's resources. To ensure that the value of the coefficient of variation is consistent with the direction of the adaptive capacity, this study takes a negative value for the coefficient of variation. The innovation capacity combines the standardized intensity of R&D expenditures with the proportion of technical staff to create an aggregate index of innovation success. These three dimensions were standardized and aggregated to form a comprehensive dynamic capability index, with higher scores denoting a superior adaptability and innovation potential.

Managerial myopia (*Myopia*). We used the word frequency ratio of keywords related to "myopia" in MD&A to portray it [34]. The specific calculations are as follows: through text analysis and Word2Vec machine learning to obtain the seed word set reflecting "managerial myopia" in MD&A, and from the internal validity and structural validity of the index validity test, we obtained 43 "managerial myopia" words, and then calculated the frequency ratio of the words related to "managerial myopia" in the MD&A section. Finally, for convenience, we multiplied the value by 100; the larger the indicator, the more short-sighted the managers.

Pay gap (*Gap*). This paper defines a pay gap as the ratio of the average management pay to the average employee pay [49], where the average management pay is the ratio of the total annual pay of directors, supervisors, and executives to the size of the management. The size of the management is determined by the sum of the number of

directors, supervisors, and executives minus the "number of independent directors" and the "number of unappointed directors". The management size is calculated by subtracting the number of independent directors from the total number of directors, supervisors, and executives, and the number of directors, supervisors, or executives not receiving remuneration. Equity payments are not included in the compensation in this study because the coverage and payment ratio of equity payments in Chinese firms are small. Similarly, the average compensation of employees is equal to the change in the "total compensation payable to employees" plus the "cash paid to and for employees" minus the "total annual remuneration of directors, supervisors, and executives" and then divided by the number of employees.

Industry concentration (*Concentration*). This study adopts the Herfindahl index to measure the industry concentration by referring to Haushalter et al. [42]. The Herfindahl index is calculated as the sum of the squares of the market shares of each company in the industry as follows: $Concentration = \sum_{t=1}^{n}(Xi/X)^2, X = \sum_{t=1}^{n} Xi$, where Xi is the annual revenue from the main business of company i in the industry, and n is the number of companies in the industry. The larger the indicator, the higher the industry concentration and the stronger the market monopoly.

Industrial digitalization (*Industry*). According to Lay et al. [50], this study adopts the total consumption coefficient in the input–output method to measure the degree of digitalization of various manufacturing industries to reflect the level of development of the digital economy in various industries. Because the complete consumption coefficient not only links the direct consumption aspect of the manufacturing industry to the digital economy-related industries but also contains the amount of value that each digital economy industry puts into each manufacturing industry indirectly, this study adopts the complete consumption coefficient to calculate the degree of digitalization of the manufacturing industry. The calculation formula is $Industry = a_{dj} + \sum_{m=1}^{N} a_{dm}a_{mj} + \sum_{n=1}^{N}\sum_{m=1}^{N} a_{dn}a_{nm}a_{mj} + \cdots$, where the first term on the right side of the equation indicates the direct consumption of the manufacturing industry d to the digital economy j, the second term indicates the first round of indirect consumption of the manufacturing industry d to the digital economy j through the sector m. The third term indicates the second round of the indirect consumption of the manufacturing industry d to the digital economy j through the manufacturing industry m and sector n, and so on.

Table 1 reports the descriptive statistics for the six antecedent conditions and the outcome variables.

Table 1. Results of descriptive statistics.

Variable	Mean	Min	Max	S.D.
Slack	0.6928	0.2043	2.6117	0.3762
Dynamic	0.0180	−0.4714	0.5840	0.2247
Myopia	0.1000	0	0.0061	0.0009
Gap	8.1909	0.8807	22.6849	6.3766
Concentration	0.1324	0.0293	0.6588	0.0964
Industry	0.3136	0.0398	0.8578	0.2886
Digital	0.0138	0.0002	0.1011	0.0185

4. Data Analysis and Discussion

4.1. Necessary Conditions in Kind Analysis

The necessary condition in kind refers to the process of recognizing the direction of the necessity influence and magnitude of the effect of each condition [24]. Because the variables involved in this study were continuous and the sample size was large, resulting in more outliers, this study used ceiling regression (CR) to plot a scatterplot of the relationship between each antecedent condition and digital transformation, and the effect size (d), significance (p-value), precision, and other parameter values of each antecedent condition were calculated for the subsequent evaluation (see Table 2).

Table 2. Results of necessary conditions analysis.

Conditions	Effect Size (d)	*p*-Value	Precision	Necessary	Range	Order
Slack	0.103 *	0.081	98.2%	No	low	5
Dynamic	0.340 ***	0.000	97.6%	Yes	large	3
Myopia	0.607 **	0.021	97.3%	Yes	very large	1
Gap	0.028	0.926	99.7%	No	/	/
Concentration	0.023	0.573	97.9%	No	/	/
	0.584 **	0.017	97.0%	Yes	very large	2
Industry	0.333 ***	0.000	97.6%	Yes	large	4

Note: (1) *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. (2) In the "Concentration" condition, the first row is the result of the parameter identifying the upper left ceiling area, which detects a positive (+NC+) necessity relationship, and the second row is the result of the parameter identifying the upper right ceiling area, which detects a negative (−NC+) necessity relationship. (3) The value range of effect size (d) is [0, 1], $0 < d < 0.1$ means "low effect", $0.1 \leq d < 0.3$ means "medium effect", $0.3 \leq d < 0.5$ means "large effect", $d \geq 0.5$ means "very large effect". (4) The upper bound envelope drawn using the CE technique strictly separates the blank areas and ensures that there are no observations in the upper bound area, so the upper bound accuracy is 100%. On the other hand, the CR-FDH is a straight trend line through the "nodes", so the upper bound envelope drawn using the CR technique contains a small number of observations in the upper bound region, so the upper bound accuracy is generally not 100%.

In the NCA, the necessary conditions need to fulfill two criteria: $d \geq 0.1$ [24], and a significant effect size ($p < 0.05$) [46]. Table 2 shows that the four antecedent conditions of dynamic capability, managerial myopia (negative), industry concentration (negative), and industrial digitalization are necessary for the digital transformation of manufacturing firms. Based on the classification criteria of the effect size proposed by Dul [24], this study ranks the degree of influence of the four necessary conditions: (i) very large effect: managerial myopia (negative) and industry concentration (negative); (ii) large effect: dynamic capability and industrial digitalization.

4.1.1. Organizational ability

Dynamic capabilities have a significant impact on digital transformation but not organizational slack. Figure 3 shows that the ceiling regions for both the organizational slack and dynamic capabilities are located in the upper left corner of the scatterplot. However, in combination with Table 2, it can be seen that only the effect size and *p*-value of the dynamic capability satisfy the necessity requirement, which suggests that a high level of dynamic capability is necessary for a high level of digital transformation. Digital transformation is accompanied by uncertainty, and dynamic capabilities are an important way to cope with environmental uncertainties. Firms with high dynamic capabilities can efficiently scan the market environment to identify potential opportunities and improve their fit with the external environment by flexibly adjusting their resource bases [51]. These results are consistent with the findings of Warner and Wäger [52], which were based on a case study of seven leading companies in traditional industries. The effect size of the organizational slack reaches the 0.1 threshold, but the *p*-value does not satisfy the significance requirement. Therefore, it cannot be recognized as a necessary condition for digital transformation. The reason for this result may be that excessive organizational slack tends to lead to a slow organizational response to market changes, which makes companies too comfortable with the status quo and means they miss the opportunity for strategic change [29]. In summary, Hypothesis 1 was not verified and Hypothesis 2 was verified.

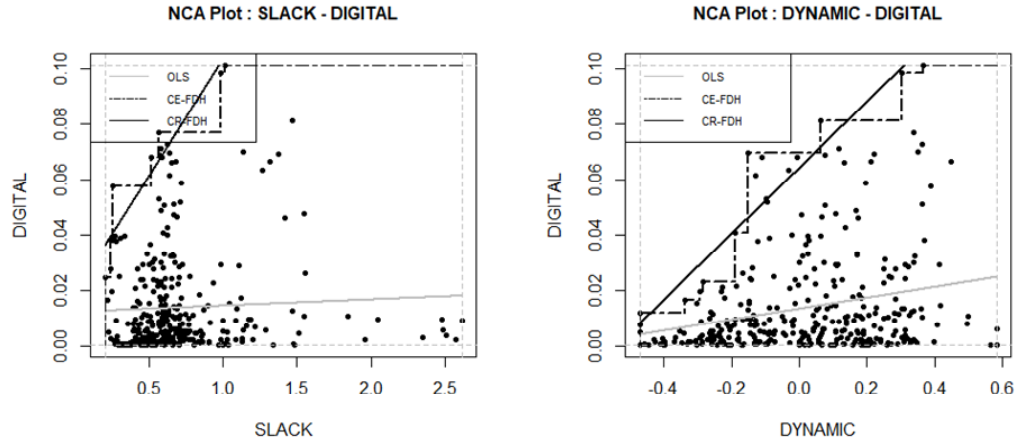


Figure 3. Scatterplot of ability conditions and digital transformation. (Note: The step function is the upper limit line of the CE−FDH, and the straight upper limit line is the upper limit line of the CR−FDH. The solid line through the middle of the data represents OLS regression for reference. Figures 4 and 5 are equally applicable).

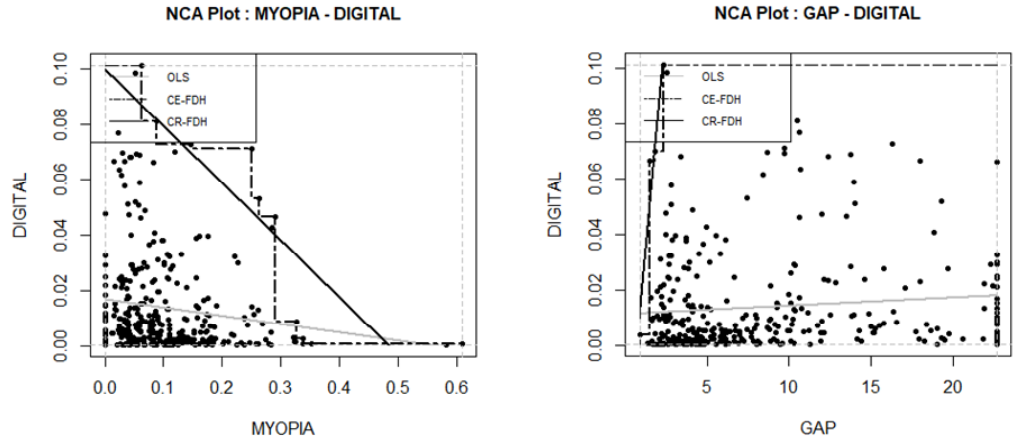


Figure 4. Scatterplot of motivation conditions and digital transformation.

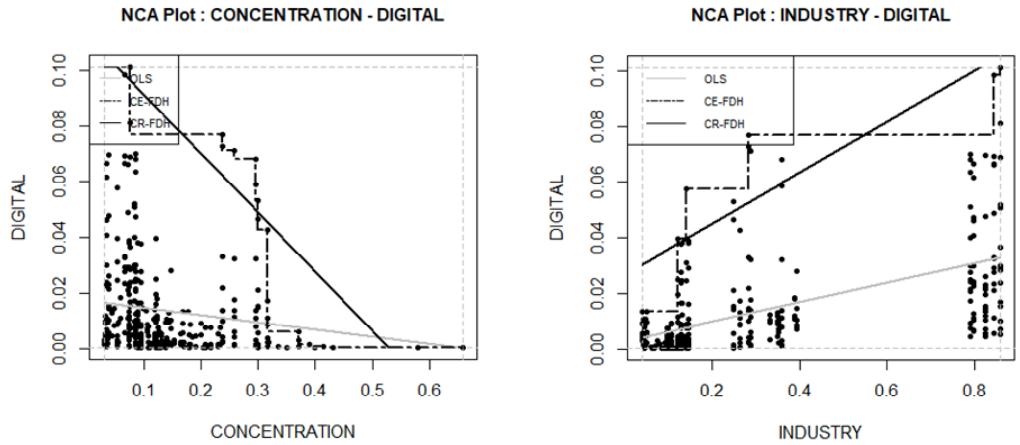


Figure 5. Scatterplot of opportunity conditions and digital transformation.

4.1.2. Organizational Motivation

Managerial myopia is necessary for digital transformation, but the pay gap fails to meet these criteria for a necessary condition. Figure 4 shows that the ceiling region for managerial myopia is located in the upper right corner of the scatterplot. The effect size is as high as 0.604 with a *p*-value of less than 0.05, suggesting that a low level of managerial myopia

is necessary for a very large effect on high levels of digital transformation. This finding is consistent with the results of regression analyses in related fields that find that short-sighted managers tend to delay digital investments to avoid the negative impacts of digital transformation, which ultimately hinders firms' digital transformation [53]. Although the ceiling region of the pay gap is in the upper left corner, the combination in Table 2 shows that its effect size does not reach the threshold requirement and does not pass the significance test, indicating that this condition is unnecessary for digital transformation. This is because, in the cultural context of China, which emphasizes collectivism and egalitarianism, the concept of "not suffering from scarcity, but suffering from unevenness" is deeply rooted in people's hearts. Excessive pay gaps imply inequitable distribution within an organization. As strategy implementers, employees have negative emotions because they feel unfairly treated, reducing their commitment to organizational change [49]. In conclusion, Hypothesis 3 was verified, and Hypothesis 4 was not verified.

4.1.3. External Opportunity

Both industry concentration and industrial digitalization are necessary for digital transformation. For industry concentration, the effect size and *p*-value of the ceiling region in the upper left corner failed to meet the necessary conditions. In contrast, the effect size of the ceiling region in the upper right corner was as high as 0.584, and the effect size was significant. This means that a low level of industry concentration has a very large necessary effect on high-level digital transformation. For industrial digitalization, the ceiling region is located in the upper left corner of the scatterplot (see Figure 5), and both the effect size and *p*-value satisfy the necessary condition requirements. This indicates that a high level of industrial digitalization is necessary for a high level of digital transformation, highlighting the importance of external industry factors for the digital transformation of manufacturing companies. Manufacturing companies usually lack technical experience and the ability to utilize knowledge flexibly. Thus, they must leverage broader ecological forces to complement their resources and capabilities to drive digital transformation [21]. Thus, the viewpoints of Siachou et al. [3] and Jacobides et al. [54] are confirmed. In summary, Hypothesis 5 was not verified, but Hypotheses 6 and 7 were both verified.

Table 3 presents the research hypotheses and findings of this paper.

Table 3. Hypotheses and results.

Hypotheses	Result
Hypothesis 1 (H1): *A high level of organizational slack is necessary for a high level of digital transformation in manufacturing companies.*	Not verified
Hypothesis 2 (H2): *A high level of dynamic capability is necessary to achieve a high level of digital transformation in manufacturing companies.*	Verified
Hypothesis 3 (H3): *Low-level managerial myopia is necessary for high-level digital transformation of manufacturing companies.*	Verified
Hypothesis 4 (H4): *A high-level pay gap is necessary for high-level digital transformation of manufacturing companies.*	Not verified
Hypothesis 5 (H5): *High-level industry concentration is necessary for the high-level digital transformation of manufacturing companies.*	Not verified
Hypothesis 6 (H6): *Low-level industry concentration is necessary for the high-level digital transformation of manufacturing companies.*	Verified
Hypothesis 7 (H7): *High-level industrial digitalization is necessary for high-level digital transformation of manufacturing companies.*	Verified

4.2. Necessary Conditions in Degree Analysis

The analysis of the necessary conditions in kind is to judge whether the presence or absence of X is necessary for the presence or absence of Y. In this part, we measure the magnitude of the necessity impact and the direction of the necessity relations. We categorize the level of digital transformation into three tiers: the initial level (transformation level

of 0–30%), the growth level (transformation level of 40–60%), and the promotion level (transformation level of 70–100%).

Table 4 shows the kinds of necessary conditions companies require and how their threshold levels change dynamically as the outcome increases. Therefore, manufacturing companies should target the conditions most likely to produce the expected outcomes based on their digital transformation goals at different stages and deploy organizational resource elements to meet their strategic development needs. Specifically, (i) at the initial stage of digital transformation, companies must consider multidimensional influencing factors comprehensively. Specifically, in terms of organizational abilities, attention should be paid to building the organization's dynamic capabilities; in terms of organizational motivation, the company should be wary of managerial myopia and set a reasonable pay gap; in terms of external opportunities, it should adapt to the external competitive environment and actively participate in the construction of the ecosystem. For example, to reach a 10% digital transformation level, the minimum threshold for dynamic capability was 1.7%, the maximum threshold for managerial myopia was 71.4%, and the maximum threshold for industry concentration was 71.9%. As the level of transformation continues to rise, the role of the pay gap and industrial digitalization gradually comes to the fore. (ii) During the growth stage of digital transformation, companies must focus on the role of organizational slack. To reach a digital transformation level of 40%, the dynamic capability, pay gap, and industrial digitalization level of enterprises must be increased to 25.8%, 2.1%, and 13.9%, respectively, and managerial myopia and industry concentration must be lowered to 47.3% and 49.2%, respectively. In addition, organizational slack, as an emerging bottleneck element at this stage, should also meet the minimum critical value of 2.2%. (iii) In the digital transformation promotion stage, enterprises should be fully aware of the importance of the three following factors: organizational ability, organizational motivation, and external opportunities. To achieve the highest level of digital transformation, industry concentration needs to drop to 3.8% and industrial digitalization needs to increase to 94.6%. In comparison, companies also need to achieve 31.9% organizational slack, 73.9% dynamic capability, a 6.4% pay gap, and overcome managerial myopia (NA).

Table 4. Bottleneck level analysis.

Grade	Level	Slack	Dynamic	Myopia	Gap	Concentration	Industry
Initial	0 (0.000)	NN	NN	79.4% (0.484)	NN	79.4% (0.529)	NN
	10% (0.010)	NN	1.7% (−0.453)	71.4% (0.435)	NN	71.9% (0.482)	NN
	20% (0.020)	NN	9.7% (−0.369)	63.4% (0.386)	0.6% (1.016)	64.3% (0.434)	NN
	30% (0.030)	NN	17.8% (−0.284)	55.3% (0.337)	1.3% (1.173)	56.7% (0.386)	0.4% (0.043)
Growth	40% (0.041)	2.2% (0.256)	25.8% (−0.199)	47.3% (0.288)	2.1% (1.330)	49.2% (0.339)	13.9% (0.153)
	50% (0.051)	7.1% (0.376)	33.8% (−0.115)	39.3% (0.239)	2.8% (1.486)	41.6% (0.291)	27.3% (0.263)
	60% (0.061)	12.1% (0.495)	41.8% (−0.030)	31.2% (0.190)	3.5% (1.643)	34.0% (0.244)	40.8% (0.373)
Promotion	70% (0.071)	17.0% (0.615)	49.8% (0.054)	23.3% (0.141)	4.2% (1.799)	26.5% (0.196)	54.2% (0.483)
	80% (0.081)	22.0% (0.734)	57.8% (0.139)	15.2% (0.093)	4.9% (1.956)	18.9% (0.148)	67.7% (0.593)
	90% (0.091)	27.0% (0.853)	65.9% (0.224)	7.2% (0.044)	5.6% (2.112)	11.4% (0.101)	81.1% (0.704)
	100% (0.101)	31.9% (0.973)	73.9% (0.308)	NA	6.4% (2.269)	3.8% (0.053)	94.6% (0.814)

Note: (1) NN (not necessary) means that for a specific level of Y, X is not necessary, that is, Y is not constrained by X; NA (not applicable) means not applicable. (2) Values in parentheses are the actual values of the conditions and results. For example, the lowest (0.000) and highest (0.101) digital transformation sample values correspond to the 0 and 100% levels in the bottleneck table, respectively.

5. Discussion

5.1. Theoretical Contribution

The main contributions of this study are as follows: First, we propose a comprehensive analytical framework that integrates multidimensional factors. Existing studies have mainly focused on exploring the relationship between organizational resources, digital investment, digital technology, policy opportunities, and other factors and digital transformation from a single theoretical perspective [21], but have neglected the combined role of firms' abilities, motivations, and external opportunities. Therefore, this study extends the AMO theory, which effectively predicts individual behavior at the organizational level. By integrating the multidimensional research perspectives of digital transformation, this study compensates for the shortcomings of previous studies that focus on discussing the relationship between a specific antecedent and the outcome from a single perspective, which can help companies strategically allocate resources according to the needs of digital transformation and avoid its blind convergence.

Second, this study introduced a research method that can identify the causal factors of necessity. Although numerous studies have explored the factors influencing digital transformation, in the face of the complex antecedents of digital transformation, how companies with limited resources can effectively allocate various resource elements has become a challenge in transformation practice. In this study, we identify four kinds of necessary conditions with different effect sizes, which can assist companies allocate their limited resources to the most important areas. By analyzing the degree of necessary conditions, we capture the order of the necessary conditions and their threshold sizes with an increase in the level of digital transformation, which can help companies understand the sequence of the necessary conditions in resource investment.

Third, we identify the key to the digital transformation of large manufacturing companies. Existing research primarily focuses on small and medium-sized enterprises (SMEs) [55], and specialized research on large companies with systemic importance and industry leadership remains insufficient. As an important pillar of the national economy, large manufacturing companies are key forces in promoting the digital and intelligent transformation of the manufacturing industry. However, digital transformation is like "turning an elephant" for these companies, and there are still many difficulties. In this regard, based on the sample data of the digital transformation of large manufacturing companies, this study not only identifies the key internal factors of their digital transformation but also further confirms the importance of external industry factors [3], which suggests that traditional industry companies actively integrate ecosystem forces in the process of transformation to maintain synergy and match with the competitive environment.

5.2. Practical Implications

The findings also provide practical insights into the digital transformation of manufacturing companies. First, top managers should adhere to the orientation of long-term management and be wary of the risks of managerial myopia. Since digital transformation is an ongoing process of renewal, managers must be prepared for a protracted effort in order to actively advance digital transformation. Second, organizations should enhance their dynamic capabilities to adapt to the complex competition environment. There is no one-size-fits-all approach, so organizations should cultivate their internal strengths and be prepared to adjust their digital transformation strategies at the right time. Third, the construction of a multi-party digital ecosystem is encouraged to promote resource sharing and cost sharing for each company to build their own sustainable competitive advantage. Companies in traditional industries often lack the necessary knowledge and skills. Therefore, it is crucial to cooperate with other companies in the digital ecosystem. Such synergistic sharing can help drive the digital transformation process and enhance market competitiveness.

5.3. Limitations and Future Research

This study has some limitations that need to be improved. First, necessity causal logic is used, which only identifies the conditions necessary for the success of digital transformation and not the conditions of sufficiency [24]. Subsequent studies can combine the logic of necessity and sufficiency and integrate an NCA with qualitative comparative analysis, structural equation modeling, multiple regression, and other research methods to draw richer conclusions. Second, this study does not fully develop a typical case analysis due to space limitations. Future research can conduct comparative studies and in-depth discussions around typical cases near the upper limit line because these cases cost the least amount of organizational resources but produce the highest expected results, and may be the most revealing cases from the perspective of efficiency [24,25].

6. Conclusions

Through an analysis of necessary conditions, this study explores the necessary conditions in kind and degree of organizational ability, organizational motivation, and external opportunities for the digital transformation of manufacturing companies. The main conclusions are as follows. First, the digital transformation of manufacturing companies must comprehensively consider the three factors of ability, motivation, and opportunity. Specifically, there are four necessary conditions, namely, dynamic capability, managerial myopia, industry concentration, and industrial digitalization. Second, each necessary condition has a different impact on the necessity for digital transformation. The specific degree of influence is as follows: (i) very large effect: managerial myopia (negative) and industry concentration (negative); (ii) large effect: dynamic capability and industrial digitalization. Organizational slack and pay gaps have no necessary effect on digital transformation in manufacturing firms. Third, the requirements for different outcome levels and their thresholds are different. Manufacturing companies ought to align their objectives with the various phases of digital transformation, strategically directing their resources and efforts towards prioritizing and fulfilling the conditions that have the highest likelihood of achieving the expected results.

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