*sustainability*

*Article*

# Research on the Digital Transformation of Producer Services to Drive Manufacturing Technology Innovation

**Zhihua Lai [1], Bifeng Wang [2,*] and Xiang He [3,4]**

1 College of Science & Technology, Ningbo University, Ningbo 315211, China
2 School of Economics and Management, Ningbo University of Technology, Ningbo 315211, China
3 Business School, Ningbo University, Ningbo 315211, China
4 Zhejiang Study Base of lndividuals of Non-Public Sectors of the Economy, Ningbo University, Ningbo 315211, China
* Correspondence: wbf1995@139.com; Tel.:+86-13363825832

**Abstract:** The digital transformation of producer services contributes to the development of manufacturing technology innovation through an intermediary role, providing an important policy basis for the effective implementation of China's innovation-driven development strategy and digital transformation. In this study, we selected panel data collected from 30 provinces, autonomous regions, and municipalities in China from 2013 to 2020 and applied a spatial Durbin model that included mediating effects to examine the mediating transmission paths of the effect of the digital transformation of producer services on manufacturing technology innovation. Our results showed that: (i) The digital transformation of producer services positively affects local manufacturing technology innovation and generates positive spatial spillover effects on neighboring regions. (ii) The digital transformation of producer services affects manufacturing technology innovation through three paths, including industrial productivity, knowledge stock, and the market environment. The direct effect of industrial productivity is the largest, followed by the market environment and knowledge stock, while the spillover effect of knowledge stock is the largest, followed by market environment and industrial productivity. (iii) There is regional heterogeneity in the mediating effect of the digital transformation of producer services, with the direct effect of industrial productivity being the largest in the east and the spillover effect of the market environment being the largest in the central region.

**Keywords:** digital transformation of producer services; technological innovation; intermediate effect; spatial Durbin model

check for updates

**Citation:** Lai, Z.; Wang, B.; He, X. Research on the Digital Transformation of Producer Services to Drive Manufacturing Technology Innovation. *Sustainability* **2023**, *15*, 3784. https://doi.org/10.3390/su15043784

Academic Editors: Andrés Fernández Miguel, Maria Pia Riccardi, Fernando Enrique García-Muiña, Davide Settembre-Blundo, Alfonso Pedro Fernández del Hoyo and Valerio Veglio

Received: 9 January 2023
Revised: 7 February 2023
Accepted: 15 February 2023
Published: 19 February 2023

**Copyright:** © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

## 1. Introduction

With the integrated breakthrough and penetration of next-generation information and communication technologies, frontier technologies such as big data, cloud computing, and the Internet are advancing resource allocation, production methods, and organizational structure optimization with unprecedented breadth and depth [1]. Digital transformation has become an important feature in high-quality economic development [2], which is conducive to improving the production efficiency of the service industry. The producer service is an offshoot of the manufacturing industry and is dominated by finance, information R&D, and technology services, which are knowledge-, technology-, and talent-intensive [3]; as an intermediate input to the manufacturing industry, it helps to introduce increasingly specialized human and intellectual capital into the manufacturing production process [4]. Its digital transformation refers to the process of change in which digital technologies, such as the Internet of Things, Industrial Internet, machine-to-machine communication, artificial intelligence, and machine vision, are applied extensively in production, operation, and service processes, or where traditional digital technologies are replaced by advanced digital technologies [5,6] in order to revolutionize existing business models and organizational processes [7], characterized by digital technology applications, smart manufacturing, internet business models, and modern information systems [8]. For example, after-sales service and product training and consultation use digital technology to deconstruct and recode the content and process of their services such that they can be traded in a digital form in the virtual space (e.g., remote operation and maintenance, online training, etc.) to break time–space synchronization and reduce transaction costs [9]. Nike and other companies embed sensors in sports shoes to provide users with health advice services by collecting their exercise data and include users in the service innovation process through the connecting role of digital technology to provide targeted services, improve the customer service experience and service quality, provide value-added services to users, and expand the functions of products. According to the White Paper on the Development of China's Digital Economy [10], the digital economy penetration rates of China's service, manufacturing, and agricultural industries increased from 37.8%, 19.5%, and 8.2% in 2019 to 40.7%, 21%, and 8.9% in 2020, respectively, which indicates that the breadth and depth of the integration of digitalization and various fields of society continue to expand. Promoting the digital transformation of producer services not only helps to inject increasingly specialized human and intellectual capital into the manufacturing production process [4], but is also an important supporting force in deepening structural reform on the supply side and strengthening the foundation of high-quality national economic development.

Digital transformation compresses the spatial and temporal distance associated with information transmission, helps to enhance the breadth and depth of inter-regional economic activity association [11]—effectively expanding the service radius [12], empowering the structural upgrading, and improving the productivity of the service industry [13]—and provides an important historical opportunity for the service industry to improve quality and efficiency under a background of new technological change. Digital transformation provides several advantages to the service industry, including improving service supply and demand, optimizing resource allocation efficiency [14], reducing transaction costs, and promoting transformation [15]. These changes will transform the service into an economy of scale and scope via the long-tail effect [9]. The new services represented by "digital+" are expected to become a new driving force for China's economic growth [16] and play an active role in enhancing the total factor productivity of the service industry by promoting technological innovation [17].

Digital transformation facilitates the integration of all parties' advantageous resources, encourages the formation of cross-sectoral and networked collaborative innovation platforms, and promotes the increasing importance of service elements such as R&D and design, production management, personnel training, trade and logistics, and financial guarantee in the sharing of manufacturing chain inputs through the integration, sharing, and re-creation of information, knowledge, and innovation resources [18]. Under the impetus of the Internet, the business model of enterprises has changed from "product-centered" to "customer-centered", and enterprises have realized precise docking with users with the help of new technologies, new platforms, and new models. These enterprises can expand their professional services, such as information consulting, operation and maintenance, product development, system integration, modern logistics, and financial leasing, and continuously broaden the scope of the service industry, thus promoting the servicization of manufacturing enterprises [19]. With the development of technologies such as the Internet of Things and big data analytics [20], the scope of services offered by service companies has changed. With the help of cloud platforms and cloud ecology, new technologies such as machine learning, data mining, IoT, and blockchain are now used to obtain consumer behavior and consumption data in a fast and timely manner to form a digital portrait of customers, which allows companies to provide targeted services to customers, improve their service experience and service quality, and promote the further extension of value-added enterprise products to the service segment [21]. On the one hand, this helps enterprises to better manage sales operations and maintain customer relationships at the front end; on the other hand, it also helps enterprises to realize product customization at the back end [22]. Enterprises use data analysis to assess their platform and promote integration and collaboration between the front end (sales) and back end (manufacturing) through the adjustment of organizational structures and processes, which promotes organizational efficiency [23]. Meanwhile, this process also stimulates organizational vitality and creates a good atmosphere for enterprise innovation. In addition, the IOT provides technical support for product information sharing, which not only helps companies to train their customers, but also helps customers to participate more easily in companies' innovation processes [22].

There are few relevant studies in the existing literature that directly explore the impact of the digital transformation of productive service industries on manufacturing technology innovation, mainly focusing on the impact of the digital transformation of service industries on the improvement of productivity, digital service inputs, manufacturing value, etc. These existing studies provide useful references for discussing the relationship between the digital transformation of productive service industries and manufacturing technology innovation. Compared with existing research, the innovation of this study mainly lies in the following three aspects: (1) The influence mechanism of the digital transformation of producer services on manufacturing technology innovation is divided into three aspects—industrial structure optimization, knowledge stock, and the market environment—and the specific action path is clarified. (2) An index system is constructed from four dimensions—the digital talent, digital input, digital income, and digital infrastructure of producer services—and the entropy value method is used to measure the comprehensive index of the digital transformation of producer services. (3) Combining the mediating effect model and spatial econometric model, the geographic and economic nested matrix is explored in depth not only to test the specific path of the effect of the digital transformation of producer services on manufacturing technology innovation, but also to explore the direct and spatial spillover effects of different factors in depth.

This paper is structured as follows: Section 1 includes an introduction, which reviews the current literature on the effect of the digital transformation of the service industry on the improvement of the productivity, digital service input, and value of the manufacturing industry. Section 2 includes mechanism analysis—that is, exploring the mechanism of the mediating effect of the digital transformation of the productive service industry on manufacturing innovation—and hypotheses formulation. Section 3 includes our research hypothesis, the construction of an econometric model, variables, and a description of data sources. Section 4 details the tests carried out on the spatial econometric model and an empirical analysis of the impact of the digital transformation of the productive service industry on manufacturing innovation through basic regression, a mediating effect test, a heterogeneity test, and a stability test. Section 5 is the conclusion, in which we put forward suggestions to promote the impact of the digital transformation of producer services on manufacturing innovation.

## 2. Mechanism Analysis and Hypothesis Formulation

### *2.1. Digital Transformation of Producer Services, Industrial Productivity, and Manufacturing Technology Innovation*

As an important input factor in the value chain of the manufacturing industry, the digital transformation of producer services fosters the optimization of manufacturing structure and positively promotes manufacturing technology innovation through human capital, innovation input, and industrial integration effects. First, with respect to the human capital effect, producer services are knowledge-, technology-, and talent-intensive and are an important intermediate input for manufacturing; their digital transformation promotes the injection of increasingly specialized human and knowledge capital into the manufacturing production chain [4]. The digital transformation of producer services further decreases the communication and cooperation between manufacturers, enhances the concentration of specialized technical talents, and facilitates the formation of a thick and diverse labor pool. Labor market sharing promotes the quantity and quality of matching between innovative talents and high-tech enterprises, thus providing human capital support for manufacturing innovation development. At the same time, it increases the opportunities for the "network clustering" and "cloud cooperation" of high quality human capital, creating a good collective learning and innovation environment. In addition, the concentration of high-quality human capital enhances the matching high-level human capital required to transform the service industry from a labor-intensive to capital-intensive industry, and then to a knowledge- and technology-intensive industry [24], which promotes the transfer of factors from traditional service industries with low allocation efficiency to knowledge- or technology-intensive productive services with high allocation efficiency [25,26], accelerating the optimization and upgrading of input factors in productive service industries. Second, with respect to the innovation input effect, the digital transformation of producer services promotes technology upgrading within each industry and technology dissemination and diffusion among different industries, driving the collection of more innovation resources and elements, changing production methods and organizational structures [11], and constantly fostering new innovation opportunities. The digital transformation of producer services promotes the accelerated sharing and flow of knowledge and data elements among enterprise systems [27] to achieve technological breakthroughs and the collaborative development of enterprise innovation, which continuously broaden the application scenarios for the integration and penetration of data and traditional elements and expand from the sharing of products and services to the sharing of production capacity and innovation capability. With the help of key data sharing to optimize the allocation of manufacturing resources, the collaborative development of R&D across enterprises, regions, and industries is realized, boosting innovation enhancement with data value networks. While promoting the efficiency of matching manufacturing and productive service industries, this also reduces the transaction costs associated with information collection and screening and other aspects of innovation cooperation, which in turn stimulates an increase in enterprise R&D investment and enhances technological innovation [28]. In addition, information on diverse and customized product consumption needs is transmitted to manufacturers in real time, facilitating them to continuously improve and optimize their products [29], which reduces costs while enhancing the targeting of R&D [17]. Thus, manufacturers can dynamically adjust and design new, more compatible business models in order to adapt to the changing external environment [30]. Third, with respect to the industry integration effect, accelerating the digital integration of service industries and the vertical integration of digital industry chains further realizes the magnified multiplier effect of digital technology on enhancing total factor productivity and achieving high-quality development. The digitalization of producer services breaks the physical distance in time and space; promotes the diffusion of knowledge and technology between industries; accelerates the integration of products, businesses, and markets between industries; and constantly gives birth to new forms and new models of business. Cross-industry digital integration facilitates the realization of complementary technologies and interactions, which not only shortens the time and cost associated with the dissemination of explicit knowledge across industries, but also extends and expands tacit knowledge. It is required to continuously strengthen the degree of informatization and virtualization of producer services, realize the extension of the digital content industry chain to the front and back of the service industry chain using the digital medium, and promote the vertical integration of manufacturing and service. In addition, it promotes a better connection between producer services and the manufacturing industry, innovates business processes, reduces the technical threshold for manufacturers to obtain production services, and accelerates the breakdown of technical barriers in the process of industrial integration. It helps to build a collaborative production service network system of "service + manufacturing", promote changes in manufacturing production methods, and enhance market competitiveness, becoming a key factor in the intelligent transformation of the manufacturing industry. For example, Fintech service companies provide services for tens of millions of micro and small enterprises through financial inclusion, thus providing innovation capital for real enterprises.

Based on this, we propose the following hypothesis:

**Hypothesis 1 (H1).** *The digital transformation of producer services enhances manufacturing innovation by promoting industrial productivity. Therefore, industrial productivity improvement is the first path through which the digital transformation of producer services affects manufacturing technology innovation.*

### *2.2. Digital Transformation of Producer Services, Knowledge Stock, and Manufacturing Technology Innovation*

The digital transformation of producer services accelerates information and technology exchange, dissemination, and diffusion, which in turn increases the innovation knowledge stock through the factor flow effect, cooperation network effect, and knowledge spillover effect, efficiently aggregating more innovation knowledge resources as intermediate inputs of manufacturing industry. With respect to the factor flow effect, digital service elements must contain rich information technology, knowledge, human capital, and other high-end production elements in order to build a high-level digital service industry chain; promote the penetration of producer services, especially high-end producer services; eliminate the spatial distance barrier between industries with the help of digital technology; effectively promote the free flow of production elements between cities and industries; enhance the efficiency of knowledge dissemination; realize the development of industrial collaborative innovation; and increase the innovative knowledge stock [31]. Accelerating the flow and diffusion of innovation resources can increase the flow of tacit knowledge brought about by the flow of human capital [32]. Reducing the transaction costs and agglomeration costs associated with innovation factors is one way to create a good collective learning and innovation environment, promote knowledge flow and sharing, accelerate knowledge spillover and diffusion, and enhance technological innovation capacity. The flow of innovation factors within and between regions can be promoted by weakening spatial and temporal constraints and transaction costs and improving the degree and efficiency of matching supply and demand [33]. Ensuring the adequate flow of technology and human capital helps to enhance technological innovation capacity and advance human capital concentration. By promoting the exchange and collision of knowledge and technology, the emergence of new innovation opportunities and technological breakthroughs is encouraged. With respect to the cooperative network effect, the digital transformation of producer services helps establish digital "links" among fixed assets and equipment—including technology research and development, procurement, manufacturing, and sales—build a resource sharing platform, realize resource sharing among enterprises, help enterprises obtain expertise from multiple channels, promote more innovative thinking [34], enhance the attraction of external knowledge and technology, and accelerate the formation of new product ideas and innovative concepts. It is more conducive to the exchange and sharing of data and knowledge among the internal systems of enterprises [27], forming a cross-domain and networked collaborative innovation ecology where service elements such as R&D and design, production management, personnel training, trade logistics, and financial guarantee occupy an increasingly important position in the total input of the manufacturing industry [18]. This effect accelerates the gathering of innovation subjects and innovation resources, forms a cooperative innovation network that is intertwined vertically and horizontally, gives full play to the network synergy effect of the innovation platform, and forms an open and collaborative innovation mechanism with complementary advantages and the linkage of elements. With respect to the knowledge spillover effect, the service industry is generally less dependent on resources; however, it usually requires facing diversified consumers in close proximity [35]. Therefore, its digital transformation can significantly enhance inter-regional accessibility, strengthen the free flow of factors and products in space, promote factor clustering and "learning exchange" among enterprises, change highly localized features of traditional knowledge [36,37], stimulate "innovation bursts", and enhance regional innovation capacity and innovation spillover effects. The digital transformation of producer services promotes knowledge flow and sharing, accelerates knowledge spillover and diffusion, and greatly reduces the difficulty of obtaining knowledge, technology, and other innovation resources in the manufacturing industry. Under the conditions of complete knowledge and information sharing, the spillover effects of both technology inflow and outflow between industries stimulate R&D in a balanced manner [38], and stronger spillover effects will be more beneficial to the development of the whole industrial chain, promote the innovation activities of downstream manufacturers [39], and even force R&D innovation in upstream industries [40]. Manufacturing firms are able to enhance their own R&D innovation by absorbing technological spillovers from diversified intermediate goods [41]. This constitutes an innovation ecology of industrial synergy and correlation, forming a cross-technology, cross-field, and cross-industry fusion-type innovation behavior with diversified industrial clusters, continuously extending into new industries, forming a layout of digital soft services and hard manufacturing in the spatial scope, and providing stronger power for innovation-driven development. Based on this, we propose the following hypothesis:

**Hypothesis 2 (H2).** *The digital transformation of producer services contributes to manufacturing technology innovation by increasing the knowledge stock. Therefore, knowledge stock is the second path by which the digital transformation of producer services influences manufacturing technology innovation.*

### *2.3. Digital Transformation of Producer Services, the Market Environment, and Manufacturing Technology Innovation*

The digital transformation of producer services accelerates the flow and sharing of production factors such as knowledge, technology, and human capital, which helps reduce transaction costs and improve the market environment through technological progress, market competition, and the optimal allocation of resources. With respect to the effect of technological progress, digital service elements are rich in information technology, knowledge, human capital, and other high-end production factors, which inject new vitality into the manufacturing industry. The formation of a new model of data-driven enterprise production and operation is conducive to achieving quality and efficiency improvement, as well as staff and cost reduction, which ultimately manifest as a decline in comprehensive costs and improvement in efficiency, representing another form of technological upgrading [42]. Digital transformation provides multi-dimensional development guarantees for the accelerated development of knowledge-intensive service industries such as digital finance and digital government [43], thus enhancing the demand for innovation factors associated with knowledge-intensive service enterprises. The allocation of innovation factors to knowledge-intensive service industries is promoted, which enhances the supply of high-end and diversified intermediate service factor inputs. Manufacturers enhance the innovation value of their own final goods by absorbing technology spillovers from intermediate products and services. By relying on high-value and diversified innovative products to meet the customized needs of consumers, manufacturing enterprises are able to rapidly expand their market share, further stimulating innovation in manufacturing enterprises. Strengthened upstream and downstream linkages generate economies of scale, giving enterprises greater economic space for technological innovation. With respect to the market competition effect, the digitization of producer services lowers the barriers to entry between industries, enhances the substitutability of service elements, and intensifies the degree of competition between enterprises, generating a strong incentive effect that forces enterprises to innovate continuously for survival and efficiency. This motivation leads to continuous technological innovation, where the application of technology in industrial development can be used transform productivity [44]. The digital transformation of producer services can promote healthy competition in an open environment, increase economic benefits, and improve innovation efficiency by sharing knowledge, stimulating demand, and increasing industrial structure flexibility, which gives rise to an intensive industrial system while improving the overall quality of the industrial chain in order to promote the high-quality development of industrial innovation. A perfect factor market promotes the transfer of factors such as labor, capital, and technology to the service sector with a higher allocation efficiency and encourages structural upgrading in the service sector [24]. At the same time, a free and orderly factor market can ensure the adequate flow of technology and human capital, which helps to enhance technological innovation capacity and advanced human capital concentration. Digital transformation drives the structural upgrading of the service industry through the effects of technological innovation and advanced human capital and injects new dynamic energy into many fields, including product manufacturing and the technological progress of enterprises. It shortens information exchange time and improves the accuracy of information exchange between consumers and producers, eases the contradiction of information division between the consumer side and the innovation side, facilitates a direct connection between the market's demand creativity and enterprises' innovation resources, and improves enterprises' adaptive innovation ability and innovation efficiency. With respect to the optimal allocation of resources, the empowering effect of digital transformation on producer services helps to improve the efficiency of the allocation of production factors and stimulate the innovation vitality of enterprises in the agglomeration area, which can help manufacturing industries accurately identify innovation opportunities and reasonably allocate innovation resources. With the advantages of transparency, sharing, and disintermediation, the platform economy and digital technology are integrated into the traditional service industry, gradually eliminating the disadvantages of the traditional business model, such as unregulated service, high transaction costs, and asymmetric and untimely information, and enhancing the appropriateness of supply and demand to promote the optimal allocation of traditional service industry resources. This shortens the matching time between innovative talents, R&D, and technical positions and the matching efficiency of the market is improved, which is conducive to the efficient allocation of innovation factors in space and stimulates innovation vitality. The effective integration and precise matching of supply and demand is carried out, which solves the coordination or transaction cost problem and greatly improves the efficiency of resource allocation [45]. The temporal and spatial boundaries between industries are broken by digital technology, which effectively reduces institutional transaction costs and search costs for manufacturing enterprises when purchasing high-end intermediate goods. The connection between manufacturing and high-end productive services becomes closer, which is one of the important reasons for the deepening division of labor among manufacturing enterprises [46]. Based on this, we propose the following hypothesis:

**Hypothesis 3 (H3).** *The digital transformation of producer services provides new momentum for manufacturing technology innovation by improving the market environment and stimulating innovation. Therefore, the market environment is the third path through which the digital transformation of producer services affects manufacturing technology innovation.*

## 3. Research Design

### *3.1. Econometric Model Specification*

The digital transformation of producer services, especially the digital transformation of high-end producer services, not only enhances cross-organizational and cross-industry communication and cooperation in the region, but also helps in the sharing of advantages between neighboring regions. In order to analyze the local and spatial spillover effects and attenuate the endogeneity bias caused by the absence of important variables [47], we adopted a mediating effects model that included spatial interactions. The model is specified as follows:

$$Inn_{it} = \alpha_0 + \alpha_1 \sum_{j=1}^{n} w_{ij} Inn_{jt} + \alpha_2 Dtp_{it} + \alpha_3 \sum_{j=1}^{n} w_{ij} Dtp_{jt} + \alpha_4 X_{it} + \alpha_5 \sum_{j=1}^{n} w_{ij} X_{jt} + \varepsilon_{it}, \quad (1)$$

$$M_{it} = \beta_0 + \beta_1 Dtp_{it} + \beta_2 \sum_{j=1}^{n} w_{ij} Dtp_{jt} + \beta_3 X_{it} + \beta_4 \sum_{j=1}^{n} w_{ij} X_{jt} + \mu_{it}, \quad (2)$$

$$Inn_{it} = \lambda_0 + \lambda_1 \sum_{j=1}^{n} w_{ij} Inn_{jt} + \lambda_2 M_{it} + \lambda_3 Dtp_{it} + \lambda_4 \sum_{j=1}^{n} w_{ij} Dtp_{jt} + \lambda_5 X_{it} + \lambda_6 \sum_{j=1}^{n} w_{ij} X_{jt} + \eta_{it}, \quad (3)$$

where $Inn_{it}$ denotes the explained variables, $Dtp_{it}$ represents the core explanatory variable, $M_{it}$ denotes the mediating effect variables, $X_{it}$ represents the control variables, and $w_{ij}$ is the Nth-order spatial weight matrix with diagonal elements of zero. The subscripts $i$ and $t$ refer to the region and time, respectively. First, Model (1) was regressed to test the effect of the digital transformation of producer services on manufacturing technology innovation; if the $\alpha_2$ parameters passed the variable significance test, the effect of the digital transformation of producer services on manufacturing technology innovation was deemed statistically significant. Second, Model (2) was regressed to test whether the effect of the digital transformation of producer services on the mediating variables was significant. Finally, Equation (3) was regressed; a positive mediating effect of digital transformation on manufacturing technology innovation was indicated if $\lambda_2 > 0$, $\lambda_3 > 0$, $\lambda_3 < \alpha_2$ and all variables passed the significance test.

### *3.2. Variable Construction*

#### 3.2.1. Manufacturing Technology Innovation (Inn)

In this study, patents granted to industrial enterprises above a designated size were used as the main proxy variable for technological innovation, representing the intermediate output of technological innovation. In addition, the final output of technological innovation was measured using new product sales revenues above a designated size, which could not only be used as part of the robustness test, but could also better reflect the application and commercialization level of innovation and make up for the deficiency in the number of patents in reflecting the quality of innovation results [48]. Technological innovation was expressed using the number of patents granted and the new product sales revenue, taken as logarithm.

#### 3.2.2. Core Explanatory Variables (Dtp)

In this study, producer services mainly included transportation, storage and postal services, information transmission and computer services, software, finance (real estate industry), leasing and business services, scientific research, technical services, and geological survey industries [49,50]. Considering that the digital transformation of producer services is not only influenced by the level of digital inputs in the industries, but also by the level of digital economy development, drawing on Dang et al. (2021) [51], Qi et al. (2022) [52], and Wang et al. (2020) [53], environmental factors were incorporated into the digital transformation index system of producer services. By combining the digital inputs and output levels, we constructed a digital transformation index system containing four dimensions—digital talent, industry digital input, industry digital revenue, and digital infrastructure—and measured the comprehensive index of the digital transformation of the productive service industry (Dtp) using the entropy value method. Here, the digital transformation of producer services can be understood as the use of digital technology to empower industry, promoting a systematic transformation of organization, operation, production, and technology; thus, its content and scope are relatively broad. Given the availability of data, following the approach of Wang et al. (2020) [54], we compiled items related to the information transmission, computer services, and software industries and e-commerce to characterize digital talent, digital inputs, and revenues for the producer services. The specific process was carried out as follows:

First, the indicators $x_{ij}$ are normalized to obtain $x'_{ij}$.

Second, the weights of the $j$th indicator of region $i$ ($z_{ij}$) are calculated.

$$z_{ij} = x'_{ij} / \sum_{i=1}^{m} x'_{ij}$$

Third, the information entropy of the $j$th indicator ($e_j$) is calculated; the smaller the information entropy is, the greater the utility of the information.

$$e_j = -K\sum_{i=1}^{m} z_{ij} ln z_{ij}, \text{ where, } \mathrm{K} = 1/\mathrm{lnm}$$

Then, the weight of the $j$th indicator ($w_j$) is calculated; a larger weight indicates that the indicator has more influence on the composite index.

$$w_j = (1 - e_j)/\left(m - \sum e_j\right)$$

Finally, the digital transformation composite index ($Dtp_j$) is calculated based on the weights.

$$Dtp_j = \sum_{i=1}^{m} w_j \times x'_{ij}$$

Weights for the digital transformation of producer services are shown in Table 1.

**Table 1.** Evaluation index system and weights for the digital transformation of producer services.

| Primary Indicators | Comprehensive Weight | Secondary Indicators | Comprehensive Weight |
|---|---|---|---|
| Digital talent | 0.2516 | Number of computers per million people | 0.0889 |
| | | Number of employees in information transmission, computer services, and software industries in urban units | 0.0888 |
| | | Number of employees in software industry | 0.0739 |
| Industry digital input | 0.2432 | Ratio of the number of R&D personnel to the total population in the software industry | 0.0805 |
| | | Information transmission, computer services, and software industry fixed investment completed as a percentage | 0.0889 |
| | | Ratio of investment in R&D to regional GDP in the software industry | 0.0738 |
| Industry digital revenue | 0.2363 | Ratio of software product revenue to regional GDP in the software industry | 0.0770 |
| | | E-commerce sales to regional GDP ratio | 0.0863 |
| | | Technology market turnover to regional GDP | 0.0730 |
| Digital infrastructure | 0.2689 | Number of websites per 100 enterprises | 0.0942 |
| | | Number of software enterprises to total regional enterprises | 0.0834 |
| | | Ratio of e-commerce enterprises to the total number of enterprises in the region | 0.0913 |

#### 3.2.3. Mediating Variables

Based on the above theoretical analysis, the following mediating variables were selected: industrial productivity (IP), used to measure the efficiency of industrial development, in the form of the logarithm of the ratio of manufacturing value added to the number of people employed in the industry [55]; knowledge stock (KS), represented by the number of teachers in general higher education and the number of university students in school, used to measure the urban knowledge stock; and market environment (ME), or the percentage of the number of private and individual employees, used to characterize each province, autonomous region, or municipality.

#### 3.2.4. Control Variables

In order to prevent the omission of important variables, which could lead to biased model estimation, and to more accurately analyze the effect of the digital transformation of productive service industries on manufacturing technology innovation, the following control variables were selected: (1) intensity of R&D investment (Sei), measured as the ratio of the sum of fiscal expenditures on science and technology and education (S&E expenditures) to fiscal expenditures in each province, autonomous region, or municipality; (2) government intervention (Gov), measured as the ratio of fiscal expenditure to GDP; (3) level of economic development (Gdp), measured using the logarithm of GDP per capita; (4) foreign direct investment (Fdi), measured as the logarithm of actual foreign capital used in the year; (5) population density (Pop), measured using the ratio of regional population (year-end resident population) to the area of the administrative region; (6) industrial structure (Upg), measured as the ratio of the value added to the tertiary industry to the value added to the secondary industry; and (7) fixed investment level (Inv), measured as the growth rate of fixed asset investment. The relevant variables are defined in Table 2.

**Table 2.** Definition of variables.

| Variable | Name | Definition |
|---|---|---|
| Inn | Manufacturing technology innovation | Number of patents granted and new product sales revenue (logarithm) |
| Dtp | Comprehensive index of the digital transformation of producer services | Construct an index system of producer services and adopt the entropy value method for measurement |
| Sei | Intensity of R&D investment | Ratio of the sum of fiscal expenditures on science and technology and education to fiscal expenditures |
| Gov | Government intervention | Ratio of fiscal expenditure to GDP |
| Gdp | Level of economic development | Logarithm of GDP per capita |
| Fdi | Foreign direct investment | Logarithm of actual foreign capital |
| Pop | Population density | Ratio of regional population (year-end resident population) to the area of the administrative region |
| Upg | Industrial structure | Ratio of the value added to the tertiary industry to the value added to the secondary industry |
| Inv | Fixed investment level | Growth rate of fixed asset investment |
| IP | Industrial productivity | Logarithm of the ratio of manufacturing value added to the number of people employed in the industry |
| KS | Knowledge stock | Number of teachers in general higher education and university students in school |
| ME | Market environment | Percentage of the number of private and individual employees |

### *3.3. Data Sources*

To ensure the consistency and completeness of the statistical data and based on our research needs, we selected panel data collected from 30 Chinese provinces, autonomous regions, and municipalities (except Tibet) from 2013 to 2020 for empirical analysis. To avoid the impact of price fluctuations on the accuracy and reliability of the estimation results, all indicators measured in monetary terms were price-deflated, where the base period was 2012. The relevant data were obtained from provincial statistical yearbooks and the WIND database; descriptive statistics are shown in Table 3.

**Table 3.** Descriptive statistics of variables.

| Variable | Mean | Min | Max | Std |
|---|---|---|---|---|
| Inn (number of patents granted) | 3.6225 | 1.9590 | 4.8494 | 0.6029 |
| Inn (sales revenue of new products) | 7.3818 | 4.9328 | 8.6465 | 0.6787 |
| Dtp | 0.2310 | 0.0850 | 0.7938 | 0.1178 |
| Sei | 0.1827 | 0.0313 | 0.2562 | 0.1058 |
| Gov | 0.2670 | 0.1129 | 0.7534 | 0.1196 |
| Gdp | 4.7198 | 0.1789 | 5.2154 | 4.3415 |
| Fdi | 5.7793 | 0.6035 | 7.2772 | 4.2663 |
| Pop | 0.0476 | 0.0709 | 0.3924 | 0.0008 |

**Table 3.** *Cont.*

| Variable | Mean | Min | Max | Std |
|---|---|---|---|---|
| Upg | 1.3968 | 0.7439 | 5.2440 | 0.6653 |
| Inv | 0.0759 | 0.0989 | 0.2800 | −0.5660 |
| IP | 91.7129 | 37.6467 | 221.4167 | 28.7620 |
| KS | 94.9388 | 58.8083 | 262.5567 | 3.35 |
| ME | 0.5208 | 0.0895 | 0.7489 | 0.2991 |

## 4. Analysis of Empirical Results

### *4.1. Spatial Econometric Model Specification Test*

This study drew on Elhorst (2010) [56] to conduct a series of relevant tests on the spatial econometric model. First, we adopted the LM method to test whether the spatial effect was caused by spatial lag correlation or spatial residual correlation; the results are shown in Table 4. Based on the linear model without the spatial effect, all the original hypotheses were rejected; therefore, the SAR and SEM models could be accepted at the same time. Second, to ensure the reliability of the model, we further adopted the LR test and Wald test to judge whether the spatial Durbin model (SDM) was more applicable.

**Table 4.** Spatial econometric model specification tests.

| Moran's I | (R)LM_Error | (R)LM_Lag | LR_SAR | LR_SEM | Wald_SAR | Wald_SEM |
|---|---|---|---|---|---|---|
| 4.0616 *** | 7.5838 *** | 5.0333 ** | 59.4147 ** | 61.5799 *** | 60.1601 ** | 62.2804 *** |

Note: ***, and ** denote 1%, and 5% significance levels, respectively.

The Wald test and LR test were used verify whether the SDM model could be degraded to a SAR model or SEM model to further validate the rationality of the SDM model. Both the Wald and LR values indicated that the original hypothesis should be rejected, suggesting that the SDM model was good at portraying the spatial correlation of technological innovation in each province, autonomous region, and municipality. In addition, a Hausman test (87.058 ***) indicated that a fixed effects model could be used. Thus, we adopted a spatial Durbin model with double fixed effects in space and time and constructed a geographic distance matrix, economic distance matrix, and nested matrix including both geographic and economic distances. For the geographic distance matrix, $w_g = 1/d_{ij}$, of which $d_{ij}$—the geographic distance between provinces (or autonomous regions/municipalities)—is measured using the latitude and longitude of each provincial government location. For the economic distance matrix, $w_e = \frac{1}{Q_i - Q_j}$, where $Q$ is the per capita gross regional product of each province (or autonomous region/municipality), reflecting the impact of regional economic development quality on spatial spillover effects. For the nested matrix including both geographic and economic distances, $w = \tau w_g + (1-\tau) w_e (0 < \tau < 1)$ was used as the judgment criterion for selection of $\tau$ in this paper based on the $R^2$ and log-likelihood values. When $\tau = 0.5$, the $R^2$ (0.9947) and log-likelihood (821.0941) values were the largest. Thus, $\tau = 0.5$ was taken to construct the geographic and economic nested matrix.

### *4.2. Base Regression Analysis*

Based on the above test results, we used the SDM model with spatiotemporal double fixed effects to analyze the relationship between the digital transformation of producer services and technological innovation in the manufacturing industry. In order to compare and analyze the robustness of the reference estimates of each variable, the estimation results of other models in turn are listed in Table 5. From the regression results in Table 5, it can be seen that the spatial autoregressive coefficients and spatial error terms are positive and significant at the 1% significance level, which further indicates a positive spatial correlation with manufacturing technology innovation in China's provinces and regions, consistent with the previous Moran 's I index estimation results. Thus, we used spatial econometric regression to test the marginal impact of the digital transformation of producer services on manufacturing technology innovation. The coefficient of the impact of the digital transformation of producer services on manufacturing technology innovation was significantly positive (0.1358); at the same time, there was a positive spatial spillover effect on manufacturing technology innovation in neighboring regions (0.7425). With the development of the digital economy, China's policies have started to focus on the digital transformation of industries, promoting the free flow of production factors such as data and technology between regions and increasing the impact of factor inputs in productive service industries on manufacturing technology innovation [57,58]. Knowledge and technology are the most critical and important elements in enhancing manufacturing technology innovation, and knowledge spillover and technology diffusion promote a positive interaction between the productive service industries and manufacturing industries while reducing the cost and threshold of knowledge absorption and technology learning, which in turn has a positive impact on manufacturing technology innovation [59].

**Table 5.** Benchmark regression results.

| Variable | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| **Inn** | **OLS** | **RE** | **FE** | **SEM** | **SAR** | **SDM** |
| Dtp | 0.8868 ***<br>(6.7531) | 0.7869 ***<br>(4.02) | 0.6853 **<br>(2.07) | 0.1691<br>(1.1217) | 0.3761 **<br>(2.4470) | 0.1358 ***<br>(4.9289) |
| Sei | 3.0651 ***<br>(4.0035) | 2.3292 ***<br>(3.90) | 2.3302 **<br>(2.68) | 2.3575 ***<br>(6.0002) | 2.4020 ***<br>(5.1077) | 2.7606 ***<br>(6.9177) |
| Gov | −1.6452 ***<br>(−5.6422) | 1.1264 ***<br>(3.26) | 1.6248 **<br>(2.24) | 0.8795 ***<br>(3.9187) | 0.6907 ***<br>(2.5859) | 1.0142 ***<br>(4.2793) |
| Gdp | −0.9099<br>(−0.5643) | 1.5812 ***<br>(8.64) | 1.7207 ***<br>(7.17) | 0.9562 ***<br>(4.4018) | 0.7756 ***<br>(4.2959) | 1.1213 ***<br>(4.4509) |
| Fdi | 0.0657 ***<br>(6.02734) | 0.0284<br>(0.66) | −0.0148<br>(−0.31) | −0.0203<br>(−0.7511) | −0.0003<br>(−0.0081) | 0.0042<br>(0.15507) |
| Pop | 0.2038<br>(0.1259) | −0.2689<br>(−1.26) | −0.2806<br>(−0.99) | −0.6908 ***<br>(−4.6728) | −0.3485 **<br>(−2.0302) | −0.6168 ***<br>(−3.9789) |
| Upg | −0.1094 ***<br>(−3.0098)) | 0.0421<br>(0.81) | 0.0419<br>(0.53) | −0.0691 *<br>(−1.6802) | −0.0206<br>(−0.4759) | −0.0697 *<br>(−1.7251) |
| Inv | −0.2925 *<br>(−1.5796) | −0.1803 ***<br>(−2.63) | −0.1924 **<br>(−2.46) | −0.0350<br>(−0.7406) | −0.0445<br>(−0.8286) | −0.0749 *<br>(−1.6291) |
| W*Dtp | | | | | | 0.7425 *<br>(1.8828) |
| W*Sei | | | | | | −1.7734 *<br>(−1.5395) |
| W*Gov | | | | | | 1.8687 ***<br>(3.4865) |
| W*Gdp | | | | | | 1.4025 **<br>(2.1148) |
| W*Fdi | | | | | | −0.0381<br>(−0.3979) |
| W*Pop | | | | | | −1.6914 ***<br>(−9.7685) |
| W*Upg | | | | | | −0.1215 *<br>(−1.7946) |
| W*Inv | | | | | | −0.3848 ***<br>(−2.6551) |
| $\alpha_1$ | | | | 1.5100 ***<br>(4.3102) | 1.6539 ***<br>(10.4017) | 1.4643 ***<br>(4.0123) |
| $R^2$ | 0.8352 | 0.7874 | 0.7564 | 0.9932 | 0.9928 | 0.9947 |

Note: *t*-values in parentheses; *, **, and *** denote 10%, 5%, and 1% significance levels, respectively.

*4.3. Test of Mediating Effects*

In this study, we adopted a mediating effects model with spatial effects to test the impact of the digital transformation of productive services on manufacturing technology innovation through industrial productivity, knowledge stock, and the market environment. Drawing on LeSage and Pacer's approach [60], we applied a partial differential method to decompose the direct and indirect effects of the estimated results under the economic-geographic matrix. The direct effect represented the effect of the digital transformation of producer services on local manufacturing technology innovation, while the indirect effect indicated the effect of the digital transformation of producer services on manufacturing technology innovation in neighboring areas. The "local-neighborhood" manufacturing technology innovation effect of the digital transformation of productive services was determined [61], as shown in Table 6.

**Table 6.** Mediating transmission path test for the effect of the digital transformation of producer services on manufacturing technology innovation.

| Effect | | Direct Effect | | | Spillover Effect | | |
|---|---|---|---|---|---|---|---|
| Variable | | Dtp | M | Control Variables | Dtp | M | Control Variables |
| Model(1) | | 0.1177 ** (2.0902) | | YES | 0.6031 ** (2.0162) | | YES |
| Industrial productivity | Model(2) | 0.1531 * (1.7024) | | YES | 0.3192 * (1.8315) | | YES |
| | Model(3) | 0.0943 *** (6.6276) | 0.1205 ** (2.0437) | YES | 0.5048 * (1.7765) | 0.2352 *** (2.9641) | YES |
| Knowledge stock | Model(2) | 0.0744 ** (2.0398) | | YES | 0.1882 *** (3.3140) | | YES |
| | Model(3) | 0.0784 *** (3.5271) | 0.0139 * (2.0139) | YES | 0.4986 * (1.7397) | 1.1118 *** (2.8289) | YES |
| Market environment | Model(2) | 0.0402 ** (2.3656) | | YES | 0.3726 * (1.9342) | | YES |
| | Model(3) | 0.0995 *** (3.6711) | 0.1127 *** (2.8142) | YES | 0.4901 * (1.7987) | 0.3030 ** (2.1285) | YES |

Note: Due to space limitations, only the estimation results for the direct and spillover effects of the core explanatory and mediating variables of the mediating effect model are reported here. *t*-values in parentheses; *, **, and *** denote 10%, 5%, and 1% significance levels, respectively.

The estimation results in Table 6 show that for both model (1) and model (3), with the inclusion of mediating variables, the digital transformation of producer services contributed significantly to local manufacturing technology innovation. With the digital transformation of producer services, communication and cooperation between different industries are gradually strengthened, which improves innovation efficiency through multi-dimensional aspects, including knowledge diffusion and sharing, industry association strengthening, and cost reduction, and promotes manufacturing enterprises to conduct technology research and development, thus enhancing manufacturing technology innovation. At the same time, the digital transformation of producer services has a positive impact on technological innovation in manufacturing industries in neighboring regions. This indicates that the digital transformation of local productive service industries can not only provide local specialized intermediate services represented by finance, R&D, etc., and technological innovation sharing and spillover, but also can have a positive effect on neighboring manufacturing technological innovation based on the input–output correlation effect [11]. After adding intermediary variables, including industrial productivity, knowledge stock, and market environment, the regression coefficients representing the effect of the digital transformation of productive service industries on manufacturing technological innovation were reduced to different degrees, indicating that the digital transformation of productive service industries can contribute to the development of manufacturing technological innovation by promoting industrial productivity, knowledge stock, and the market environment; this intermediary effect was significant.

In terms of the mediating transmission path of industrial productivity, model (1) in Table 6 shows that the digital transformation of productive service industries positively affects the technological innovation of manufacturing industries in local and neighboring regions. The industrial productivity model (2) shows that both the direct and spillover effects of the digital transformation of productive services were significantly positive at the 10% level, indicating that the digital transformation of productive services significantly contributes to the improvement of industrial productivity [62,63]. The results of the estimation of the industrial productivity model (3) show that after including industrial productivity as a mediating variable in the model, the digital transformation of the productive service industry was found to significantly contribute to technological innovation in manufacturing, and the coefficient of industrial productivity was significantly positive. Comparing the estimated values of the coefficients of each variable, we found that the estimated values of the parameters of the digital transformation of the producer services in model (3) were lower than those in model (1), indicating that the increase in industrial productivity due to the digital transformation of producer services had a significant positive effect on manufacturing technology innovation, i.e., industrial productivity has a significant transmission-mediating effect. The above estimation results fully verify the conclusion that the digital transformation of producer services plays a mediating effect in manufacturing technology innovation through the transmission path of industrial productivity enhancement. Digital transformation gathers a thick pool of high-quality talents and generates a knowledge center for deepening the professional division of labor, which is an important factor in promoting technological innovation in the manufacturing industry.

In terms of the mediating transmission path of knowledge stock, the knowledge stock model (2) in Table 6 shows that the digital transformation of producer services had significant positive effects, indicating that the digital transformation of producer services significantly promotes the accumulation of knowledge stock. The estimation results of the knowledge stock model (3) show that after including the knowledge stock as a mediating variable in the model, the digital transformation of producer services was found to significantly contribute to technological innovation in the manufacturing industry, and the coefficient of knowledge stock was significantly positive. Comparing the estimated values of the coefficients of each variable, we found that the estimated values of the parameters for the digital transformation of producer services in model (3) were lower than those in model (1), indicating that the accumulation of knowledge stock due to the digital transformation of producer services has a significant positive effect on manufacturing technology innovation, i.e., knowledge stock has a significant transmission-mediating effect. With the enhancement of knowledge stock, the digital transformation of high-end productive service industries such as finance and technology is more conducive to embedding in the industrial production chain and promoting technological innovation through knowledge interaction [31,64]. The above estimation results fully validate the conclusion that the digital transformation of productive service industries plays a mediating effect on manufacturing technology innovation through the transmission path of enhancing knowledge stock. Digital transformation technology links industries to form a close innovation cooperation network; its high mobility becomes a mediator of outward technology diffusion, promoting the spillover linkages of industries, closer interaction between productive services and manufacturing industries, innovation interdependence, and expanded innovation effects [65,66]. In this process, the knowledge spillover effects of the digital transformation of productive service industries form closer industrial linkages and constitute an innovation ecology of industrial synergistic linkages [67,68].

In terms of the mediating transmission path of the market environment, the market environment model (2) results in Table 6 show that the direct and spillover effects of the digital transformation of productive service industries on the market environment were positively significant, indicating that the digital transformation of productive service industries significantly contributes to the improvement of the market environment. The estimation results of the market environment model (3) show that after including the market environment as a mediating variable in the model, the digital transformation of producer services was found to significantly contribute to technological innovation in the manufacturing industry, and the parameter estimates for the market environment were significantly positive. Comparing the coefficient estimates of each variable, it was found that the parameter estimates for the digital transformation of producer services in model (3) were lower than those in model (1), indicating that the development of the market environment due to the digital transformation of producer services has a significant positive effect on manufacturing technology innovation, i.e., the market environment has a significant transmission-mediating effect. An improved market environment increases the demand for productive service industries, especially for the transformation and upgrading of traditional industries, with a higher degree of production factor matching and a more market-oriented flow of resources. The digital transformation of producer services is conducive to the positive externality, which facilitates industrial transformation and upgrading by promoting industrial linkages and is conducive to promoting manufacturing technology innovation. The above estimation results fully verify the conclusion that the digital transformation of producer services plays a mediating effect in promoting manufacturing technology innovation through the path of improving the market environment. When the development and application of the digital transformation of productive service industries expand, market information becomes more transparent, which is conducive to reducing information asymmetry problems, lowering transaction costs, and strengthening inter-firm communication and cooperation [69–71]. With the transformation and upgrading of the manufacturing industry, its demand for intermediate products and services tends to diversify; the digital transformation of producer services enhances the allocation efficiency of each factor, which allows for the formation of market competition effects and technological progress effects among complementary industries such as knowledge, technology, and other innovative factors, which in turn have a positive impact on the market environment and the technological progress of the manufacturing industry.

In terms of the magnitude of the mediating effect, the direct effect of industrial productivity is the largest, followed by the market environment, and finally knowledge stock. On the other hand, the spillover effect of knowledge stock is the largest, followed by the market environment, and finally industrial productivity. This indicates that the direct transmission channel of industrial productivity and the indirect transmission channel of knowledge stock are the most significant. The digital transformation of producer services generates a large number of new business models and modes, which become the new driving force for economic development, while the technological improvement of the service economy brings increases in industrial productivity. At this stage, the impact of the digital transformation of producer services on manufacturing technology innovation mainly relies on accelerating the flow of production factors such as knowledge, information, and technology. The digital economy brings great opportunities for China to implement innovation-driven development strategies; however, it is necessary to effectively guide digital technology to serve industrial efficiency improvement and knowledge stock accumulation.

### *4.4. Heterogeneity Test*

Due to the variability in economic endowment and location conditions, there may be regional variability in the observed impact on manufacturing technology innovation. In order to test for regional heterogeneity effects, the sample was divided into eastern, central, and western regions for split-sample regression. The eastern region included Beijing, Tianjin, Hebei, Fujian, Shanghai, Jiangsu, Hainan, Liaoning, Shandong, Guangdong, Zhejiang, etc.; the central region included Shanxi, Henan, Heilongjiang, Anhui, Jiangxi, Jiling, Hubei, Hunan, etc.; and the western region included Guangxi, Inner Mongolia, Qinghai, Sichuan, Guizhou, Yunnan, Xinjiang, Gansu, Chongqing, Ningxia, Shaanxi, etc. The results of the heterogeneity test are shown in Table 7. From the estimation results, it is clear that industrial productivity in the eastern and central regions has a significant positive impact on manufacturing technology innovation in both local and neighboring areas, as the coefficient value of the direct effect was larger than that of the spillover effect. There exists a positive spatial correlation between manufacturing technology innovation in the eastern and central regions and geographically adjacent provinces. In other words, manufacturing technology innovation depends not only on local industrial productivity; the improvement of industrial productivity in neighboring provinces will also result in a positive spatial spillover effect on local manufacturing technology innovation through spatial correlation, as the direct effect was also larger than the spillover effect. The eastern and central regions—characterized by higher levels of economic development—form factor concentration centers with more comprehensive and mature industrial layouts and richer talent and technology reserves, which provide effective connection and complementary advantages to the local manufacturing industry. On the contrary, industrial productivity in the western region was found to have a suppressive but statistically insignificant effect. These results indicate that there are significant regional differences in the mediating effect of industrial productivity on manufacturing technology innovation, where the indirect promotion effect of industrial productivity on manufacturing technology innovation is more obvious in economically developed regions. In terms of the mediating effect of knowledge stock, the direct effect of knowledge stock was found to be the largest in the western region, while the spillover effect was the largest in the eastern region. Thus, the digital transformation environment has accelerated the free flow of innovation factors such as knowledge, technology, information, and talents, and the efficient development of inter-enterprise innovation cooperation is the key to promoting manufacturing technology innovation. Compared with economically developed regions, the digital transformation of producer services is more conducive to the flow and sharing of knowledge and the formation of cooperation networks in relatively economically immature regions [72,73]; thus, it can promote the development of manufacturing technology innovation in the western region. In terms of the mediating effect of the market environment, it was found to have a significant positive mediating effect in the eastern and central regions but an inhibiting effect in the western region. The level of manufacturing technology innovation and the degree of market environment vary greatly among different provinces, and it is difficult to achieve effective connections between local manufacturing industries. The siphoning effect of provinces with good market environments on neighboring innovation is greater than the positive spillover effect from neighboring areas, which leads to the spatial inhibition of manufacturing technology innovation in neighboring areas. Further, it will also lead to a break in the equilibrium of the supply and industrial chains in some places in the western region, hindering manufacturing technology innovation.

### 4.5. Robustness Test

The above empirical analyses were all discussed based on the estimation results of the economic-geographic nested matrix. We next determined if the above findings changed with the replacement of the spatial weight matrix. In addition, we determined if the empirical results were robust if the explanatory variables and estimation samples were replaced. To ensure the robustness of the study findings, we applied three methods to test the robustness of the full sample. The first was to replace the spatial weight matrix and use the economic-geographic matrix estimation at $\tau = 0.5$. Second, we replaced the explanatory variables and the indicator with the proportion of new product sales revenue to operating revenue for regression. Third, data tailoring was performed. Considering that the sample data could have outliers, we winsorized 1% in each tail of the sample data and then carried out the regression. The specific results are shown in Table 8; it can be seen from the estimation results that there was no significant change in the coefficient size, sign, and significance for the three regression results, which confirms the strong robustness of the findings of this paper.

**Table 7.** Regional heterogeneity test.

| Effect | | Direct Effect | | | Spillover Effect | | |
|---|---|---|---|---|---|---|---|
| Variable | | Dtp | M | Control Variable | Dtp | M | Control Variable |
| Industrial productivity | East China | 0.2639 *** (2.9706) | 0.7303 ** (2.7677) | YES | 0.1299 * (1.8527) | 0.0204 ** (2.6533) | YES |
| | Central China | 0.2417 ** (2.7994) | 0.4712 ** (2.3941) | YES | 0.1701 (1.2065) | 0.0576 * (1.7010) | YES |
| | West China | 0.1433 * (1.9879) | −0.2549 (−1.1079) | YES | −0.1510 (−0.9694) | −0.0858 (−1.6329) | YES |
| Knowledge stock | East China | 0.6788 ** (2.5541) | 0.1409 ** (2.1724) | YES | 0.0917 * (2.0014) | 0.2729 ** (2.9344) | YES |
| | Central China | 0.4953 *** (3.6305) | 0.0948 * (1.9078) | YES | 0.0385 (0.9535) | 0.2539 * (1.9476) | YES |
| | West China | 0.7099 *** (3.3549) | 0.2347 *** (3.3611) | YES | 0.5787 *** (3.1738) | 0.1958 *** (3.2551) | YES |
| Market environment | East China | 0.2811 ** (2.9778) | 0.7158 * (1.8459) | YES | 0.1684 ** (2.1798) | 0.2177 * (2.0660) | YES |
| | Central China | 0.9982 ** (2.5755) | 0.3562 ** (2.7063) | YES | 0.3515 ** (2.6359) | 0.4708 * (1.8768) | YES |
| | West China | 0.2529 (0.7519) | −0.1099 ** (−2.2673) | YES | 0.6183 ** (2.4812) | −0.1795 *** (−4.2937) | YES |

Note: Due to space limitations, only the estimated direct and spillover effects of the core explanatory and mediating variables of the mediated utility model (3) are reported here, as in the following table. *t*-values in parentheses; *, **, and *** denote 10%, 5%, and 1% significance levels, respectively.

**Table 8.** Robustness test.

| Effect | | Direct Effect | | | Spillover Effect | | |
|---|---|---|---|---|---|---|---|
| Variable | | Dtp | M | Control Variable | Dtp | M | Control Variable |
| Industrial productivity | Replacing the spatial weight matrix | 0.4042 *** (2.5769) | 0.4377 * (1.7363) | YES | 0.2019 *** (3.2536) | 0.5931 ** (2.5613) | YES |
| | Replacing explained variable | 0.1185 ** (2.7916) | 0.1184 (1.0061) | YES | 0.6047 ** (2.0504) | 0.2444 ** (2.0589) | YES |
| | Winsorizing each tail | 0.1861 *** (2.7761) | 0.4957 ** (2.6163) | YES | 0.2471 *** (2.5054) | 0.9238 ** (2.1878) | YES |
| Knowledge stock | Replacing explained variable Winsorizing each tail | 0.0887 *** (6.8954) | 0.0049 *** (3.7902) | YES | 0.4876 ** (2.5061) | −0.1535 ** (−2.5099) | YES |
| | Replacing explained variable Winsorizing each tail | 0.1555 *** (3.7792) | 0.1098 *** (5.2709) | YES | 0.8278 *** (3.1547) | 0.6934 * (1.9896) | YES |
| | Replacing explained variable Winsorizing each tail | 0.1448 *** (2.8462) | 0.0784 *** (4.5261) | YES | 0.6629 * (2.0725) | −0.1679 * (−2.0766) | YES |
| Market environment | Replacing explained variable Winsorizing each tail | 0.1048 ** (3.5421) | 0.1079 *** (3.7786) | YES | 0.4849 * (1.9856) | −0.3025 ** (−2.4552) | YES |
| | Replacing explained variable Winsorizing each tail | 0.1536 ** (2.1051) | 0.0513 *** (5.9715) | YES | 0.7774 * (1.8473) | −0.2041 *** (−4.2536) | YES |
| | Replacing explained variable Winsorizing each tail | 0.1187 ** (2.1728) | 0.0667 * (1.8867) | YES | 0.6291 * (2.0867) | 0.4299 *** (3.0989) | YES |

*t*-values in parentheses; *, **, and *** denote 10%, 5%, and 1% significance levels, respectively.

## 5. Conclusions

In this paper, by constructing a mediating effects model that included spatial interactions, the influence mechanism of the digital transformation of productive service industries on manufacturing technology innovation was examined in terms of industrial productivity, knowledge stock, and the market environment. Our main conclusions are as follows:

(1) The digital transformation of producer services promotes manufacturing technology innovation and generates positive spatial spillover effects.

(2) The digital transformation of producer services affects manufacturing technology innovation through three paths: industrial productivity, knowledge stock, and the market environment. Among these paths, the direct effect of industrial productivity is the largest, followed by the market environment and knowledge stock, while the spillover effect of knowledge stock is the largest, followed by market environment and industrial productivity.

(3) There is regional heterogeneity in the mediating effect of the digital transformation of productive service industries. The largest direct effect of industrial productivity was observed in the eastern regions of China, while the largest spillover effect of the market environment was found in the central regions of China. In addition, an inhibitory effect of industrial productivity and the market environment was observed in the western regions of China; however, the mediating utility was statistically insignificant.

Based on these conclusions, we put forward the following policy recommendations:

First, the digital transformation of productive service industries and associated improvements in the spatial spillover effect should be vigorously promoted. The interactions and correlations between industries in neighboring regions should be considered in an integrated manner to increase inter-regional industrial collaboration and backward and forward correlations and improve the spatial mismatch of resources. In addition, a complementary and benign interactive industrial linkage pattern should be formed, and full play should be given to the active role of the digital transformation of advanced productive service industries in finance, information technology, and scientific research in neighboring regions on the technological innovation of local manufacturing industries. Increasing financial and tax support for digital frontier technologies and digital innovation fields and utilizing core technologies in digital fields will help to achieve a safe and efficient digital transformation of the technology system. A high-level digital industry chain should also be created to promote the digital transformation of local producer services while further strengthening economic ties and industrial cooperation with neighboring regions to inject new momentum and vitality into the digital transformation of the producer services. Governments should also aim to strengthen the flow, integration, and sharing of innovation resources; give full play to the technological innovation enhancement effect on the manufacturing industry resulting from the digital transformation of producer services in a wider scope; and promote efficient cross-regional collaborative innovation activities.

Second, full play should be given to the intermediary roles of industrial productivity, knowledge stock, and the market environment in the technological innovation of manufacturing driven by producer services. Therefore, while vigorously promoting digital transformation, local governments should promote the gathering of high-quality talents, accumulate knowledge stock, and enhance the market environment to create a new innovation space and platform. In addition, they should encourage talent training, promote enterprises to establish joint R&D centers with universities and research institutes, enhance inter-industry knowledge exchange and sharing, and stimulate the innovation vitality of market players. By creating a favorable market environment, full play can be given to the decisive role of the digital transformation of producer services in resource allocation, reducing factor distortion and improving resource allocation efficiency and thus promoting the development of manufacturing technology innovation.

Finally, the balanced development of the potential of the digital transformation of regional productive service industries for the development of manufacturing technology innovation should be promoted. Different regions should develop productive service industries that match the needs and scale characteristics of their local industrial developments, implement suitable digital transformation modes of productive service industries, and give full play to the effect of the digital transformation of productive service industries on enhancing manufacturing technology innovation. The eastern and central regions provide more and higher quality digital services for local and adjacent regions; here, we should aim at the international technology frontier to promote manufacturing transformation, upgrading, and high-quality development. With the goal of adapting to the development needs of the leading manufacturing industry and combining its factor endowment and resource environment, the western region can enhance the digital transformation effect and technological innovation of its producer services through characteristic digital services. The potential of the digital transformation of productive service industries in promoting manufacturing technology innovation can be fully realized to foster new dynamic energy for economic growth in the western region. Regions with higher levels of economic development promote a "downward spillover" effect, while lagging regions actively learn and absorb advanced digital technologies according to their own conditions.

**Author Contributions:** Conceptualization, Z.L. and B.W.; methodology, B.W.; software, Z.L.; validation, Z.L., B.W. and X.H.; formal analysis, Z.L.; investigation, Z.L., B.W. and X.H.; resources, Z.L.; data curation, X.H.; writing—original draft preparation, Z.L.; writing—review and editing, B.W.; project administration, Z.L.; funding acquisition, Z.L., B.W. and X.H. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by the Zhejiang Soft Science Research Program (2022C35049; 2023C35112), National Statistical Science Research Program of China (2022LY069), General Projects of Humanities and Social Sciences Research of Ministry of Education of PRC (21YJA630028), and Zhejiang Soft Science Research Key Program (2023C25031).

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References


1. Guo, M.C.; Du, C.Z. Mechanism and Effect of Information and Communication Technology on Enhancing the Quality of China's Economic Growth. *Stat. Res.* **2019**, *03*, 3–16.
2. Xu, X.C.; Zhang, M.H. Research on the Scale Measurement of China's Digital Economy-Based on the Perspective of International Comparison. *China Ind. Econ.* **2020**, *05*, 23–41.
3. Li, P.; Fu, Y.F.; Zhang, Y.F. Can the Productive Service Industry Become New Momentum for China's Economic Growth? *China Ind. Econ.* **2017**, *12*, 5–21.
4. Xi, Q.M.; Chen, X.; Li, G.P. Study on the Pattern Selection of Chinese Urban Producer Services Oriented by the Improvement of Industrial Efficiency. *China Ind. Econ.* **2015**, *2*, 18–30.
5. Ebert, C.; Duarte, C.H.C. Digital Transformation. *IEEE Softw.* **2018**, *35*, 16–21. [CrossRef]
6. Sebastian, I.M.; Ross, J.W.; Beath, C.; Mocker, M.; Moloney, K.G.; Fonstad, N.O. How big old companies navigate digital transformation. *MIS Q. Exec.* **2017**, *16*, 197–213.
7. Kwon, K.H. Exploratory Study on Digital Transformation of Manufacturing-based MNCs. *Inter. Bus. Rev.* **2018**, *22*, 1–25. [CrossRef]
8. Zhao, C.Y. Digital development and servitization: Empirical evidence from listed manufacturing companies. *Nankai Bus. Rev.* **2021**, *24*, 149–163.
9. Jiang, X.J.; Luo, L.B. Globalization of Services in the Internet Age—A New Engine, Acceleration and the Competitiveness of Major Power. *Soc. Sci. China* **2019**, *2*, 68–91.
10. China Academy of Information and Communications Technology (CAICT). *Digital Economy Development in China*; China Academy of Information and Communications Technology: Haidian, China, 2020; Volume 7.
11. Zhao, T.; Zhang, Z.; Liang, S.K. Digital Economy, Entrepreneurship, and High-Quality Economic Development: Empirical Evidence from Urban China. *J. Manag. World* **2020**, *36*, 65–75.
12. Kolko, J. The High-Tech Rural Renaissance? Information Technology, Firm Size and Rural Employment Growth. *Small Bus. Res. Sum.* **2000**, *201*, 2.

13. Jiang, X.J. Resource Reorganization and the Growth of the Service Industry in an Interconnected Society. *Econ. Res. J.* **2017**, *3*, 4–17.
14. Peters, B.; Riley, R.; Siedschlag, I.; Vahter, P.; McQuinn, J. Internationalisation, Innovation and Productivity in Services: Evidence from Germany, Ireland and the United Kingdom. *Rev. World Econ.* **2018**, *154*, 585–615. [CrossRef]
15. Fu, K.B.; Chen, X. Research on the Influencing Factors of China's Service Industry Productivity in Post Industrialization Period. *Inq. Econ. Issues* **2021**, *03*, 181–190.
16. Xia, J.C. China's service industry towards the "14th Five-Year Plan": Trend prediction, key breakthrough and policy thinking. *J. Beijing Tech. Bus. Uni. (Soc. Sci.)* **2020**, *35*, 1–10, 31.
17. Chen, J.; Huang, S.; Liu, Y.H. Operations Management in the Digitization Era: From Empowering to Enabling. *J. Manag. World* **2020**, *02*, 117–128, 222.
18. Tong, Y.H. Research on Integrated development of "Internet + Manufacturing Service". *Econ. Rev. J.* **2015**, *10*, 62–67.
19. Zhao, C.Y. Research on the Impact of Digital Transformation on Corporate Social Responsibility. *Mod. Econ. Sci.* **2022**, *44*, 109–116.
20. Tronvoll, B.; Sklyar, A.; Sörhammar, D.; Kowalkowski, C. Transformational shifts through digital servitization. *Ind. Mar. Manag.* **2020**, *89*, 293–305. [CrossRef]
21. Johnson, M.; Mena, C. Supply chain management for servitised products: A multi-industry case study. *Int. J. Prod. Econ.* **2008**, *114*, 27–39. [CrossRef]
22. Frank, A.G.; Mendes, G.H.S.; Ayala, N.F.; Ghezzi, A. Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technol. Forecast. Soc. Change* **2019**, *141*, 341–351. [CrossRef]
23. Kohtamäki, M.; Parida, V.; Patel, P.C.; Gebauer, H. The relationship between digitalization and servitization: The role of servitization in capturing the financial potential of digitalization. *Technol. Forecast. Soc. Change* **2020**, *151*, 119804. [CrossRef]
24. Dai, K.Z.; Li, X.L.; Luo, S.X. Human Capital Structure Upgrading, Factor Market Development and Service Industry Structure Upgrading. *Financ. Tra. Econ.* **2020**, *10*, 129–146.
25. Chenery, H.B.; Robinson, S.; Syrquin, M. *Industrialization and Growth: A Comparative Study*; Oxford University Press: New York, NY, USA, 1986.
26. Gan, C.H.; Zheng, R.G.; Yu, D.F. Cyclical Fluctuations and Nonlinear Dynamics of Inflation Rate. *Econ. Res. J.* **2011**, *5*, 4–16, 31.
27. Shen, G.B.; Yuan, Z.Y. The Effect of Enterprise Internetization on the Innovation and Export of Chinese Enterprises. *Econ. Res. J.* **2020**, *1*, 33–48.
28. Goldfarb, A.; Tucker, C. Digital Economics. *J. Econ. Lit.* **2019**, *57*, 3–43. [CrossRef]
29. Baines, T.; Lightfoot, H.W. Servitization of the manufacturing firm: Exploring the operations practices and technologies that deliver advanced services. *Int. J. Oper. Prod. Manag.* **2014**, *34*, 2–35. [CrossRef]
30. Ferreira, F.N.H.; Proença, J.F.; Spencer, R.; Cova, B. The transition from products to solutions: External business model fit and dynamics. *Ind. Mar. Manag.* **2013**, *42*, 1093–1101. [CrossRef]
31. Arthub, W.B. The structure of invention. *Res. Pol.* **2007**, *36*, 274–287. [CrossRef]
32. Yuan, H.; Xia, J.C. Research on the Impact of Digital Infrastructure Construction on the Upgrading of China's Service Industry Structure. *Econ. Rev. J.* **2022**, *6*, 85–95.
33. Tao, C.Q.; Xu, M. Measuring the allocation level of China innovation elements from the perspective of economic high-quality development. *J. Quan. Tech. Econ.* **2021**, *3*, 3–22.
34. Qi, Y.D.; Xiao, X. Transformation of Enterprise Management in the Era of Digital Economy. *J. Manag. World* **2020**, *36*, 135–152+250.
35. Kolko, J. Agglomeration Economics: Urbanization, Agglomeration, and Coagglomeration of Service Industries. In *NBER Chapters*; University of Chicago Press: Chicago, IL, USA, 2010; pp. 151–180.
36. Rosenthal, S.S.; Strange, W.C. Evidence on the Nature and Sources of Agglomeration Economics. *Hand. Reg. Urb. Econ.* **2004**, *4*, 2119–2171.
37. Xu, H.; Zhang, Y.L.; Cao, Y.J. Digital Economy, Technology Spillover and Dynamic Coopetition Policy. *J. Manag. World* **2020**, *11*, 63–84.
38. Chalioti, E. Spillover feedback loops and strategic complements in R&D. *J. Public Econ. Theory* **2019**, *21*, 1126–1142.
39. Wood, P. Urban Development and Knowledge Intensive Business Services: Too Many Unanswered Questions? *Growth Change* **2006**, *37*, 335–361. [CrossRef]
40. Milliou, C.; Petrakis, E. Vertical integration and knowledge disclosure. *Econ. Let.* **2019**, *177*, 9–13. [CrossRef]
41. Dai, K.Z. Vertical specialization and R&D input: An empirical evidence from high-tech industry in China. *J. Financ. Econ.* **2012**, *05*, 38–48.
42. He, D.A.; Xu, Y.F. Digital Economy Operation and Supply-side Structure Remodeling. *Economist* **2020**, *04*, 57–67.
43. Chen, J.J.; Chen, G.L.; Huang, J. A study of producer services agglomeration and its influencing factors in the perspective of new economic geography from empirical evidence of 222 cities in China. *J. Manag. World* **2009**, *4*, 83–95.
44. Wang, J.Y. The Analysis of industrial integration and innovation based on informatization. *J. Sichuan Uni. (Soc. Sci. Ed.)* **2009**, *03*, 102–107.
45. Ding, Z.F. Research on the mechanism of digital economy driving high-quality economic development: A theoretical analysis framework. *Mod. Econ. Res.* **2020**, *01*, 85–92.
46. Huang, Q.H.; Yu, Y.Z.; Zhang, S.L. Internet Development and Productivity Growth in Manufacturing Industry: Internal Mechanism and China Experiences. *China Ind. Econ.* **2019**, *08*, 5–23.

47. Halleck, V.S.; Elhorst, J.P. The SLX model. *J. Reg. Sci.* **2015**, *55*, 339–363. [CrossRef]
48. Bai, J.H.; Jiang, F.X. Synergy innovation, spatial association and regional innovation performance. *Econ. Res. J.* **2015**, *50*, 174–187.
49. Gu, N.H. Spillover effects of urban productive service agglomeration on industry and its regional boundary in China—An empirical study based on HLM model. *Financ. Trade Ecol.* **2011**, *05*, 115–122.
50. Li, L.G.; Xue, L. Research on the impact of producer services agglomeration on the efficiency of green economy. *Stu. Sci. Sci.* **2022**, *40*, 1968–1978.
51. Dang, L.; Li, X.S.; Shen, S. Manufacturing Digital Transformation and Its Export Technological Sophistication. *J. Int. Trade* **2021**, *6*, 32–47.
52. Qi, J.Y.; Ren, Y.D. Digital economy development, institutional quality and upstreamness of global value chains. *Int. Econ. Trade Res.* **2022**, *38*, 51–67.
53. Wang, Q.; She, S.; Zeng, J.J. The mechanism and effect identification of the impact of National Hig-tech Zones on urban green innovation. *China Pop. Res. Environ.* **2020**, *30*, 129–137.
54. Wang, Y.; Wang, T.N.; Yi, X.W. Research on the Synergistic Effect of R&D Expenditures for IT investment: A Contingent View of Internal Organizational Factors. *J. Manag. World* **2020**, *36*, 77–89.
55. Yang, X.M.; Hou, W.; Wang, Y.F. Digital Investment and Employment Structure Changes within China's Industry: "Upgrade" or "Polarization". *J. Shanxi Univ. Financ. Econ.* **2022**, *44*, 58–68.
56. Elhorst, J.P. Applied spatial econometrics: Raising the bar. *Spat. Econ. Ana.* **2010**, *5*, 9–28. [CrossRef]
57. Griliches, Z. Issues in assessing the contribution of research and development to productivity growth. *Bell J. Econ.* **1979**, *10*, 92–116. [CrossRef]
58. Duranton, G.; Puga, D. Micro-foundations of urban agglomeration economies. In *Handbook of Regional and Urban Economics*, 1st ed.; Henderson, J.V., Thisse, J.F., Eds.; National Bureau of Economic Research: Cambridge, MA, USA, 2003; Volume 4, Chapter 48; pp. 2063–2117.
59. Hornuf, L.; Klus, M.F.; Lohwasser, T.S.; Schwienbacher, A. How do Banks Interact with Fintech Startups? *Small. Bus. Econ.* **2021**, *57*, 1505–1526. [CrossRef]
60. LeSage, J.; Pace, R.K. *Introduction to Spatial Econometrics*; Chapman and Hall/CRC: Boca Raton, FL, USA, 2009.
61. Jaffe, A.B.; Trajtenberg, M.; Henderson, R. Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *Q. J. Econ.* **1993**, *108*, 577–598. [CrossRef]
62. Vial, G. Understanding digital transformation: A review and a research agenda. *J. Strateg. Inf. Syst.* **2019**, *28*, 118–144. [CrossRef]
63. Teece, D.J. Explicating Dynamic Capabilities: The Nature and Microfoundations of (Sustainable) Enterprise Performance. *Strat. Manag. J.* **2007**, *28*, 1319–1350. [CrossRef]
64. Xue, L.; Jang, L.D.; Huang, Y.; Liang, Z. Resource heterogeneity, knowledge flow and synergy innovation of industry-university-research institute: An empirical study on AI industry. *Stud. Sci. Sci.* **2019**, *37*, 2241–2251.
65. Varian, H.R. Computer mediated transactions. *Am. Econ. Rev.* **2010**, *100*, 1–10. [CrossRef]
66. Singh, J. Distributed R&D, cross-region knowledge integration and quality of innovative output. *Res. Pol.* **2008**, *37*, 77–96.
67. Li, H.J.; Tian, Y.X.; Li, W.J. Mobile Internet Thinking and Traditional Business Reengineering. *China Ind. Econ.* **2014**, *10*, 135–146.
68. Aitken, B.J.; Harrison, A.E. Do domestic firms benefit from direct foreign investment? Evidence from Venezuela. *Am. Econ. Rev.* **1999**, *89*, 605–618. [CrossRef]
69. Taylor, T.L. CyberPower: The Culture and Politics of the Internet. *Contemp. Soc.* **2002**, *31*, 290. [CrossRef]
70. Cai, Y.Z.; Ma, W.J. How Data Influence High-quality Development as a Factor and the Restriction of Data Flow. *J. Quan. Tech. Econ.* **2021**, *38*, 64–83.
71. Abramova, N.; Grischenko, N. ICTs, Labour Productivity and Employment: Sustainability in Industries in Russia. *Proc. Manu.* **2020**, *43*, 299–305. [CrossRef]
72. Chen, X.H. Trend analysis of technology fusion and application innovation in the digital economy era. *J. Cent. Sou. Uni. (Soc. Sci.)* **2018**, *24*, 1–8.
73. Zhang, X.W. Research on Evolution of Innovation Model under the Condition of Digital Economy. *Economist* **2019**, *07*, 32–39.


**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.