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Research Article

IT Usage and Innovation Performance of SMEs in China: A New Perspective

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Existing studies on the information technology (IT) usage of firms are constrained within the perspective of "IT tool" or "IT investment." Few studies have analyzed the IT usage of firms from a new perspective. This study aims to fill this gap by examining the impact of IT usage on the innovation performance of small- and medium-sized enterprises (SMEs) from the perspective of the product value chain (PVC). A research model integrating IT usage width, IT usage frequency, manufacturing flexibility, human capital quality, and firm innovation performance was proposed for this analysis. Furthermore, a quantitative analysis was performed on a sample of more than 1300 Chinese manufacturing firms using the newest data provided by the World Bank. Results validate that IT usage width and IT usage frequency have a significantly positive impact on the innovation performance of SMEs. Manufacturing flexibility plays a partially mediating role between IT usage frequency and the innovation performance of SMEs. Moreover, human capital quality has a significantly positive moderating effect on IT usage width and the innovation performance of SMEs. IT usage width and IT usage frequency appear to be important predictors of the innovation performance of SMEs, whereas there are substantial differences in the influencing mechanism of IT usage width and IT usage frequency on the innovation performance of SMEs.

1. Introduction

Recently, the new generation of information technology (IT) represented by artificial intelligence has profoundly changed the daily lives of people and has made increasing contributions to productivity improvement and economic growth. Against this background, countries around the world, especially advanced manufacturing powers such as Germany and Japan, are scrambling to develop the new generation of IT [1]. Driven by the wave of informatization and digitization, China has also formulated its own development strategy of digital economy and intelligent manufacturing, hoping to improve productivity and boost economic growth through the development of the IT industry.

With the rapid development of IT, the traditional business model has undergone profound changes and even subversion [2]. An increasing number of firms realize that only by applying IT well can they adapt to the new survival rules and achieve sustainable development. This is especially true given the increasingly fierce competition among firms and the fact that any "black swan" events (e.g., war, plague, trade conflict, and economic crisis) may have a profound impact on the global economy in the globalization era. Compared with large firms, small- and medium-sized enterprises (SMEs) are often faced with a shortage of capital and human resources. Therefore, the importance of IT usage for the innovation and sustainable development of SMEs is self-evident.

As firms pay considerable attention to IT usage, academia has conducted a series of research on the relationship between IT usage and firm performance (such as the IT productivity paradox; see [3]). However, it is a pity that there are few empirical studies on the relationship between IT usage and the innovation performance of firms. Additionally, very little attention has been paid to the influencing mechanism of IT usage on the innovation performance of firms. Previous studies,

hence, provide a relatively limited understanding of the relationship between IT usage and the innovation performance of firms, which can be problematic for business managers to develop appropriate IT strategies and for policy makers to formulate effective policies to support the development of the IT industry. What is more, existing studies investigate the IT usage of firms from the perspective of "IT tool" (measured by asking whether a firm has broadband access and network connection or network homepage or whether it uses e-mail in communication with its suppliers or customers [4–6], or which types of IT tools are used by it [7]), "IT investment [8, 9]," or "IT tool and IT investment [10]." Firm activities are, nonetheless, composed of several closely connected product value chain (PVC) links, and IT investment or the usage of IT tools will penetrate into the PVC links of firms [11]. That is, the differences in "IT investment" or "IT tool" among firms can be reflected in the differences in the supporting effect of IT on the PVC activities of firms. Thus, it is more direct and targeted to explore the effect of the IT usage of firms on their innovation performance from the PVC perspective.

Accordingly, this study attempts to investigate the IT usage of firms from the PVC perspective. On the basis of existing research, IT usage is decomposed into two components, namely, IT usage width and IT usage frequency. The study also scrutinizes the impact of IT usage on the innovation performance of SMEs. Compared with that of previous studies, the marginal contribution of this paper is fivefold. First, this study evaluates the IT usage of firms from the PVC perspective, thereby complementing the existing studies that have largely focused on IT tool and IT investment. Second, this research reveals key insights into how IT usage influences the innovation performance of firms by decomposing IT usage into two components (i.e., IT usage width and IT usage frequency) and examining the potential heterogeneous impact of these two components on the innovation performance of firms. Third, this study empirically examines the influencing mechanism of the IT usage of firms on the innovation performance of SMEs and, hence, deepens the understanding of the relationship between IT usage and the innovation performance of firms. Fourth, the research explores the moderating effects of human capital quality on the relationship between IT usage and the innovation performance of SMEs and, thus, adds to the understanding of external boundary conditions that shape the effects of IT usage. Last but not least, this study analyzes the nexus between IT usage and the innovation performance of SMEs in emerging economies, thereby enriching the existing studies that have mainly targeted at developed economies. This is especially important given the fact that SMEs have contributed more than half of the technological innovation, tax revenue, and urban employment of China [12]. The findings provide key managerial implications for business managers.

2. Research Design

2.1. Theoretical Hypotheses

2.1.1. IT Usage and Firms' Innovation Performance. The resource-based view (RBV) of firms considers firms to be "bundles of resources" and holds that the sustainable competitive advantage of firms stems from their valuable, rare, difficult-to-imitate, and irreplaceable resources and their capabilities to utilize and allocate these resources [13]. According to the RBV, IT facilities (i.e., all necessary computer hardware, software, and personnel within enterprises to support the distribution of IT tools [14]) are an essential part of the unique resources of firms [15]. Therefore, the ability of firms to apply IT facilities to support new product development and sales activities can boost potential competitive advantages. That is, the IT usage of firms affects their innovation performance and, ultimately, influences their competitiveness.

Current studies on IT usage have mainly focused on IT tools or IT investments, and their policy implications normally guide firms to pay more attention to the types of IT tools or the scale of IT investments. Nevertheless, as mentioned before, firm activities comprise several closely connected PVC links, and the usage of IT within firms will penetrate into the specific links of the PVC [11]. Due to the differences in the ability of firms to apply IT, the number of PVC links that use IT and the usage frequency of IT in each PVC link (thus the average usage frequency of IT in all PVC links) are dissimilar. Hence, investigating the differences in IT usage among firms and examining the impact of differences in IT usage on the innovation performance of firms from the PVC perspective are necessary and feasible.

Recently, some scholars have tried to investigate the IT usage of firms from the PVC perspective. For instance, Barczak et al. [7, 14] explored the impact of the extent of IT usage on the performance of new product development (NPD). The extent of IT usage here refers to the number of tools employed for different activities (including communication and collaboration, product development, project management, information and knowledge management, and market research and analysis) across three stages of the NPD process (i.e., fuzzy front-end, development and testing, and launch). In addition, Mauerhoefer et al. [16] studied the impact of the usage frequency of the NPD IT tool on NPD performance. The usage frequency of the NPD IT tool refers to the usage frequency of project and resource management IT tools, information and knowledge management IT tools, collaboration IT tools, and product development and process planning IT tools. These studies have begun to examine firm IT usage from the PVC perspective; however, they are not free from the shackles of the IT tool perspective.

On the basis of previous studies [7, 14, 16], this paper proposes the concepts of IT usage width and IT usage frequency from the PVC perspective. The former captures the number of PVC links (including partner relations, product and service enhancement, production and operations, marketing and sales, and customer relations; see [17, 18]) supported by IT within a firm. The latter describes the average usage frequency of IT in all the PVC links of a firm. The combination of the two (IT usage width and IT usage frequency) can clearly depict the level of IT usage within a firm.

This study argues that IT usage width and IT usage frequency have a significantly positive impact on the innovation performance of SMEs. In terms of IT usage width, the more PVC link uses IT, the better communication,

coordination, and synergy can be achieved between the PVC links of firms. The improvement of PVC synergy helps reap the benefits of open innovation [19], thereby improving the innovation performance of firms. On the contrary, if IT is only utilized in one PVC link or a few PVC links, then it is fairly difficult for firms to share and transmit information and knowledge in the whole PVC, which is not conducive to the integration and creation of knowledge; it is also difficult to spark innovation because innovation is essentially a process of knowledge acquisition, absorption, integration, and recreation [20]. Because all PVC links are closely connected, the lack of IT usage in one link will depress the positive effects of IT usage on other links. For instance, if IT is not used in the link of product and service enhancement, then firms will not have an advantage in achieving rapid design and shortening the R&D cycle of new products, which will undoubtedly increase the risk of new product development and sales. Furthermore, if IT is not employed in the link of customer relations, then the product and service enhancement of firms will be restricted because firms cannot understand customer preferences and needs very well. Only when IT is used effectively in each link of the PVC and all links gain from each other can the innovation performance of firms be improved to the greatest extent.

In terms of IT usage frequency, the more frequently IT is utilized in each PVC link of a firm, the more information and knowledge will be obtained. In the meantime, knowledge features increasing marginal returns [21],which is conducive to the improvement of the innovation performance of firms. Frequent IT usage in any of the five links of the PVC will promote the innovation performance of firms, but only when IT is frequently used in all the links of the PVC can the innovation performance of firms be improved to the maximum. Specifically, frequent IT usage in the link of partner relations can achieve effective communication with business partners because effective communication generally involves feedback, which requires repeated communication. Frequent IT-based communication helps firms develop a better understanding with business partners, breed common values, cultivate trust and consensus, and improve mutual commitment levels [22]. Thus, frequent IT usage in partner relations helps achieve effective communication. Meanwhile, frequent IT usage in the link of product and service enhancement helps integrate internal and external technologies and the knowledge of product design and identifies the direction for product improvement, thereby improving product design efficiency. Moreover, the repeated use of some technical products (such as the technical module in modular design) can effectively reduce the cost of new product development [11]. Similarly, frequent IT usage in the link of production and operations not only realizes the effective control and coordination of the production processes but also helps optimize the production processes by eliminating repetitive and non-value-added (NVA) ones [11]. As for frequent IT usage in the link of marketing and sales, it helps firms make full use of customer data resources and perform targeted marketing activities, thereby improving product sales. Similarly, frequent IT usage in the link of customer relations helps deepen an understanding of customer demand preferences and, hence, maintains good relations with customers [23, 24].

Too high IT usage frequencies may lead to information overload (i.e., too much redundant information makes it difficult for firms to effectively use the acquired information [8]), which is not conducive to the improvement of the innovation performance of firms. However, using IT in all PVC links is commonly difficult for SMEs due to their disadvantages in capital and human resources; thus, information overload generally will not be a problem for SMEs. On the basis of the above analysis, this study hypothesizes the following:

Hypothesis 1: IT usage width positively affects the innovation performance of SMEs

Hypothesis 2: IT usage frequency positively affects the innovation performance of SMEs

2.1.2. Mediating Role of Manufacturing Flexibility. The concept of manufacturing flexibility was first proposed by Hayes and Wheelwright [25]. They asserted that manufacturing flexibility is one of the main dimensions of the competitive strategy of a firm. Since then, research on manufacturing flexibility has increased daily. Scholars have also defined the concept of manufacturing flexibility at different levels, such as strategic management and operation management. These definitions have strong commonality; that is, they describe manufacturing flexibility as the ability of a manufacturing system to respond to environmental changes [26]. Additionally, many definitions involve the time required for adjustments, the cost of the adjustments, and the effort required [26]. Scholars have also recognized that manufacturing flexibility is a multidimensional concept. But views on the specific dimensions of manufacturing flexibility are different from one another [26]. Despite this, scholars generally agree that manufacturing flexibility is essentially the ability of a firm to adapt to environmental uncertainty [27].

Current research verifies that IT usage affects the innovation performance of firms not only directly but also indirectly through influencing manufacturing flexibility. For instance, Wang and Li [6] believed that IT usage can improve the "flexibility" level of firms and, hence, promote their innovation performance besides its direct effects (i.e., accelerating knowledge spillover and facilitating information transmission). One reason why IT usage can improve firm flexibility is that the higher the level of IT usage (including IT usage width and IT usage frequency) is, the more effective the communication between firms and their partners will be. Another reason is that the higher the level of IT usage is, the more flexible the design and production can be; the more accurate control and adjustment can be made on inventory, procurement, production planning, production, and sales volume; and the more rapid responses can be made to changes in external environments, such as competitive pressure, technological improvement, demand change, namely, and the improvement of manufacturing flexibility. In terms of empirical evidence, Chen et al. [28] affirmed that

IT usage supports the strategic flexibility of firms. Khouja and Kumar [29] also corroborated that IT usage improves the information flow within the supply chain and enables the earlier detection of changes in demand. That is, IT enhances firm flexibility.

In the meantime, the enhancement of manufacturing flexibility can improve the innovation performance of firms. The empirical results of Oke [30] supported this argument, and Javier et al. [31] further confirmed that the reason is that the enhancement of firm flexibility enables firms to better implement the strategies of exploratory and exploitative innovation and, hence, improves organizational learning ability. Therefore, IT usage width and IT usage frequency not only directly affect the innovation performance of SMEs but also indirectly affect it through manufacturing flexibility. On the basis of the above analysis, we hypothesize the following:

Hypothesis 3a: Manufacturing flexibility plays a partial mediating role between IT usage width and the innovation performance of SMEs

Hypothesis 3b: Manufacturing flexibility plays a partial mediating role between IT usage frequency and the innovation performance of SMEs

2.1.3. Moderating Role of Human Capital Quality. According to the theory of human capital, human capital has a crucial impact on the innovation and performance of firms. Meanwhile, research on IT usage shows that IT is a skill-biased technology [32]; therefore, the higher the level of IT usage is, the greater the requirement for a high-quality labor force will be. Although scholars hold two views (i.e., substitution and complementarity) on the relationship between IT usage and the demand of labor force quantity [33, 34], most studies believe that there is a complementary relationship between IT usage and the demand for labor skill quality.

This research argues that the human capital quality moderates the relationship between IT usage and the innovation performance of firms. The reasons are threefold. First, with the improvement of the width and frequency of firms' IT usage, the number of the IT facilities owned by firms also increases. The use of these facilities, especially automation machines, programmed processes, and other facilities, requires employees to have the ability to use highly computerized systems. Second, the informatization will bring considerable data for firms and lead to profound changes in organizational structure, management practice, and the production process [35]. These changes give employees more discretion, require them to have high data analysis and problem-solving abilities, and increase their communication tasks (including communication with suppliers, customers, colleagues, and subordinates), thereby requiring them to have high coordination, communication, and interpersonal skills. Third, adapting to the new mode of production and organizational structure itself puts forward greater requirements for the quality of employees, requiring them to have stronger cognitive ability, flexibility, and self-management ability than before. Therefore, high-quality human capital (i.e., the ability to use IT facilities, analyze data, solve problems, and perform self-management) can strengthen the positive effects of IT usage width and IT usage frequency on the innovation performance of SMEs. Hence, we hypothesize the following:

Hypothesis 4a: Human capital quality positively moderates the relationship between IT usage width and the innovation performance of SMEs

Hypothesis 4b: Human capital quality positively moderates the relationship between IT usage frequency and the innovation performance of SMEs

Figure 1 illustrates the research model.

2.2. Sample Selection and Data Collection. The data used in this study were obtained from the 2012 World Bank Enterprise Survey (WBES). This questionnaire survey was conducted by the World Bank in 2012 and early 2013; thus, the data correspond to 2011. We chose this dataset for three reasons. First, the WBES adopts a stratified random sampling method to determine the sample firms and covers 25 major cities in eastern, central, and western China and 20 industries [36]; hence, the dataset is balanced and representative. Second, this dataset provides detailed information on the competitive environment, innovation and technology, and business–government relations of firms. More importantly, the dataset includes several key questions directly related to IT usage and the innovation performance of firms. In addition, the respondents are all firm owners or senior managers, thereby guaranteeing data quality, which makes the dataset by far the best to study how IT usage affects the innovation performance of firms. Third, the data for 2012 are the newest data that have been open to researchers for academic use [37]. Notably, the World Bank conducted similar surveys in 2002 and 2005 [38, 39], but these two datasets were relatively far away. More importantly, they did not include key questions for measuring the IT usage of firms. Thus, we utilized the data for 2012, which are available at https://microdata.worldbank.org/index.php/catalog/1559. This dataset has also been used extensively in recent research (e.g., Gao et al. [40]; Mu et al. [41]; Wang and Qi [42]; Zhu et al. [43]), which demonstrates its validity and potential.

A total of 2848 valid samples were obtained through the WBES, including 2700 private firms and 148 fully state-owned enterprises (SOEs). The original data were processed according to the following steps. First, the 148 SOEs were excluded because of their peculiarity. Second, service firms were eliminated because they generally do not engage in formal R&D activities [44]. Third, according to the definition of SMEs (see China's Regulations on the Standards for the classification of small- and medium-sized enterprises, 2011) in China, only firms with fewer than 1000 employees were retained. After the omission of invalid observations for the variables of this study, the final sample comprised 1369 firms.

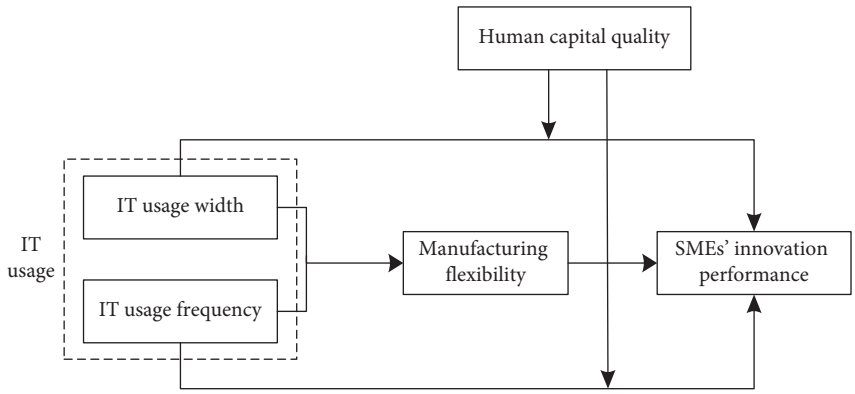

Figure 1: Research model.

2.3. Variable Measurement.

(1) *Dependent Variable*. The dependent variable in the present study is the innovation performance of SMEs. In terms of firm innovation performance, the three most commonly employed measures are the natural logarithm of new product sales, the ratio of new product sales in total product sales, and the number of patents granted by firms. Given that there is a long time lag between patent application and patent authorization and that this research uses cross-sectional data, the number of patent grants is not employed to measure the innovation performance of firms. Xie et al. [45] believed that the natural logarithm of new product sales has the advantage of providing greater construct validity than the ratio of new product sales. Following prior research [45] and considering data availability, we operationalized the dependent variable as the natural logarithm of new product sales.

(2) *Independent Variables*. The independent variables in this study are IT usage width and IT usage frequency. According to the previous description, IT usage width captures the number of the PVC links supported by IT within a firm, while IT usage frequency depicts the average usage frequency of IT in all the PVC links of a firm. The WBES questionnaire investigates the degree of IT support for the following five PVC links: (1) partner relations (suppliers and contractors), (2) product and service enhancement, (3) production and operations, (4) marketing and sales, and (5) customer relations. The optional answers include five categories, namely, never, rarely, sometimes, frequently, and all the time, with a value of one to five. Therefore, the number of PVC links that use IT and the average usage frequency of IT in all PVC links were used to measure IT usage width and IT usage frequency, respectively.

(3) *Moderating Variable*. Human capital quality is the moderating variable in this research. Referring to Zhang et al. [46], it was characterized by the average years of education of all the employees in a firm, which is a common measurement method in the existing research.

(4) *Mediator Variable*. As mentioned earlier, although many scholars have theorized manufacturing flexibility as a multidimensional concept [27, 31], manufacturing flexibility is essentially the ability of a firm to adapt to environmental uncertainty [27]. Following prior research [47] and considering data availability, we used the answers of firms to the following question: "Has the firm taken action to improve production flexibility in the past three years?" in the questionnaire to measure manufacturing flexibility.

(5) *Control Variables*. Following previous research [5, 7, 16], several variables that may influence the innovation performance of SMEs were included as control variables to avoid possible endogenous problems as far as possible. First, firm size (Size) was measured by the natural logarithm of the number of employees. Second, firm age (Age) was measured by the natural logarithm of "the difference between the year of the survey (2012) and the year of firm incorporation plus 1." Third, state-owned enterprise (State) was measured by the proportion of government shares in the firm. It took the value of 1 if the proportion exceeded 50% and 0 if otherwise. Fourth, R&D investment (R&D) was measured as a dummy on the basis of the question of whether the firm had R&D investments. Fifth, technology introduction (Technology) was measured as a dummy according to the question of whether the firm used the technology licensed by a foreign-owned company. Sixth, international quality certification (Certification) was measured by a dummy variable indicating whether the firm had an internationally recognized quality certification, such as ISO 9000, ISO 14000, or HACCP. Seventh, export intensity (Export) was defined as the proportion of direct export and indirect export sales in the total sales. Eighth, financing constraint (Financing) was defined as the degree of the impact of financing availability on the current operations of firms (0 = no obstacle; 1 = minor obstacle; 2 = moderate obstacle; 3 = major obstacle; and 4 = very severe obstacle). Ninth, business–government relations (Relation) were defined as the proportion of time spent by firm executives in a typical week over the previous year in dealing with the requirements

imposed by government regulations (e.g., dealing with officials and completing forms involving taxes, customs, labor regulations, licensing, and registration). Tenth, the gender of the top manager (Gender) was measured by a dummy variable indicating whether the top manager was male. Last, the management experience of the top manager (Experience) was defined as the years of experience working in the current sector. In addition, the industry and city dummy variables were introduced into all regression models, except where noted, to control industry and city-fixed effects, respectively.

2.4. Model Selection. Considering the characteristics of the dependent variable in this paper and referring to existing studies, this research established the following linear regression model to investigate the impact of IT usage (including IT usage width and IT usage frequency) on the innovation performance of SMEs as follows:

$$\mathrm{IP}_{jic} = \alpha + \beta_1 \mathrm{ITW}_{jic} + \beta_2 \mathrm{ITF}_{jic} + +\gamma X_{jic} + \varepsilon_{jic}, \quad (1)$$

where IP_{jic} represents the innovation performance of firm j in industry i and city c. ITW_{jic} denotes the IT usage width of firm j in industry i and city c. Furthermore, ITF_{jic} stands for the IT usage frequency of firm j in industry i and city c. X_{jic} refers to the set of the control variables described above. ε_{jic} is the random error term.

3. Empirical Results

3.1. Descriptive Statistics. Table 1 exhibits the descriptive statistical results of the variables. In the research sample, the average value of the IT usage width of firms is 4.292, which indicates a relatively high level of the IT usage width of sample firms. More specifically, IT usage involves approximately four PVC links. The average value of the IT usage frequency of firms is 3.234, which indicates that the IT usage frequency of sample firms is between "sometimes" and "frequently" (roughly medium level).

In this study, multicollinearity diagnosis was performed for the variables, and the variance inflation factor (VIF) of each variable was calculated. The results validate that the VIF values of all variables are less than 3 (Table 1), far lower than the critical value of 10 [48]. Therefore, there is no multicollinearity among variables in this study.

3.2. Hypothesis Testing. In this study, STATA 14.0 software was used for empirical analysis. The empirical results report the robust standard errors to minimize the impact of heteroscedasticity caused by using cross-sectional data.

3.2.1. Baseline Results. Table 2 presents the results of the models. Model 1 only includes the control variables, while Model 2 adds the independent variables, including IT usage width and IT usage frequency. The R^2 of Model 2 is significantly higher than that of Model 1, indicating that model explanatory power is significantly enhanced after the independent variables are included. According to the results of Model 2, IT usage width ($\beta = 0.525$, $p < 0.01$) and IT usage frequency ($\beta = 0.540$, $p < 0.05$) have significantly positive effects on the innovation performance of SMEs. H1 and H2 are supported.

The aforementioned empirical results may face the threat and perplexity of endogenous problems for two reasons. First, although this study tried to avoid endogenous problems caused by missing variables, other important explanatory variables may still be omitted due to a limited number of questionnaire questions. Second, there may be a reverse causal relationship between IT usage and firm innovation performance. On the one hand, IT usage can enhance the innovation performance of firms; on the other hand, firms with high innovation performance are more likely to maintain a high level of IT usage (including IT usage width and IT usage frequency). Following prior research [49], the mean value of the IT usage width of firms in the same industry and the same city was taken as the instrument variable (IV) of IT usage width. Similarly, the mean value of the IT usage frequency of firms in the same industry and the same city was taken as the IV of IT usage frequency. We then used these instrumental variables (with 2SLS) to estimate the causal effect of the two endogenous variables (i.e., IT usage width and IT usage frequency). The results of the Hausmann test confirm that the original hypothesis that all explanatory variables are exogenous can be rejected at a significance level of 5%; therefore, performing IV-2SLS estimation is appropriate. Meanwhile, the Wald test affirms that the minimum eigenvalue statistic is 268.46, which is far greater than a corresponding critical value of 4.58. Hence, believing that there is no weak instrumental variable problem is reasonable. The 2SLS regression results (Model 3) confirmed that the regression coefficients of IT usage width and IT usage frequency were significantly positive, consistent with the previous results.

3.2.2. Mediating Effect Test. This study used the Baron and Kenny [50] three-step method to test the mediating effect. In the first step, the regression coefficients of the independent variables to the dependent variable are significant. In the second step, the regression coefficients of the independent variables to the mediator variable are also significant. In the third step, when the independent variables and the mediator variable are included in the model, the regression coefficients of the independent variables to the dependent variable are insignificant or significantly reduced. Table 2 depicts the regression results of the mediating effect model.

According to Model 2 in Table 2, the regression coefficients of IT usage width and IT usage frequency on the innovation performance of SMEs reach a significant level, indicating that IT usage can improve the innovation performance of SMEs. According to Model 7 in Table 2, the regression coefficient of IT usage frequency to manufacturing flexibility is significant, whereas the regression coefficient of IT usage width to manufacturing flexibility is insignificant, indicating that IT usage frequency can improve the manufacturing flexibility of SMEs, whereas IT

Table 1: Descriptive statistics of variables.

Variable name	Indicator name	Mean	Std. dev.	Min.	Max.	VIF
Innovation performance of SMEs	IP	7.016	7.715	0	21.822	—
IT usage width	ITW	4.292	1.410	0	5	2.35
IT usage frequency	ITF	3.234	1.181	1	5	2.41
Human capital quality	Human	10.125	1.903	1	18	1.06
Manufacturing flexibility	Flexibility	0.638	0.481	0	1	1.33
Firm size	Size	4.270	1.082	1.609	6.856	1.32
Firm age	Age	2.502	0.452	0	4.836	1.17
State-owned enterprise	State	3.641	17.369	0	95	1.29
R&D investment	R&D	0.432	0.496	0	1	1.27
Technology introduction	Technology	0.239	0.427	0	1	1.18
International quality certification	Certification	0.702	0.458	0	1	1.28
Export intensity	Export	13.608	26.283	0	100	1.09
Financing constraint	Financing	0.832	0.880	0	4	1.08
Business–government relations	Relation	1.236	2.829	0	35	1.07
Gender of the top manager	Gender	0.915	0.280	0	1	1.03
Management experience of the top manager	Experience	17.053	7.515	1	47	1.23

Table 2: Regression results.

Variables	IP						Flexibility
	Model 1 (OLS)	Model 2 (OLS)	Model 3 (2SLS)	Model 4 (OLS)	Model 5 (OLS)	Model 6 (OLS)	Model 7 (logit)
Constant	2.361 (1.542)	−0.908 (1.566)	−4.779*** (1.444)	−1.052 (1.563)	−1.945 (1.769)	−2.067 (1.767)	−0.962 (0.940)
Size	0.528*** (0.166)	0.393** (0.166)	0.283 (0.177)	0.386**0.166	0.386** (0.166)	0.402** (0.166)	0.090 (0.081)
Age	−0.472 (0.406)	−0.395 (0.396)	−0.105 (0.411)	−0.404 (0.397)	−0.403 (0.397)	−0.394 (0.396)	0.017 (0.178)
State	−0.031***(0.008)	−0.013*(0.008)	0.018**(0.008)	−0.011 (0.008)	−0.010 (0.008)	−0.011 (0.008)	−0.025***(0.006)
R&D	5.565*** (0.431)	5.136*** (0.441)	5.814*** (0.441)	5.033*** (0.447)	5.008*** (0.447)	5.028*** (0.447)	0.924*** (0.179)
Technology	2.590*** (0.483)	2.215*** (0.482)	2.712*** (0.472)	2.159*** (0.481)	2.130*** (0.482)	2.144*** (0.485)	0.564** (0.222)
Certification	0.750* (0.435)	0.536 (0.432)	0.126 (0.419)	0.476 (0.435)	0.467 (0.435)	0.424 (0.435)	0.454** (0.177)
Export	0.001 (0.007)	0.001 (0.007)	−.005 (0.007)	0.001 (0.007)	0.000 (0.007)	−0.001 (0.007)	0.000 (0.004)
Financing	0.374 (0.239)	0.220 (0.235)	0.130 (0.215)	0.201 (0.235)	0.198 (0.236)	0.204 (0.236)	0.208* (0.110)
Relation	0.083 (0.069)	0.046 (0.068)	0.131* (0.067)	0.042 (0.068)	0.034 (0.069)	0.031 (0.068)	0.094 (0.071)
Gender	−0.157 (0.685)	0.145 (0.674)	0.352 (0.653)	0.178 (0.671)	0.190 (0.672)	0.201 (0.674)	−0.269 (0.281)
Experience	0.054 (0.028)	0.044 (0.027)	−0.004 (0.025)	0.042 (0.027)	0.041 (0.027)	0.043 (0.027)	0.016 (0.012)
ITW		0.525*** (0.169)	0.919*** (0.324)	0.510*** (0.168)	0.495*** (0.168)	0.540*** (0.169)	0.001 (0.082)
ITF		0.540** (0.240)	0.968*** (0.370)	0.450* (0.246)	0.444* (0.246)	0.440* (0.245)	0.798*** (0.113)
Flexibility				0.766* (0.442)	0.796* (0.441)	0.777* (0.440)	
Human					0.110 (0.109)	0.096 (0.108)	
ITW × Human						0.169* (0.100)	
ITF × Human						−0.077 (0.127)	
Industry-fixed effect	Controlled	Controlled	—	Controlled	Controlled	Controlled	Controlled
City-fixed effect	Controlled	Controlled	—	Controlled	Controlled	Controlled	Controlled
R^2/Pseudo R^2	0.429	0.444	0.355	0.445	0.446	0.447	0.337
F	41.72***	45.77***	—	45.28***	44.43***	43.27***	—
Wald chi2	—	—	1476.10***	—	—	—	384.65***
N	1369	1369	1369	1369	1369	1369	1365

Note. * $p < 0.1$, ** $P < 0.05$, and *** $P < 0.01$; since the key variables in Model 3 are mean data in city-industry level, the industry-fixed effect and city-fixed effect are not included in the model.

usage width has no significant effect on manufacturing flexibility. Model 4 in Table 2 shows that when IT usage width, IT usage frequency, and manufacturing flexibility are included in the regression model simultaneously, the regression coefficient of IT usage frequency to the innovation performance of SMEs is still significantly positive. Nonetheless, its value is significantly reduced, and its significance is greatly weakened, from the original ($\beta = 0.540$, $p < 0.05$) to ($\beta = 0.450$, $p < 0.1$). This indicates that manufacturing flexibility partially mediates the relationship between IT usage frequency and the innovation performance of SMEs; hence, H3b is verified. However, H3a is not supported; that is, manufacturing flexibility does not play a mediating role between IT usage width and the innovation performance of SMEs. The reason may be that the achievement of manufacturing flexibility relies on the full acquisition of high-quality information [51, 52], while the acquisition of enough high-quality information depends on high-frequency communication, which is mainly dependent on IT usage frequency rather than IT usage width. If the level of IT usage frequency in a firm is low, then even if the level of IT usage width is very high, the shallow and superficial use of IT is not conducive to obtaining sufficient and accurate high-quality information.

3.2.3. Moderating Effect Test. Table 2 displays the moderating effect of human capital quality on the relationship between IT usage width (or IT usage frequency) and the innovation performance of SMEs. According to Aiken and West [53], IT usage width (or IT usage frequency) and human capital quality were mean-centered, and interaction terms were computed by multiplying these centered predictors to minimize the threat of multicollinearity before further analysis. Model 6 in Table 2 shows that the interaction item between IT usage width and human capital quality is positive and is significant at a level of 10% ($\beta = 0.169$, $p < 0.1$), indicating that human capital quality plays a positive moderating role between IT usage width and the innovation performance of SMEs. Therefore, H4a is verified. To show the moderating effect of human capital quality on the relationship between IT usage width and the innovation performance of SMEs more intuitively, we plotted the interaction effect in Figure 2. Figure 2 illustrates that the regression slopes differ significantly from one another under distinct levels of human capital quality. More specifically, the slope of the regression line is greater when the level of human capital quality is high, indicating that the positive impact of IT usage width on the innovation performance of SMEs is stronger at this point.

According to Model 6 in Table 2, the interaction term between IT usage frequency and human capital quality is

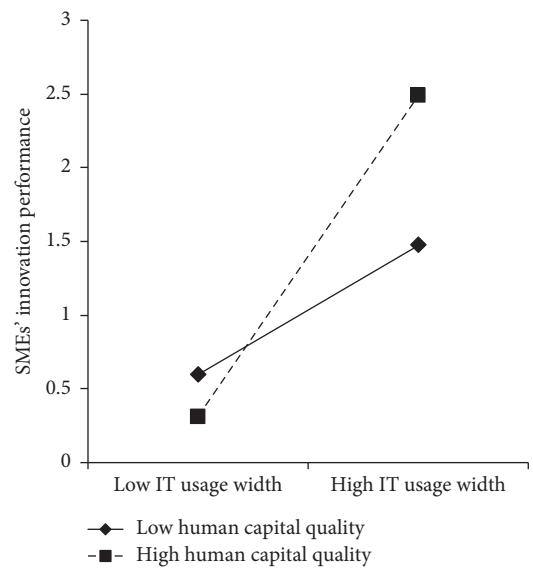

Figure 2: Moderating effect of human capital quality on the relationship between IT usage width and the innovation performance of SMEs.

negative but insignificant ($\beta = -0.077$, $p > 0.1$), indicating that the human capital quality does not have a positive moderating effect on the relationship between IT usage frequency and the innovation performance of SMEs. Therefore, H4b is not supported. The reason may be that, with the improvement of the specialization of labor division within the firm, the employees of each department relevant to the corresponding PVC link are very familiar with their own work; hence, the role of professional competence becomes increasingly important. Accordingly, the impact of the human capital quality (measured by the average education years of employees) on the relationship between IT usage frequency and the innovation performance of SMEs is greatly weakened.

3.2.4. Robustness Checks. The robustness check was performed to verify the stability of the research results. As the WBES data did not provide alternate variables of key variables, the method of replacing key variables for a robustness check is not applicable to this study. Hence, the robustness check was conducted by adjusting the sample size. Specifically, although domestic government agencies and academia define an SME as a workplace with fewer than 1000 employees, the most commonly used criterion is 500 employees [54]. This research thus removed enterprises with more than 500 employees and reconducted the regression analysis (Table 3). The previous research results remain unchanged; that is, the research results are relatively stable.

Table 3: Results of robustness check.

Variables	IP (OLS)				Flexibility (logit)
	Model 8	Model 9	Model 10	Model 11	Model 12
ITW	0.503*** (0.171)	0.485*** (0.169)	0.471*** (0.170)	0.514*** (0.171)	0.007 (0.082)
ITF	0.541** (0.246)	0.431* (0.253)	0.425* (0.252)	0.422* (0.252)	0.790*** (0.114)
Flexibility		0.927** (0.444)	0.956** (0.443)	0.938** (0.442)	
Human			0.103 (0.111)	0.089 (0.110)	
ITW × Human				0.173* (0.102)	
ITF × Human				−0.092 (0.130)	
Constant	−0.618 (1.611)	−0.773 (1.608)	−1.608 (1.830)	−1.725 (1.829)	−1.183 (0.954)
Control variables	Controlled	Controlled	Controlled	Controlled	Controlled
Industry-fixed effect	Controlled	Controlled	Controlled	Controlled	Controlled
City-fixed effect	Controlled	Controlled	Controlled	Controlled	Controlled
R^2/pseudo R^2	0.436	0.439	0.439	0.440	0.334
F	41.05***	40.57***	39.82***	38.75***	—
Wald chi2	—	—	—	—	367.91***
N	1312	1312	1312	1312	1308

Note. * $p < 0.1$, ** $P < 0.05$, and *** $P < 0.01$.

4. Conclusions and Discussion

4.1. Conclusions. In light of the fact that firms increasingly use IT as a facilitator of innovation, this study proposes a new perspective (PVC) that offers a basis for interpreting the difference of IT usage among firms. On the basis of the novel perspective, this research also develops a typology of IT usage, which considers IT usage width and IT usage frequency. Within a valid research framework, this study examines how IT usage (including IT usage width and IT usage frequency) impacts the innovation performance of SMEs.

This research yields some intriguing findings. First, our findings validate that SMEs could reap innovation gains from IT usage. This finding concurs with the literature [55–59] that IT usage matters for firm innovation, and it supports the finding that the driver of IT impacts is IT usage rather than IT investment [60]. Second, IT usage width and IT usage frequency have a significantly positive impact on the innovation performance of SMEs. This finding broadens our vision to realize the IT usage of firms and paves the way for a new direction in the link between IT usage and firm innovation. Third, the findings of this study verify that manufacturing flexibility partially mediates the relationship between IT usage frequency and the innovation performance of SMEs, confirming the results of previous studies [28, 29] that IT can enhance firm flexibility. Finally, this study shows that human capital quality has a significantly positive moderating effect on the relationship between IT usage width and the innovation performance of SMEs. This finding provides new empirical evidence to a heated debate as to whether human capital and IT are complements or substitutes in predicting the performance of firms [33, 34, 61, 62]. This finding also broadens the still fragmentary knowledge of the conditions under which IT usage could have more or less positive effects on the innovation performance of firms.

4.2. Theoretical Contributions. This study makes several theoretical contributions. First, it contributes to the IT usage research in that it is an initial attempt to study IT usage from the PVC perspective. Second, this research contributes to the firm innovation literature by analyzing whether IT usage (including IT usage width and IT usage frequency) helps firms enhance innovation performance. Third, the study identifies the mediator with which IT usage influences the innovation performance of SMEs. Fourth, it uncovers interesting findings on the moderating effects of human capital quality on the relationship between IT usage width, IT usage frequency, and the innovation performance of SMEs.

4.3. Managerial Implications. Our findings have important managerial implications. First, this study offers a brand-new perspective of IT usage, which may lead to the improved prioritization of IT strategies. Specifically, making IT investments is necessary, and intensive IT usage is also essential in enhancing the innovation performance of SMEs. Moreover, firms should examine the level of IT usage from the PVC perspective. Second, expanding IT usage width and improving IT usage frequency are vital to improve the innovation performance of SMEs, and neither should be overemphasized at the expense of the other. Third, our findings indicate that, to enhance manufacturing flexibility, firms should pay more attention to improving IT usage frequency. Fourth, the moderating effects of human capital quality on the link between IT usage and firm innovation performance recommend business managers to adhere to the principles of "different firms, different strategies." More specifically, when implementing IT usage strategies (including expanding width strategy and improving frequency strategy), business managers should decide whether the practices of the human resource strategy should be adjusted (e.g., recruiting more highly educated employees) to maximize the positive effects of IT usage on firm innovation performance.

4.4. Limitations and Future Research. This study has several limitations, which may pave avenues for further research. First, the research only focused on SMEs in China; therefore,

whether its conclusions apply equally to large firms or firms in other countries needs further investigation. Second, it relies on cross-sectional data due to the limitation in data availability, which makes us unable to infer more reliably the causal relationship between IT usage and the innovation performance of firms. Nonetheless, we have tried to ensure the reliability of our conclusions by selecting appropriate instrumental variables for 2SLS regression. Future studies could conduct their analyses in a panel data context to provide greater exploratory power. Third, one should consider that the results presented in this study are based on an "imperfect" measure of the IT usage of firms. This research investigated the IT usage of SMEs, but it did not elaborate on which IT facilities are specifically included. Notably, if the IT only includes telephone, fax, e-mail, and broadband and network connections, then it is no surprise that firms have a similar level of IT usage, particularly IT usage width. Moreover, the rapid development of IT infrastructure has led to increased necessity and probability to conduct comparative research by using the latest available data. To confirm the robustness of our findings or yield new discoveries, we hope to investigate the impact of IT usage on the innovation performance of firms while focusing on specific IT facilities and using new firm-level survey data in the near future.

Data Availability

The data used to support the findings of this study may be released upon request to the World Bank, which can be contacted at https://microdata.worldbank.org/index.php/catalog/1559.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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