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Article

# Digital Transformation and Substantive Innovation in High-Tech SMEs: Evidence from China


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**Abstract:** Due to digital transformation, small and medium-sized enterprises (SMEs) in the high-tech industry confront both possibilities and constraints. These businesses typically faced constraints regarding both personnel and financial resources. Considering the moderating influence of equitable incentives and government subsidies, this study investigated how substantive innovation and digital transformation were related to the SMEs. The study's findings, based on panel data from Chinese companies listed on the Science and Technology Innovation Board from 2019 to 2022, showed that digital transformation greatly improved substantive innovation in addition to fostering strategic innovation. Government subsidies improved the inventive effect of digitization and positively mitigated this relationship by alleviating financial stress. Conversely, equity incentives acted as alternatives to digital transformation and had a moderating effect. Our findings contributed to the corpus of knowledge by clarifying how digitalization drove different forms of creativity in resource-constrained enterprises. Furthermore, for managers and policymakers looking to boost innovation outputs in competitive and dynamic marketplaces and speed up the digitization of SMEs, this study had practical consequences.



**Keywords:** Digital Transformation, Substantive Innovation, High-Tech SMEs, Government Subsidies, Equity Incentives

## 1. Introduction

The United States' unilateralist practices of imposing technological restrictions and blockades on China, coupled with the ongoing escalation of trade disputes between China and the United States in recent years, have made it essential for our nation to enhance the capacity of businesses to innovate in core technologies independently. In order to address foreign "chokepoint" issues, the Report of the 20th National Congress of the Communist Party of China proposes "accelerating the implementation of the innovation-driven development strategy" and "stepping up efforts to advance scientific and technological self-reliance." It also emphasizes the necessity of "supporting the development of small, medium, and micro enterprises" as well as "supporting the development of specialized, refined, distinctive, and innovative enterprises." As the driving force behind technological innovation, scientific and technological small and medium-sized enterprises (SMEs) blend the high-tech content and inventiveness of technology-based enterprises with the adaptability and quick response times of small and medium-sized businesses, making them dynamic and extremely promising subjects for innovation. China's economic growth and the execution of the innovation-oriented development strategy have been directly impacted by its independent inventiveness.

Furthermore, innovation is the inevitable path for organizations to acquire a competitive advantage and realize long-term sustainable development. Our nation introduced the Mass Entrepreneurship and Innovation Policy in 2014, which aims to promote entrepreneurship and innovation aggressively. The policy highlights the critical role that these SMEs play in fostering innovation and development, as well as economic transformation and upgrade. Scientific and technological SMEs continue to engage in high-quality substantive innovation activities in an effort to strengthen their autonomous innovation capabilities as the development of innovation-driven strategies continues. In addition to being a crucial means for scientific and technological SMEs to acquire new technologies, expertise, and experience, substantive innovation is also a prerequisite for businesses to gain market share and a competitive advantage. However, some companies have resorted to strategic innovation activities with lower costs and more manageable risks in order to receive innovation-related policy incentives. However, this type of subpar innovation behavior does not essentially address the issue that SMEs founded on science and technology are not sufficiently capable of independent innovation.

Moreover, SMEs founded on science and technology have consistently prioritized innovation as the primary driver of development. As digital technology continues to evolve and gain popularity, scientific and technological SMEs, as innovators, actively introduce new digital concepts and related technologies, and integrate digitalization with big data, cloud computing, artificial intelligence, the Internet of Things, and smart gadgets. In order to create more intelligent, safe, and efficient business operations and product services, blockchain technology is integrated with digital security. This, in turn, accelerates the industrial structure improvement and economic system optimization through the digital upgrading of businesses. Some academics have noted that there is ambiguity in the relationship between enterprise innovation and digitization. This may even widen the "digital divide" due to industry and enterprise differences, which hinders meaningful innovation by businesses. What effects does the level of enterprise digitalization have on the creative endeavors of scientific and technological SMEs? Can it encourage significant innovation in scientific and technological SMEs? And how might one strengthen their capacity for autonomous, self-driven innovation? The corpus of existing literature has not been thoroughly discussed.

Additionally, the issue of inadequate funding and brain drain is a concern for the digitization of scientific and technological SMEs. Just 7% of research and technology-based SMEs have successfully upgraded to digital technology. Can government subsidies in this situation effectively encourage businesses to upgrade to digital technology? How might the function of equity incentives affect talents?

Based on the aforementioned practical needs and theoretical inadequacies, this study has both significant theoretical value and practical relevance. First off, this work contributes to the empirical research on the digitization and substantive innovation of scientific and technological SMEs at the theoretical level. Few studies examine how digitalization affects substantive innovation from the viewpoint of scientific and technological SMEs. In terms of GDP and employment rates, SMEs with a science and technology foundation make a substantial contribution to the national economy. Thus, this paper closes this gap, expands the scope and content of research on the high-quality development of scientific and technological SMEs. We also provide theoretical support and policy recommendations for promoting the sustainable growth of these SMEs, which also helps illuminate the internal relationship and interaction mechanism between digitalization and substantive innovation in scientific and technological SMEs.

Besides, from a practical perspective, several important considerations are worth noting. First, accelerate the digitization of research and technology-dependent SMEs. Researching how digitalization impacts the high-quality development of scientific and technological SMEs can enhance the effectiveness and caliber of corporate digitalization progress. Second, support SMEs' expansion and technological and scientific innovation. This encourages the growth of the entire innovation ecosystem and increases the vitality of innovation by supporting the innovation of scientific and technological SMEs. Third, assist in the formulation of public policy. In order to develop appropriate policies and measures that support corporate digitalization, the government can benefit from examining the impact of digitalization on the development of scientific and technological SMEs. Fourth, increase the effectiveness of resource allocation and technical staff development. Allocating resources as effectively as possible can improve production efficiency. Technicians who receive ongoing training and development are better able to maintain their competitiveness and adapt to changing market conditions. Lastly, encourage the growth of the digital economy. SMEs must be digitalized based on research and technology to support the expansion of the digital economy. Thus, it is essential to carefully consider how digitalization affects and moderates the substantive innovation of scientific and technological SMEs.

This study utilizes 571 listed companies on the Science and Technology Innovation Board (STIB) from 2019 to 2022 as samples to methodically examine the aforementioned content. Its main objective is to investigate how the degree of digitalization affects substantive innovation in technology SMEs (SMEs in the tech sector).

This study primarily uses two fundamental research approaches. The first is the literature analysis method on the research status and related concepts. This section clarifies key concepts, including scientific and technological SMEs, enterprise digitalization, and substantive innovation through a comprehensive analysis of domestic and international literature. Considering the findings of other studies, this article focuses on analyzing the opportunities and challenges faced by scientific and technological SMEs in the digital era. The literature review focuses on the effects of enterprise digitalization on the substantive innovation of scientific and technological SMEs.

The second approach is panel data regression analysis. This paper mainly makes use of databases like the China Patent Database, the CSMAR database, and the China Research Data Service Platform (CNRDS). Significant innovation is the dependent variable, and the degree of digitalization of businesses is the independent variable. Panel data regression analysis is used, taking into account the two most crucial factors for scientific and technological SMEs: talent and capital. The degree of equity incentives and government subsidies is chosen as the moderating factor, and a regression analysis is performed on the sample panel data using statistical software.

## 2. Literature Review

### *2.1 Corporate Digitalization*

#### *2.1.1 The Connotation of Corporate Digitalization*

The notion of corporate digitalization was first proposed by the International Business Machines Corporation (IBM). Berman (2012) introduces the concept of corporate digitalization based on digital technological innovation, but academics have not provided a precise definition of this notion. However, scholars have reached a crucial consensus regarding certain core elements. O'Hea (2011) believes that the course of corporate digital transformation involves organizations improving business value by enhancing their digital capabilities and developing proprietary processes to further develop these capabilities. Singh and Hess (2017) define corporate digitalization as the application of digital technologies by enterprises to improve operational efficiency and create an entirely new business model. Vial (2019) proposes that corporate digitalization refers to the change in the value creation path of enterprises through the integration of information, communication, technology, and other aspects at the strategic level.

Additionally, according to the different key definitions of corporate digitalization provided by various scholars, the core of corporate digitalization generally refers to the process of transforming an enterprise's business operations by deeply integrating digital technology with management and operations, and upgrading and transforming the original business processes of the enterprise.

#### *2.1.2 Measurement Methods for Corporate Digitalization Level*

Regarding the measurement methods for corporate digitalization level, a variety of different approaches have emerged in current research. The existing literature has formed various ways to measure the level of corporate digitalization. The first popular approach is to consult the annual reports of listed firms as a basis and measure according to the company's financial data. Anitesh Bharadwaj (2000) builds a measurement system based on indicators such as information technology infrastructure investment, the number and skill level of technical personnel, and the proportion of IT budget. Warner and Wäger (2019) propose that the measurement of digital transformation should focus on the strategic update process.

Furthermore, the dynamic capability perspective, as proposed by Teece, Pisano, and Shuen (1997), provides a core framework for digital measurement, emphasizing the need to evaluate enterprise digitalization across three stages: perceiving opportunities, integrating resources, and reconstructing capabilities. Gökalp and Martinez (2022) constructed a digital transformation maturity model covering seven dimensions: strategic preparation, technical infrastructure, organizational structure and culture, data management, capability development, business process optimization, and outcome impact. Davenport (1993) advocates for precise measurement of the actual effectiveness of digitalization by evaluating indicators such as the penetration rate of big data analysis in decision optimization.

The second common method is to collect corporate-related data through surveys. Halpern et al. (2021) constructed a survey on digital technology for managers of 94 airports worldwide. Pettersson, Siljebo, Ferry, and Wolming (2023) develop and validate the Digital Transformation Scale (DTS) questionnaire, identifying concepts such as digitalization and digital transformation as hierarchical aspects of societal change. Bertschek, Ohnemus, and Viete (2018) developed a special ICT survey questionnaire and collected ICT usage data from German manufacturing and service companies through computer-assisted telephone interviews (CATI). Kaiser and Gadár (2023) designed an online questionnaire with a sample of 2,520 respondents to measure the digital readiness of the group from dimensions such as digital literacy, device usage preferences, and technological attitudes.

Additionally, scholars currently adopt text analysis primarily to construct a dictionary of corporate digitalization levels by mining and analyzing keywords in annual reports pertaining to corporate digitalization, thereby forming evaluation indicators for corporate digitalization levels. Wamba, Akter, Edwards et al. (2015) construct a digital dictionary based on the digital technology classification framework, containing 12 core terms such as cloud computing, big data, and artificial intelligence. Warner and Wäger (2019) have developed a digital transformation dictionary for manufacturing enterprises, covering three dimensions: technology application, process reconstruction, and organizational change. Feroz and Chiravuri ( 2021) conduct text mining on sustainability reports from over 300 multinational corporations, identifying six major digital themes, such as digital supply chain, intelligent customer service, and data security governance.

### *2.2 Substantive Innovation*

#### *2.2.1 Connotation of Substantive Innovation*

Schumpeter (1912) suggests that the essence of innovation is a process of quantitative accumulation and reorganization of various production factors. Varadarajan (2018) categorizes corporate innovation into substantive innovation and strategic innovation based on the innovative behaviors implemented. Strategic innovation refers to low-cost, low-quality innovative behaviors conducted by enterprises to demonstrate a positive innovative attitude to the outside world, or to obtain government financial subsidies and financing assistance, and to meet other corporate objectives (Drejer, 2006). Substantive innovation refers to high-quality innovative practices that aim to promote technological innovation, achieve corporate technological progress, and enable the use of products in the market to gain competitive advantages for the enterprise (Granados, Ayala, and Ramos-Mejia, 2024).

### *2.2.2 Methods for Measuring Substantive Innovation*

In the early stages, some scholars quantify substantial innovation through the objective features of patents, with Trajtenberg (1990) combining patent quantity and citation frequency to measure the scale of innovation and technological value. Then, Griliches (1998) uses citation frequency and breadth to address the issue that patent quantity cannot reflect quality. Subsequently, Hall et al. (2000) construct a two-dimensional framework, "patent family size-citation strength", forming a progressive measurement system. Besides, Khan (2015) constructs a "technological deepening" indicator based on the technical description of the patent text, combining the three-year average annual growth rate of patents in the target technology category with keyword concentration. Finally, Van Ark, Hao et al. (2009) identify intangible inputs such as R&D, intellectual property, and organizational innovation through mining corporate annual reports and financial texts, and construct an "intangible capital-innovation output-productivity" correlation model.

### *2.3 The Impact of Corporate Digitalization on Substantial Innovation*

In recent years, corporate digitalization has become a growing concern in the academic community, and academia has confirmed the necessity of corporate digitalization (Fernandez-Vidal, Gonzalez, Gasco, and Llopis, 2022). Lyytinen, Yoo, and Boland (2016) note that through the comprehensive integration and application of digital technology, enterprises can streamline their production processes and reduce costs. The use of digital technology can promote collaboration between internal departments, improve internal management, and organizational governance within enterprises (Li, Zhu, Wei, and Yang, 2022). Furthermore, it can win a larger share in the market competition and improve its competitiveness and market position (Tohãnean, Buzatu, Baba, and Georgescu, 2020).

On the other hand, the process of corporate digitalization may also bring a series of challenges and negative impacts. Karhade and Dong (2021) found that digitalization does not always promote corporate innovation activities, but rather presents an inverted U-shaped relationship. Moreover, digital transformation may not only fail to bring digital technology dividends but can even lead to a digital divide in substantial innovation (Švarc, Lažnjak, and Dabić, 2021).

For the digitalization of scientific and technological SMEs, Cha et al. (2015) suggest that information technology optimization should serve as the foundation for the digital transformation process, with a focus on the digitalization of human resources and organizational capabilities. Banerjee and Ma (2012) point out that the difficulties and challenges faced by corporate digitalization are mainly limited by their own development conditions. Currently, for scientific and technological SMEs, insufficient funds for digitalization and a lack of relevant talent in the field of digital technology have become the main issues that need to be addressed (Chandavarkar and Nethravathi, 2023).

### *2.4 Literature Review*

The review of relevant literature reveals that domestic and international research on corporate digitalization and substantial innovation is mainly concentrated on its connotation, scope definition, technical support, indicators, application level, and impact significance. At the same time, current research mainly focuses on large enterprises or multinational corporations, while there remains a lack of research on the important component of scientific and technological SMEs. It is particularly noteworthy that the issues of capital and talent faced by scientific and technological SMEs in the process of digitalization and substantial innovation have been largely overlooked in specific research. This paper thoroughly examines the impact and role of digital transformation on the high-substantial innovation of China's scientific and technological SMEs, clarifying the underlying mechanisms. It can help promote the deepening of reforms in scientific and technological SMEs, effectively boost their innovative development, and also contribute to the improvement of the government's policy support system for these SMEs. It has significant practical implications for the long-term growth of SMEs focused on research and technology, as well as enhancing the government's policy framework for these businesses.

## 3. Theoretical Foundation and Research Hypothesis

### *3.1 Theoretical Foundation*

#### *3.1.1. Innovation Theory*

Schumpeter first introduced the notion of innovation theory in his work, Economic Development Theory. Within this theoretical framework, entrepreneurs are regarded as the core of capitalism, whose responsibility is not only to achieve this innovation but also to lead the direction of economic development. With the evolution and development of innovation theory, Christensen further proposed the concept of disruptive innovation in 1997. Chesbrough first systematically elaborated on the concept of open innovation in 2003, advocating that enterprises should not only rely on internal research and development but also share expertise, technological capabilities, and resources with outside partners to expedite innovation procedures. With the continuous changes in market demand, enterprises can stay competitive and adjust to the constantly shifting market environment with the aid of innovation (Hitt, Keats, and DeMarie, 1998).

#### *3.1.2 Dynamic Capabilities*

The dynamic capabilities theory was proposed by the American scholar David Teece in 1992. He points out that the traditional resource-based view emphasizes the importance of crucial competencies and resources to a company's ability to compete. However, this viewpoint overlooks how businesses modify and realign their assets and competencies in response to a dynamic environment. Dynamic theory states that a company's current static resources provide less of its competitive advantage, including money, equipment, and patents, and more from its dynamic capabilities, or the ability to quickly learn, adapt, and innovate. They include the company's ability to learn rapidly, adapt, and innovate. Firms utilize IT, organizational, and management resources to continuously drive innovation and change within the organization, cultivate unique capabilities, and thus maintain a long-term competitive advantage (Teece, 2010).

#### *3.1.3 Signal Transmission Theory*

Michael Spence initially proposed the signal transmission theory in the 1970s. The information transmission theory mainly discusses the problem of information asymmetry among various economic entities within the market environment. The side with the information advantage can release signals to the party with less information. Through this information transmission method, it can alleviate the problem of high-quality producers being eliminated by low-quality producers due to information asymmetry (Carlson, 1974). Enterprises can convey positive information about digital transformation and innovation to the government. In turn, the government implements relevant incentive support policies by reviewing and certifying enterprises that actively implement innovative activities, helping enterprises carry out substantial innovative initiatives.

*3.2 Research Hypothesis*

1. The Impact of Corporate Digitalization on Enterprise Innovation Behavior.

Businesses will constantly acquire, integrate, and reaffirm administrative organizational technologies, resources, and functional capabilities both internally and externally, in accordance with Teece's thesis of dynamic capabilities. Under the continuous growth of digital platforms driven by the digital economy, technological changes not only help enterprises better integrate information and build a framework for digital dynamic capabilities through digital technology, but they must also adapt their talents and resources in a dynamic environment. Corporate digitalization is transforming enterprises' business models and operational modes through digital technology. The digitalization of scientific and technological SMEs is an inevitable consequence of the current market environment, which presents both opportunities and challenges for these enterprises (Thrassou, Uzunboylu, Vrontis, and Christofi, 2020).

On one hand, innovation in digital technology contributes to increasing corporate governance and internal management effectiveness, enhancing the effectiveness of operations and SMEs' ability to make decisions, amplifying the core capabilities of enterprises, and gaining competitive advantages. Enterprise digitalization can also lower the cost of innovation for scientific and technological SMEs (Opoku, Okafor, Williams, Aribigbola, and Olaleye, 2024). Scientific and technological SMEs, in accordance with their own strategic orientation, undertake high-quality, substantial innovation activities, drive internal innovation through enterprise digitalization, and thereby support product transformation and upgrading.

On the other hand, scientific and technological SMEs may also be unwilling or unable to carry out effective substantial innovation due to their own reasons, and may instead opt for strategic innovation. For scientific and technological SMEs, both digitalization and substantial innovation activities are long-term, high-investment, high-yield, and high-risk endeavors (Ramdani, Raja, and Kayumova, 2022). In order to comply with government regulations and secure government subsidies, strategic innovation typically involves pursuing innovation quantity (Li, Ren, Zhang, Li, and Duan, 2020).

The following theories are put out in light of the analysis above:

H1: There are variations in the effects of corporate digitalization on substantial innovation and strategic innovation.

H1a: Corporate digitalization will promote substantial innovation in enterprises.

H1b: Corporate digitalization will promote strategic innovation in enterprises.

2. The Regulatory Role of Government Subsidies

The Ministry of Industry and Information Technology has released the "Guidelines for the Digital Transformation of Small and Medium Enterprises" to accelerate digital empowerment and reduce barriers to digitalization, thereby strengthening policy support for SMEs. SMEs find it extremely challenging to improve their digital capabilities solely through their own research and development expenditures due to their limited resources. Furthermore, scientific and technological SMEs are less inclined to take part in sustained, significant innovation initiatives. The signal transmission theory suggests that government subsidies can focus and transmit signals, making them able to support the digital transformation of SMEs that rely on technology. Consequently, this can pique their interest in digital modernization and encourage the effectiveness of significant innovation outputs using digital technologies (Wang, 2020). Nevertheless, there are instances in which businesses fall short of the government's innovation requirements even after obtaining government subsidies. As a result, some enterprises choose to shift from substantive innovation to strategic innovation, thus maximizing their own interests and continuing to secure government subsidies.

The following theories are put out in light of the analysis above:

H2: Government subsidies have a beneficial moderating effect on the relationship between firm digitalization and both substantive and strategic innovation.

3. The Regulatory Role of Equity Incentive Intensity

Due to their relatively small scale, the SMEs exhibit characteristics of high growth, high innovation, and high human resource demand. Talents with creativity and forward-thinking are of strategic significance for the long-term development of enterprises. In the environment of SMEs, talents have a greater impact (Yu and Zhang, 2021). When SMEs conduct digital transformation activities, they not only need professional talents to provide suitable paths for digital transformation and upgrade, but also require them to implement specific measures for empowering digital technology (Krishnanand Scullion, 2017). However, some scholars also point out that according to the social comparison theory, under an equity incentive system, this may lead to conflicts within the team and even result in the loss of talent, inhibiting the enterprise's innovative behavior.

According to this paper, companies should continue to implement long-term equity incentive measures from a sustained perspective to maintain an advantage in the face of increasingly fierce market competition. These measures should align employees' personal interests with the long-term development of the company, match the lengthy cycle needed for significant innovation and digital transformation, and assist the company in retaining its core talent.

The following hypothesis is put out in light of the analysis above:

H3: The influence of enterprise digitalization on significant and strategic innovation is positively regulated by the degree of equity incentives.

## 4. Research Design

### *4.1 Sample Selection and Data Sources*

SMEs could be easily listed in the STIB. These businesses could be financed more easily thanks to the STAR Market's flexible registration system and investor protection mechanism, which contributed to a deeper comprehension of the relationship between SMEs and the capital market in the context of scientific and technological innovation. Therefore, this article selected science and technology enterprises listed on the STAR Market as of December 31, 2022, specifically from 2019 to 2022, as the research object and constructed panel data. Finally, this process yielded 1,244 sample observations from 572 listed companies, with a data structure of unbalanced panel data. The sample data came from the CSMAR database, the China News Information Network, and the Incopat Global Patent Database.

*4.2 Variable Measurement*

*4.2.1 Core Explanatory Variable*

Corporate Digitalization Level (Dig). In order to ascertain the level of digitization of listed companies, this article ultimately decided to employ text analysis to statistically quantify the frequency of digital-related terminology in the companies' annual reports. The terms used in the annual reports represented the company's operating conditions during the previous year as well as its strategic direction planning. Therefore, this method was relatively objective and could provide a more comprehensive measure of the corporate digitalization level. This study measures the degree of corporate digitalization using word frequency statistics of keywords related to corporate digitalization in the annual reports; the reference keywords are displayed in Table 1 of the appendix. For ease of expression, the index was multiplied by 100. The micro-level degree of corporate digitalization was then calculated by dividing the total word frequency related to corporate digitalization by the length of the paragraphs in the annual reports.

*4.2.2 The Explained Variable*

Substantial innovation (Patenti) and strategic innovation (Patentud). This study measured an organization's substantial innovation activity by counting the number of invention patent applications it submitted in the current year. The organization's strategic innovation behavior was gauged by the quantity of non-invention patent filings (such as utility model and design patents) in the current year. Because some companies in the sample had no invention patent applications in some years, this paper adopts Li Wenjing's methodology by adding 1 to the number of invention patent applications in the current year of the enterprise and using the natural logarithm as a proxy indicator for the enterprise's substantial innovation behavior besides adding 1 to the total number of non-invention patent applications filed by the company that year and using the natural logarithm as a proxy indicator for the enterprise's strategic innovation behavior.

*4.2.3 Adjusting Variables*

Government Subsidy (Sub). The government subsidy amount was deducted from the operating income of the government subsidy in the yearly reports of the listed enterprises. The government subsidy was calculated as the total amount of money the company had received in the current year.

Equity Incentive Intensity (Emp). In general, there were two ways to quantify the strength of equity incentives: the total number of awards or the number of new grants awarded annually.

The ratio of all outstanding shares to the number of restricted shares or stock options awarded for equity incentives was used in this article.

*4.3 Model Framework Construction*

Based on the hypotheses proposed in the preceding text, this article constructed the following research model in combination with the selected variables.

$$Patenti = \alpha_0 + \alpha_1 Dig_{it} + \alpha_2 \sum control_{it} + \varepsilon_{it}$$
$$Patentud = \beta_0 + \beta_1 Dig_{it} + \beta_2 \sum control_{it} + \varepsilon_{it}$$
$$Patenti = \alpha_0 + \alpha_1 Dig_{it} + \alpha_2 Sub_{it} + \alpha_3 Dig_{it} * Sub_{it} + \alpha_4 \sum control_{it} + \varepsilon_{it}$$
$$Patentud = \beta_0 + \beta_1 Dig_{it} + \beta_2 Sub_{it} + \beta_3 Dig_{it} * Sub_{it} + \beta_4 \sum control_{it} + \varepsilon_{it} \quad (4)$$
$$Patenti = \alpha_0 + \alpha_1 Dig_{it} + \alpha_2 Emp_{it} + \alpha_3 Dig_{it} * Emp_{it} + \alpha_4 \sum control_{it} + \varepsilon_{it}$$
$$Patentud = \beta_0 + \beta_1 Dig_{it} + \beta_2 Emp_{it} + \beta_3 Dig_{it} * Emp_{it} + \beta_4 \sum control_{it} + \varepsilon_{it}$$

Among them, $\sum control_{it}$ represented all control variables, $\varepsilon$ represented the random disturbance term, i indicated the firm, and t indicated the year.

## 5. Empirical Results Analysis

*5.1 Descriptive Statistics*

The descriptive statistical results for the full sample—comprising 572 companies listed on the STIB from 2019 to 2022—are presented in Table 1. The relevant variables included substantial innovation, strategic innovation, corporate digitalization, government subsidies, equity incentive intensity, and control variables. The analysis indicators included mean, standard deviation, maximum, and minimum, with a total of 1244 observations.

**Table 1.** Descriptive Statistics

| Variable Name | Observation | Value | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Patenti | 1,244 | 3.414 | 1.445 | 0 | 6.657 |
| Patentud | 1,244 | 0.935 | 0.705 | 0 | 2.533 |
| Dig | 1,244 | 2.043 | 1.713 | 0 | 5.615 |
| Sub | 1,244 | 3.332e+07 | 5.325e+07 | 1.613e+06 | 3.513e+08 |
| Emp | 1,244 | 0.00539 | 0.0101 | 0 | 0.0500 |
| Soe | 1,244 | 0.0748 | 0.263 | 0 | 1 |
| Age | 1,244 | 0.814 | 0.912 | 0 | 3 |
| Lev | 1,244 | 0.252 | 0.167 | 0.0314 | 0.723 |
| Profit | 1,244 | 0.00192 | 1.222 | -11.02 | 0.622 |
| Size | 1,244 | 21.56 | 0.889 | 19.75 | 24.68 |
| Roa | 1,244 | 0.0538 | 0.0799 | -0.276 | 0.344 |

In terms of innovation, the maximum substantial innovation of the sample enterprises was 6.657, the minimum was 0, and the standard deviation was 1.445. The maximum strategic innovation of the sample enterprises was 2.533, the minimum was 0, and the standard deviation was 0.705. This suggested that there was a noteworthy distinction in the level of innovation among enterprises, especially in substantial innovation, suggesting that both enterprises' innovation capability and their innovation activities required further enhancement.

Regarding digitalization, the maximum level of digitalization of the sample enterprises was 5.615, the minimum was 0, and the standard deviation was 1.713. This demonstrated a clear split in the extent of digital transformation among businesses, with notable variations in the degree of digitalization across various businesses. This suggested that businesses should place more attention on digitalization.

In terms of adjusting variables, the maximum government subsidy was 3.513e+08, the minimum was 1.613e+06, and the standard deviation was 5.325e+07. The maximum equity incentive was 0.0500, the minimum was 0, and the standard deviation was 0.0101. This suggested that the government highly valued the SMEs, but the gap in the intensity of government subsidies to different enterprises was also huge. Moreover, the gap in the intensity of internal equity incentives within enterprises is also significant, indicating a substantial difference in the degree of importance that different enterprises place on talent equity incentives.

In terms of control variables, the maximum value of the firm size was 24.68, the minimum value was 19.75, and the standard deviation was 0.889. This indicated that although the sample firms were all SMEs on the Innovation Board, a particular gap still exists in firm size. The maximum value of the debt-paying ability was 0.723, the minimum value was 0.0314, and the standard deviation was 0.167. This showed a notable distinction in the asset-liability ratios of the sample firms. Additionally, the maximum value of the operating profit margin was 0.622, the minimum value was -11.02, the average value was 0.00192, and the standard deviation was 1.222. This indicated a sizeable gap in profits among firms, and the majority of firms had negative operating profit margins. The maximum value of the return on assets was 0.344, the minimum value was -0.276, the average value was 0.0538, and the standard deviation was 0.0799. This suggested that most sample firms were still able to make a profit, but some firms could not. All of the businesses on the STIB were new, as shown by the company's maximum age value of three and minimum of zero.

### *5.2 Correlation Analysis*

**Table 2.** Correlation Analysis

| | **Patenti** | **Patentud** | **Dig** | **Sub** | **Emp** | **Soe** | **Age** |
|---|---|---|---|---|---|---|---|
| Patenti | 1 | | | | | | |
| Patentud | 0.671*** | 1 | | | | | |
| Dig | 0.094*** | 0.0400 | 1 | | | | |
| Sub | 0.351*** | 0.254*** | 0.062** | 1 | | | |
| Emp | 0.076*** | 0.061** | 0.113*** | 0.00500 | 1 | | |
| Soe | 0.096*** | 0.058** | -0.00700 | 0.163*** | -0.116*** | 1 | |
| Age | 0.191*** | 0.156*** | 0.076*** | 0.086*** | 0.241*** | -0.0390 | 1 |
| Lev | 0.300*** | 0.340*** | 0.0160 | 0.274*** | 0.075*** | 0.170*** | 0.104*** |
| Profit | 0.0100 | 0.132*** | 0.084*** | -0.00700 | 0.0150 | 0.0290 | 0.062** |
| Size | 0.402*** | 0.302*** | -0.077*** | 0.653*** | -0.00500 | 0.278*** | 0.161*** |
| Roa | -0.0420 | 0.101*** | -0.092*** | -0.061** | -0.127*** | -0.00400 | -0.0460 |

| | Lev | Profit | Size | Roa |
|---|---|---|---|---|
| Lev | 1 | | | |
| Profit | -0.051* | 1 | | |
| Size | 0.346*** | -0.00400 | 1 | |
| Roa | -0.194*** | 0.494*** | -0.049* | 1 |

The correlation coefficients between the variables are shown in Table 2. The findings provided preliminary evidence that corporate digitalization could foster major innovation, with a correlation coefficient of 0.671 between the degree of corporate digitalization (Dig) and considerable innovation (Patenti), and a significant association at 1% level. Although strategic innovation (Patentud) and digital transformation (Dig) had failed the significance test, the precise link between the variables had to be examined further in the regression model that follows. At the 1% level, there is a strong correlation between the government subsidy (Sub) and both strategic innovation (Patentud) and substantial innovation (Patenti), with correlation coefficients of 0.245 and 0.351, respectively. Therefore, significant and strategic innovation efforts might be encouraged by government subsidies.

Additionally, the hypothesis that equity incentives could encourage substantial innovation and strategic innovation activities by luring talent was also tentatively verified by the following correlation coefficients: the intensity of equity incentives (Emp) and substantial innovation (Patenti) had a correlation coefficient of 0.076. The correlation was significant at the 1% level, while the correlation coefficient with strategic innovation (Patentud) was 0.061 and was significantly correlated at the 5% level.

### *5.3 Regression Result Analysis*

**Table 3.** Benchmark Regression Results

| | (1) | (2) | (3) | (4) | (6) | (7) |
|---|---|---|---|---|---|---|
| VARIABLES | Patenti | Patentud | Patenti | Patentud | Patenti | Patentud |
| Dig | 0.066** | 0.024** | 0.087*** | 0.028** | 0.065** | 0.024** |
| | (2.55) | (1.99) | (3.35) | (2.34) | (2.51) | (2.02) |
| Sub | | | 0.000*** | 0.000** | | |
| | | | (3.65) | (2.13) | | |
| Dig*Sub | | | 0.000*** | 0.000*** | | |
| | | | (5.48) | (2.73) | | |
| Emp | | | | | 5.092 | 2.502 |
| | | | | | (1.53) | (1.54) |
| Dig*Emp | | | | | -3.577* | -1.908** |
| | | | | | (-1.89) | (-2.07) |
| Soe | -0.159 | -0.149** | -0.196 | -0.157** | -0.145 | -0.141** |
| | (-1.18) | (-2.41) | (-1.48) | (-2.55) | (-1.07) | (-2.26) |
| Age | 0.146*** | 0.059*** | 0.141*** | 0.058*** | 0.142*** | 0.054*** |
| | (3.36) | (2.95) | (3.30) | (2.90) | (3.23) | (2.67) |
| Lev | 1.146*** | 0.874*** | 1.095*** | 0.860*** | 1.137*** | 0.866*** |
| | (5.08) | (8.40) | (4.93) | (8.28) | (5.03) | (8.31) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Profit | -0.041 | 0.015 | -0.034 | 0.017 | -0.043 | 0.014 |
| | (-1.24) | (0.97) | (-1.04) | (1.09) | (-1.29) | (0.90) |
| Size | 0.536*** | 0.160*** | 0.413*** | 0.126*** | 0.537*** | 0.161*** |
| | (12.58) | (8.14) | (7.67) | (5.02) | (12.57) | (8.18) |
| Roa | 0.222 | 1.032*** | 0.097 | 1.003*** | 0.244 | 1.064*** |
| | (0.43) | (4.38) | (0.19) | (4.27) | (0.47) | (4.49) |
| Constant | -9.016*** | -3.799*** | -6.594*** | -3.132*** | -9.014*** | -3.818*** |
| | (-8.43) | (-7.70) | (-5.21) | (-5.30) | (-8.42) | (-7.73) |
| Observations | 1,244 | 1,244 | 1,244 | 1,244 | 1,244 | 1,244 |
| R-squared | 0.340 | 0.411 | 0.363 | 0.417 | 0.341 | 0.412 |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES |
| F test | 0 | 0 | 0 | 0 | 0 | 0 |
| r2 | 0.340 | 0.411 | 0.363 | 0.417 | 0.341 | 0.412 |
| a | . | . | . | . | . | . |
| F | 39.53 | 53.55 | 38.84 | 48.69 | 35.16 | 47.67 |

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3. shows the main regression results. Columns (1) and (2) presented the regression results without the moderating variables, only including control variables. According to Column (1), the regression coefficient between significant innovation (Patenti) and company digitalization level (Dig) was 0.106, and it was significantly positive at the 5% level. This indicated that digital transformation could promote substantial innovation, and H1a was verified. Moreover, from Column (2), the regression coefficient between strategic innovation (Patentud) and business digitalization level (Dig) was 0.026, and it was significantly positive at the 5% level. This indicated that the level of corporate digitalization could also promote strategic innovation, and H1b was verified.

Furthermore, Columns (1) and (2) also showed that compared to strategic innovation, the corporate digitalization level was more helpful for substantial innovation, which verified H1. Columns (3) and (4) added government subsidies and the interaction term between government subsidies and corporate digitalization level to Columns (1) and (2). In Column (3), the regression coefficient of government subsidies (Sub) was significantly positive at the 1% level, and the regression coefficient of the interaction term between government subsidies and corporate digitalization level (Dig*Sub) was significantly positive at the 1% and 5% levels in Columns (3) and (4), respectively. This indicates that government subsidies exerted a positive moderating effect on the impact of enterprises' digitalization level on substantial innovation and strategic innovation, and $H_2$ was verified.

Besides, Columns (5) and (6) added the intensity of equity incentives and the interaction term between the intensity of equity incentives and digital transformation to Columns (1) and (2). In Columns (5) and (6), the regression coefficient of the interaction term between the intensity of equity incentives and digital transformation (Dig*Emp) was significantly negative at the 1% and 5% levels, respectively. This indicated that the intensity of equity incentives played a negative moderating role in the impact of corporate digitalization level on substantial innovation and strategic innovation, and H3 was not verified, rejecting the null hypothesis of H3.

*5.4 Robustness Check*

*5.4.1 Control Variables*

Referring to previous studies, the control variables used in this paper include: firm size (Size), measured by taking the logarithm of the total assets at the end of the sample firm; leverage (Lev), represented by the ratio of total liabilities to total assets; operating profit margin (Profit), represented by the ratio of operating profit to operating revenue; firm age, which was determined by how long the company had been listed; firm nature, which was assigned a value of 0 for companies that were not state-owned and 1 for those that were, and return on assets (Roa), which was the ratio of net profit to total assets.

In summary, the variable names, variable codes, and variable calculation formulas in Table 4. provided a summary of the definitions of the several variables used in this work.

**Table 4.** The Definitions of Various Variables

| Variable Type | Variable Name | ariable Symbol | ariable Definition |
|---|---|---|---|
| The explained variables | Substantial Innovation | Patenti | total number of corporate patent applications + 1, take the logarithm |
| | Strategic innovation | Patentud | Total number of patent applications for corporate inventions + 1, take the logarithm |
| Core Explanatory Variable | corporate digitalization | Dig | Ratio of digital-related word frequency to segment length * 100 |
| Adjusting Variables | government subsidies | Sub | Total amount of government subsidies received by the company that year |
| | equity incentive ntensity | Emp | The ratio of the actual number of stock options or restricted shares granted under equity incentives to the total number of outstanding shares |
| Control Variables | company size | Size | The total assets of the enterprise at the end of the period, take the logarithm |
| | debt-paying ability | Lev | The ratio of total liabilities to total assets |
| | operating profit margin | Profit | Profit margin ratio relative to operating revenue |
| | nature of the enterprise | Roe | State-owned enterprises are 1, otherwise 0 |
| | asset return rate | Roa | The ratio of net profit to total assets |
| | company age | Age | Number of years since the company went public |

*5.4.2 Replacement of the Explained Variable*

This study employed the technique of substituting proxy indicators for robustness checks in place of the explained variable in order to ensure the validity of the empirical research findings previously discussed. This paper selected the number of authorized invention patents (Patenti2) and the number of authorized non-invention patents (Patentud2) as proxy variables for substantial innovation (Patenti) and strategic innovation (Patentud) for analysis. The results were shown in Table 5., where the regression coefficient for corporate digitalization on substantial innovation was positive at the 1% significance level. The regression associated with strategic innovation was only confirmed when government subsidies were promoted. Government subsidies and company digitization had a very positive interaction term, while the interaction term between equity incentives and the degree of corporate digitalization was significantly negative. Nonetheless, the impact of significant innovation was essentially in line with the findings in the preceding section, confirming the strength of the conclusions.

**Table 5.** Robustness Test

| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** |
|---|---|---|---|---|---|---|
| **VARIABLES** | **Patenti2** | **Patentud2** | **Patenti2** | **Patentud2** | **Patenti2** | **Patentud2** |
| Dig | 0.031*** | 0.020 | 0.035*** | 0.023* | 0.031*** | 0.020 |
| | (2.61) | (1.48) | (2.85) | (1.72) | (2.62) | (1.49) |
| Sub | | | 0.000*** | 0.000 | | |
| | | | (4.64) | (1.45) | | |
| DigSub | | | 0.000*** | 0.000* | | |
| | | | (2.97) | (1.88) | | |
| Emp | | | | | 4.094*** | 2.780 |
| | | | | | (2.79) | (1.64) |
| DigEmp | | | | | -0.689 | -1.962** |
| | | | | | (-0.83) | (-2.03) |
| Soe | -0.114* | -0.228*** | -0.119* | -0.235*** | -0.097 | -0.218*** |
| | (-1.83) | (-3.36) | (-1.94) | (-3.45) | (-1.56) | (-3.19) |
| Age | 0.055*** | 0.050** | 0.053*** | 0.050** | 0.047** | 0.046** |
| | (2.74) | (2.30) | (2.69) | (2.26) | (2.33) | (2.04) |
| Lev | 0.219** | 0.910*** | 0.187* | 0.900*** | 0.204* | 0.901*** |
| | (2.10) | (7.97) | (1.82) | (7.88) | (1.96) | (7.88) |
| Profit | -0.022 | 0.015 | -0.019 | 0.017 | -0.024 | 0.014 |
| | (-1.45) | (0.92) | (-1.26) | (1.00) | (-1.58) | (0.84) |
| Size | 0.247*** | 0.128*** | 0.175*** | 0.103*** | 0.249*** | 0.129*** |
| | (12.57) | (5.95) | (6.98) | (3.73) | (12.66) | (5.99) |
| Roa | -0.208 | 0.914*** | -0.233 | 0.892*** | -0.156 | 0.948*** |
| | (-0.88) | (3.53) | (-1.00) | (3.45) | (-0.66) | (3.64) |
| Constant | -4.198*** | -2.926*** | -2.720*** | -2.427*** | -4.222*** | -2.943*** |
| | (-8.50) | (-5.40) | (-4.63) | (-3.73) | (-8.55) | (-5.43) |
| Observations | 1,244 | 1,244 | 1,244 | 1,244 | 1,244 | 1,244 |
| R-squared | 0.231 | 0.317 | 0.250 | 0.320 | 0.234 | 0.317 |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES |

| | | | | | | |
|---|---|---|---|---|---|---|
| F test | 0 | 0 | 0 | 0 | 0 | 0 |
| r2 | 0.231 | 0.317 | 0.250 | 0.320 | 0.234 | 0.317 |
| a | . | . | . | . | . | . |
| F | 23.03 | 35.53 | 22.70 | 32.00 | 20.79 | 31.66 |

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

*5.4.3 Endogeneity Treatment*

The benchmark regression results of this paper might have endogeneity issues arising from reverse causality. Consequently, this study performed an endogeneity test using regression analysis on significant innovation utilizing the two-stage least squares method and applying the average degree of digitalization of other businesses in the same industry and location as an instrumental variable. Table 6. presents the results, and the identification test and weak instrument test proved the validity of the instrumental variable. The regression results showed that, after addressing the endogeneity problem, the digitalization of enterprises could still significantly promote substantial innovation of enterprises.

**Table 6.** Endogeneity Treatment

| | **(1)** | **(2)** |
|---|---|---|
| | **firstDig** | **second** |
| **VARIABLES** | **Dig** | **Patenti** |
| AvDig | 0.9502*** | |
| | (34.46) | |
| Size | -0.1188*** | 0.5594*** |
| | (-2.91) | (12.67) |
| Lev | 0.8215*** | 1.4725*** |
| | (3.74) | (6.27) |
| Profit | 0.0228 | -0.0175 |
| | (0.71) | (-0.50) |
| Growth | -0.2905*** | -0.3807*** |
| | (-3.46) | (-4.12) |
| Roa | 0.3271 | 1.0276* |
| | (0.64) | (1.86) |
| Age | -0.0475 | 0.1387*** |
| | (-1.23) | (3.35) |
| Dig | | 0.0748** |
| | | (2.40) |
| Constant | 2.5436*** | -9.3728*** |
| | (2.94) | (-9.96) |
| Anderson canon. corr. LM statistic | 609.57*** | 609.571*** |
| Cragg-Donald Wald F statistic | 1187.57*** | 1187.570*** |
| | (16.38) | (16.38) |

| | | |
|---|---|---|
| Observations | 1,244 | 1,244 |
| R-squared | | 0.228 |

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

## 6. Conclusion and Recommendations

The digital level and substantial innovation of scientific and technological SMEs are crucial for economic expansion and social advancement (Ho, Ruan, and Hang, 2016). Digitalization presents both opportunities and challenges to scientific and technological SMEs. Additionally, there is a need to address the insufficient capital and limited talent available to SMEs in digitalization and innovation activities. To solve these problems, this study employs panel data from 572 businesses listed on the STIB between 2019 and 2022 to conduct an empirical analysis. After cleaning, filtering, and organizing the data, it draws the following conclusions:

1. Digital transformation encourages significant creativity in businesses as well as strategic innovation. This suggests that digital transformation can support technological advancement and the modernization of management operations and company procedures, in addition to stimulating more creative business practices.

2. Subsidies from the government play a constructive regulatory function in the effect of enterprise digitalization on substantial and strategic innovation. Government subsidies alleviate the financial pressure on scientific and technological SMEs, thereby reducing the cost and risk of digitalization and substantial innovation for these enterprises, and enhancing their willingness to engage in digitalization and substantial innovation.

3. The potency of equitable incentives negatively regulates the effects of digitization in businesses on significant and strategic innovation. The influence of digitalization on substantial and strategic innovation in scientific and technological SMEs cannot be favorably regulated by the intensity of equity incentives, despite a considerable positive correlation with both. Conversely, the severity of equity incentives has a major detrimental regulatory impact on it.

### *6.1 Research Implications*

#### *6.1.1 At the National and Government Level*

SMEs are a pivotal cornerstone of China's national economy, accounting for 99% of the total number of enterprises in the country, and have generated more than 50% of the country's taxes, over 75% of technological innovations, and greater than 80% of new goods. Against the backdrop of the digital economy's development, SMEs must undergo transformation and upgrading through digital technology, continuously carry out substantial innovation, and better integrate into the digital economy.

The government is a vital source of support for significant innovation efforts and the digital transformation of small and medium-sized businesses. The government can lessen the operational strain on SMEs and encourage them to take an active role in technological advancements and innovation by offering financial subsidies. The government can offer them technical assistance and pertinent policy recommendations in addition to financial support, which will accelerate their growth in the digital economy.

Simultaneously, the government should strengthen regulatory oversight over the application and use of subsidies. This includes establishing a comprehensive internal audit mechanism and ensuring the authenticity and accuracy of the application documents. After the funds are released, the government should establish special supervisory departments or agencies responsible for overseeing and supervising the use of subsidy funds, ensuring their effective use.

*6.1.2 At the Enterprise Level*

SMEs founded on science and technology should utilize subsidies for digitalization and substantial innovation activities in a scientific and reasonable manner. Firstly, enterprises should formulate clear digitalization and innovation development plans, define goals and roadmaps, and ensure that the enterprise's development strategy aligns with the utilization of subsidy funds. Secondly, enterprises need to strengthen internal management and technical capabilities. This includes enhancing the digital skills of employees, training core technical personnel, and introducing advanced digital technology and management tools. Besides, businesses can achieve ongoing and healthy growth by collaborating with government agencies and research institutions. It is worth noting that enterprises should further improve the equity incentive system, directly linking the equity incentive mechanism with substantial innovation output to mitigate the counterproductive effects of related measures on innovation, which is significantly affected by enterprise digitalization.

*6.2 Limitations and Prospects*

Due to constraints from various aspects, the research still has the following shortcomings, which also offer guidelines for how research in adjacent domains should proceed in the future.

1. The subject of this paper's research is the listed companies since the founding of the STIB. The conclusions drawn are not universal because the STIB was only established a short time ago, and the listed companies on the board have issues with being fewer in number and having shorter years. To make the findings more general, it may be feasible to include more companies and data years in subsequent studies.

2. This study gauges the company's level of significant and strategic innovation by looking at the quantity of invention and non-invention patent applications filed in the current year. Using the type of invention to distinguish different innovative behaviors of the company may lead to errors. Therefore, in future research, it is possible to establish a more reasonable evaluation system and select more comprehensive measurement indicators for analysis.

3. This paper only tests the regulatory effects of government subsidies and the intensity of equity incentives. It does not further test other variables that may affect the two major difficulties of SMEs. Therefore, in future research, it is possible to incorporate other variables that may affect the capital and talents of SMEs, and explore the specific pathways of action.

## AUTHOR CONTRIBUTIONS

Chin Wei Mun: Conceptualization; methodology; investigation; data collection; formal analysis; validation; writing – original draft; writing – review and editing; project administration.

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## CONFLICT OF INTEREST STATEMENT

The authors declare that there are no commercial or financial relationships that could be construed as a potential conflict of interest.

## DATA AVAILABILITY STATEMENT

The data generated and analyzed in this study are available from the corresponding author upon reasonable request. All data will be provided without undue restriction.

## References

1.Berman, S. J. (2012). Digital transformation: opportunities to create new business models. Strategy & leadership,40(2), 16-24.https://doi.org/10.1108/10878571211209314

2.O'Hea, K. (2011). Digital capability: how to understand, measure, improve and get value from it. IVI Executive Briefing Series.https://mural.maynoothuniversity.ie/id/eprint/6396/

3.Singh, A., & Hess, T. (2020). How chief digital officers promote the digital transformation of their companies. In Galliers, R.D.& Leidner, D.E.& Simeonova, B. (Eds.),Strategic information management (pp. 202-220). Routledge.https://doi.org/10.4324/9780429286797

4.Vial, G. (2021). Understanding digital transformation: A review and a research agenda.In Hinterhuber, A.& Vescovi, T.& Checchinato, F. (Eds.), Managing digital transformation: understanding the strategic process (pp.13-66).Routledge.https://doi.org/10.4324/9781003008637

5.Bharadwaj, A. S. (2000). A resource-based perspective on information technology capability and firm performance: an empirical investigation.MIS quarterly, 24(1),169-196.https://doi.org/10.2307/3250983

6.Warner, K. S., & Wäger, M. (2019). Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal. Long range planning,52(3), 326-349.https://doi.org/10.1016/j.lrp.2018.12.001

7.Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. Strategic management journal,18(7), 509-533.https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z

8.Gökalp, E., & Martinez, V. (2022). Digital transformation maturity assessment: development of the digital transformation capability maturity model.International Journal of Production Research,60(20), 6282-6302.https://doi.org/10.1080/00207543.2021.1991020

9.Davenport, T. H. (1993).Process innovation: reengineering work through information technology. Harvard business press.https://www.kiphub.com/paper/623d88a0ef25c15d1e1524e7

10.Halpern, N.,Mwesiumo, D.,SuauSanchez, P.,Budd, T.& Svein B.(2021).Ready for digital transformation? The effect of organisational readiness, innovation, airport size and ownership on digital change at airports.Journal of Air Transport Management,90,101949-101949.https://doi.org/10.1016/j.jairtraman.2020.101949

11.Pettersson, F., Siljebo, J., Ferry, M., & Wolming, S. (2023). Development and validation of the di gital transformation scale: A questionnaire for measuring digitalization as sociocultural change in educational contexts.Available at SSRN 4455906:https://dx.doi.org/10.2139/ssrn.4455906
12.Bertschek, I., Ohnemus, J. & Viete, S. (2018). The ZEW ICT Survey 2002 to 2015: Measuring th e Digital Transformation in German Firms. Jahrbücher für Nationalökonomie und Statistik, 238(1), 87-99. https://doi.org/10.1515/jbnst-2016-1005
13.Kaiser Tamás & Gadár László.(2023).Survey data on the attitudes towards digital technologies and the way of managing e-governmental tasks.Data in brief,46,108871-108871.https://doi.org/10.1016/J.DIB.2022.108871.
14.Wamba, S. F., Akter, S., Edwards, A., Chopin, G., & Gnanzou, D. (2015). How 'big data'can ma ke big impact: Findings from a systematic review and a longitudinal case study.International jour nal of production economics,165, 234-246.https://doi.org/10.1016/j.ijpe.2014.12.031.
15.Warner, K. S., & Wäger, M. (2019). Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal. Long range planning,52(3), 326-349.https://doi.org/10.1016/j.lrp.2018.12.001
16.Feroz, A.K., Zo, H.,& Chiravuri, A.(2021).Digital transformation and environmental sustainability: A review and research agenda.Sustainability,13(3), 1530.https://doi.org/10.3390/su13031530
17.Varadarajan, R. (2018). Innovation, innovation strategy, and strategic innovation. Emerald Publishi ng Limited. https://doi.org/10.1108/S1548-643520180000015007
18.Drejer, A. (2006). Strategic innovation: a new perspective on strategic management. Handbook of business strategy, 7(1), 143-147.https://portal.sclib.cn/interlibSSO/goto/11/+cnh9nqf/10.1108/10775730610618756
19.Granados, C., Ayala, Y., & Ramos-Mejia, M. (2024). Is it substantive or just symbolic? Understan ding innovation theater in organisations: The case of technology-based innovation. Technovation, 129, 102880.https://doi.org/10.1016/j.technovation.2023.102880
20.Trajtenberg, M. (1990). A penny for your quotes: patent citations and the value of innovations.The Rand journal of economics, 21(1),172-187.https://doi.org/10.2307/2555502
21.Griliches, Z. (1998). Patent statistics as economic indicators: a survey. In Zvi G.(Eds.) ,R&D and productivity: the econometric evidence(pp. 287-343). University of Chicago Press.https://doi.org/10.3386/w3301
22.Hall, B. H. , Jaffe, A. B. , & Trajtenberg, M. (2000). Market value and patent citations: a first l ook.NBER working papers, 16-38.https://doi.org/10.1007/s11127-005-3550-0
23.Khan, B. Z. (2015). Inventing prizes: a historical perspective on innovation awards and technology policy.Business History Review,89(4), 631-660.hppts://doi.org/10.2307/43896955
24.Van Ark, B., Hao, J. X., Corrado, C., & Hulten, C. (2009). Measuring intangible capital and its c ontribution to economic growth in Europe.EIB papers,14(1), 62-93.https://hdl.handle.net/10419/44905
25.Fernandez-Vidal, J., Gonzalez, R., Gasco, J., & Llopis, J. (2022). Digitalization and corporate trans formation: The case of European oil & gas firms.Technological Forecasting and Social Change,174, 121293.https://doi.org/10.1016/j.techfore.2021.121293
26.Lyytinen, K., Yoo, Y., & Boland Jr, R. J. (2016). Digital product innovation within four classes o f innovation networks.Information systems journal,26(1), 47-75.https://doi.org/10.1111/isj.12093.

27.Li, L., Zhu, W., Wei, L., & Yang, S. (2022). How can digital collaboration capability boost servi ce innovation? Evidence from the information technology industry.Technological Forecasting and Social Change,182,121830.https://doi.org/10.1016/J.TECHFORE.2022.121830.

28.Tohãnean, D., Buzatu, A. I., Baba, C. A., & Georgescu, B. (2020). Business model innovation thr ough the use of digital technologies: Managing risks and creating sustainability.Amfiteatru Econo mic,22(55), 758-774.https://doi.org/10.24818/ea/2020/55/758.

29.Karhade, P.P.,Dong & John Qi.(2021) Information technology investment and commercialized innov ation performance: Dynamic adjustment costs and curvilinear impacts. Mis Quarterly,45(3): 1007-1024.https://doi.org/10.25300/MISQ/2021/14368

30.Švarc, J., Lažnjak, J., & Dabić, M. (2021). The role of national intellectual capital in the digital t ransformation of EU countries. Another digital divide?Journal of Intellectual Capital,22(4), 768-79 1.https://doi.org/10.1108/jic-02-2020-0024

31.Cha, K.J.,Hwang, T.& Gregor, S.(2015).An integrative model of IT-enabled organizational transform ation A multiple case study.Management decision,53(8),1755-1770.https://doi.org/10.1108/MD-09-20 14-0550

32.Probir Kumar Banerjee & Louis C. Ma.(2012).Routinisation of B2B E-commerce by small firms: A process perspective.Information Systems Frontiers,14(5),1033-1046.https://doi.org/10.1007/s10796-0 11-9329-6

33.Chandavarkar, N. D., & Nethravathi, P. S. (2023). Analysis of Challenges faced during Adoption of ICT by Small and Medium Enterprises in India. International Journal of Management, Techno logy, and Social Sciences, 8(2), 1-21.https://doi.org/10.47992/ijmts.2581.6012.0267.

34.Hitt, M. A., Keats, B. W., & DeMarie, S. M. (1998). Navigating in the new competitive landscap e: Building strategic flexibility and competitive advantage in the 21st century.Academy of Manag ement Perspectives,12(4), 22-42.https://doi.org/10.5465/ame.1998.1333922

35.Teece, D. J. (2010). Technological innovation and the theory of the firm: the role of enterprise-le vel knowledge, complementarities, and (dynamic) capabilities. In Handbook of the Economics of Innovation (Vol. 1, pp. 679-730). North-Holland.https://doi.org/10.1016/S0169-7218(10)01016-6

36.Carlson, S. (1974). International transmission of information and the business firm. The Annals of the American Academy of Political and Social Science,412(1), 55-63.https://doi.org/10.2307/10403 99

37.Thrassou, A.,Uzunboylu, N.,Vrontis, D. &Christofi Michael.(2020).Digitalization of SMEs: A Revie w of Opportunities and Challenges.Palgrave Studies of Cross-Disciplinary Business Research, in Association with EuroMed Academy of Business,179-200.https://doi.org/10.1007/978-3-030-45835-5 _9.

38.Opoku, E., Okafor, M., Williams, M., Aribigbola, A.,&Olaleye, A. (2024). Enhancing small and m edium-sized businesses through digitalization. World Journal of Advanced Research and Reviews, 23(2), 222.https://doi.org/10.30574/wjarr.2024.23.2.2313

39.Ramdani, B., Raja, S., & Kayumova, M. (2022). Digital innovation in SMEs: a systematic review, synthesis and research agenda. Information Technology for Development,28(1), 56-80.https://doi.or g/10.1080/02681102.2021.1893148

40.Li, J., Ren, H., Zhang, C., Li, Q., & Duan, K. (2020). Substantive innovation or strategic innovati on? Research on multiplayer stochastic evolutionary game model and simulation. Complexity,2020 (1), 9640412.https://doi.org/10.1155/2020/9640412

41.Wang, L. (2025). Research on the enhancement mechanism of big data-driven government innovation subsidy policy on the multi-level financing model of science and technology-based enterprises. Applied Mathematics & Nonlinear Sciences,10(1).https://doi.org/10.2478/amns-2025-0076
42.Yu, X., & Zhang, B. (2021). Innovation strategy of cultivating innovative enterprise talents for young entrepreneurs under higher education. Frontiers in Psychology,12, 693576.https://doi.org/10.3389/fpsyg.2021.693576
43.Krishnan, T. N., & Scullion, H. (2017). Talent management and dynamic view of talent in small and medium enterprises. Human Resource Management Review, 27(3), 431-441.https://doi.org/10.1016/j.hrmr.2016.10.003
44.Ho, Y. P., Ruan, Y., Hang, C. C., & Wong, P. K. (2016). Technology upgrading of small-and-medium-sized enterprises (SMEs) through a manpower secondment strategy–A mixed-methods study of Singapore's T-Up program. Technovation,57,21-29.https://doi.org/10.1016/j.technovation.2016.07.001.