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Value Chain and the Integrated Development of Manufacturing and Modernized Services: A Case Study of Shandong Province, China

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Abstract: The integrated development of manufacturing and modernized service (IDMMS) is an important direction for the transformation and upgrading of manufacturing. Building upon value co-creation, industry chain theory and the industrial boundary literature, this paper explores an analytical framework of IDMMS, combining theoretical and empirical evidence. Then, this study constructs several indicators for measurement of industrial integration. The results indicate that: (1) manufacturing has more self-circulation, and the degree of backward correlation between the modernized services and the manufacturing is weak, while the support and driving effect of the manufacturing is insufficient; (2) most industrial sectors play a relatively stable role in influencing production demand. The findings reveal that there exist several problems referring to industry and enterprises. Finally, this paper discusses the mechanism of IDMMS and reaches its conclusions. The conclusions provide a comprehensive and detailed industrial understanding of the formation of comprehensive and systematic regional economic strategies and suggest targeted industrial policies to achieve sustainable development.

Keywords: manufacturing; modernized services; industrial integration; input-output tables; sustainability; value co-creation; industrial chain

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1. Introduction

"Agenda 21" has mentioned that "(a) country's sustainable development capacity depends to a large extent on the capacity of its people and institutions under its ecological and geographical conditions, specifically, the capacity building includes the development and enhancement of a country's human, scientific, technological, organizational, institutional, and resource capabilities" [1]. The application of sustainable development theory in economic development therefore accelerates the efficient allocation of resources, optimizes the industrial structure, and maintains the sustainable use capacity and function of resource regeneration and utilization. The COVID-19 pandemic has profoundly affected and changed global and regional economic activities [2–4], which has driven the transformation of manufacturing. Facing the competition of low-end industries in developing countries and the double squeeze of the "reindustrialization" strategy of manufacturing powers [5], China's government has introduced a series of policies. "Made in China 2025" points out that China should realize the high-quality development of manufacturing industry, which should ensure both the speed of manufacturing development and the quality of development. The high-quality development of manufacturing industry not only promotes the development of economy [6], but also can promote the sustainable development of society. Therefore, in 2018, the Central Economic Work Conference put forward the specific requirements of "promoting the deep integration of advanced manufacturing industry and modern service industry and building a manufacturing power" [7,8].

Currently, existing research has explored the integrated development of manufacturing and modernized services (hereafter abbreviated as IDMMS) from two theoretical perspectives. On the one hand, the manufacturing servitization view perspective believes that the servitization of manufacturing should focus on "value co-creation" [9]. The concept of "servitization" was first proposed by Vandermerwe and Rada in the late 1980s, who argued that manufacturing enterprises ought to adopt a comprehensive "product-service package" model while producing goods [10]. This view means that manufacturers must change from "manufacturing-centric" to "service-centric", which implies that manufacturers should focus on customer-centric services, support, self-service, and knowledge [4]. To increase competition, achieve industrial added-value and continuously adapt to technological changes, traditional industrial boundaries gradually disappeared and blurred [11,12]. Several scholars have discussed the driving effects of technological innovation on IDMMS [13,14]. For example, Legewie [15] considered that technological progress and the relaxation of regulations promoted industrial integration, which reduced the barriers between industries through technological innovation and strengthened the competition and cooperation between enterprises. Some scholars have divided four servitization models in terms of value co-creation [16]. Li summarized three modes in the process of the integrated development of manufacturing and services; these are: cross-integration mode, embedded integration mode, and bundled integration mode [17]. On the other hand, the value-chain or industry-chain perspective argues that manufacturing and service industries penetrate each other and embed in each other's industrial value chain system with the increase of specialization level, thus forming a close relationship [18]. The input of high-end service elements can facilitate the innovation of enterprises' technological innovation and management mode [7], because it reduces unnecessary expenses, thus forming spillover effects among enterprises or within industries and improving factor productivity to promote industrial transformation and value chain upgrading [19]. Several scholars have explored industrial integration from the perspective of value-chain. For example, Qi studied the influence factors of the convergence of China's equipment manufacturing industry and producer services based on the perspective of global value chain (GVC) [18]; Mattila and Wirtz explored the integration process of media industry and communication industry from the perspective of value chain, and proposed that the integration process included stages of value-chain decomposition and value-chain reconstruction [20]. Some other scholars have believed that the process of IDMMS includes not only the embedding of the two industries into each other's industrial value chain, but also the situation in which the two industries break their original industrial boundaries and integrate to form new industries, new formats, and new models [21]. Zhou early-on proposed that it was a trend that new industries would be formed by the industrial integration [22].

Although many scholars have discussed the process, drivers and models of IDMMS, which allows us to know the evolutionary logic of IDMMS in a deeper way, generally, the existing research has either explored the integration of manufacturing and service industry from one specific aspect, or analyzed the connotation and development of manufacturing servitization in a general way. Therefore, systemic, comprehensive, and dynamic research from the lens of mechanism of IDMMS remains highly limited. Further, sustainable development is now an imperative parameter [23]. Manufacturing, as a key influencer of the economies of nations and enterprises, although its recent global growth rate has been negatively affected by the COVID-19 pandemic, is still regarded as an avenue of paramount importance for all countries to meet their 2030 Sustainable Development Goals [24]. IDMMS is an important direction for the transformation and upgrading of the manufacturing industry, as well as an inherent requirement for achieving high-quality economic development. With these facts, it can be clearly articulated that the relationships between sustainability and technology in manufacturing, as well as IDMMS, deserve further research. In addition, the overall structure and characteristics of industrial integration, whether at the global level or of that of a single country, have been fully studied [1,25]. However, the industrial integration and its relationship with sustainable development within the region is still not

clear. As one of China's most developed provinces, with the most complete industrial categories, the strongest foundation and the most complete structure, Shandong Province has shown outstanding achievements in IDMMS in recent years, and the economic growth is more clearly characterized by a shift from industry-led to service-led. Specially, Shandong province has built new digital, networked and intelligent infrastructure and a new industrial ecology based on innovative applications of the industrial Internet. At present, the level of integration of information technology and industrialization in Shandong is the second in China, and several projects have become Chinese benchmarks. Hence, the study on the industrial system of Shandong province is valid and meaningful for other manufacturing contexts.

To address these research gaps, this study draws on the value co-creation theory and industrial integration literature to develop a model linking IDMMS, sustainable development and firm performance. Our goal is to answer the following question: How do the process, mechanism, and path of IDMMS support the high-quality economic development to achieve the United Nation's Sustainable Development Goals (SDGs)? By doing so, we contribute to the current literature in two ways. First, we respond to the call for a comprehensive framework of IDMMS, including macroeconomic-sustainable-development, meso-industrial-integration, and micro-enterprise-performance-improvement. Second, we provide evidence as to the importance of IDMMS in sustainable development.

The remainder of the study is organized as follows: Section 2 summarizes the relevant literature. Section 3 proposes the methodology and data. Section 4 shows the results. Section 5 first discusses the existing problems of Shandong's IDMMS, then explores the mechanism of IDMMS based upon the theory of value co-creation. Finally, the conclusions, contribution, limitations and future research are presented.

2. Literature Review

2.1. Industrial Boundaries and the Process of IDMMS

The traditional industrial system was based on the fixation of industrial boundaries and the labor division among industries. After analyzing the characteristics of traditional telecommunications, broadcasting and publishing industries as well as industrial production industries, Zhou used four dimensions of technology, business, operation and market to define the industry boundaries [22], as shown in Figure 1.

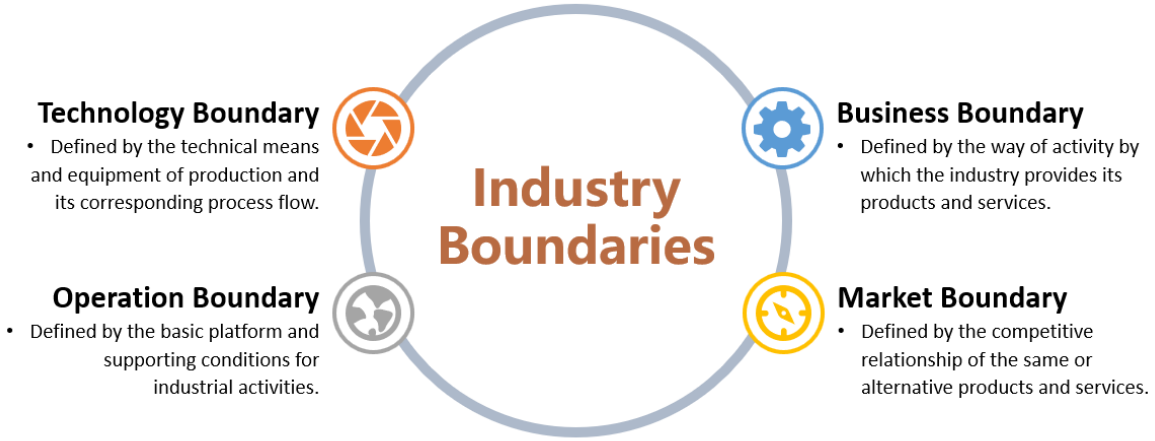

Figure 1. Four dimensions of industry boundaries.

Industrial integration is an inevitable product of economic development to a certain level, which was first and formally put forward by Uekusa [26]. In the Marshall period, the economic level was relatively backward, the industries were relatively single, and industrial integration did not give full play to the economic benefits. With the development of the economy in the past 30 years, the manufacturing industry has been developing rapidly and the service industry has been growing [27]. As the two engines of economic

development, the integration between manufacturing and service industries has become a hot topic. Actually, the research on industrial integration stemmed from the observation of the phenomenon whereby the application of general technology spreads to different industries [25]. Technological innovation is regarded as the driving force of industrial integration, which means that a common scientific and technological base among industries is the major condition for industrial integration [28]. The gradual penetration of information technology into manufacturing and service industries eliminates the technology boundary between them. Service factors are regarded as "high-end factors" with intermediate input. Specifically, with the possession, input and allocation of intellectual resource, as well as the production, distribution and consumption of knowledge products, the modern service industry gradually replaces the traditional manufacturing industry's crude production factors to achieve high-quality, high-efficiency, low-consumption, clean and flexible production [29,30]. Based on the theoretical background, we proposed the given hypothesis:

Hypothesis 1. *IDMMS is the process of blurring the technological boundaries between manufacturing and modernized services to achieve high-quality, high-efficiency and clean production.*

Besides technological innovation, several scholars defined servitization as the innovation of an organization's capabilities and processes to shift from selling products to selling integrated products and services that deliver value in use [31]. During this transition process, there are various services that can be offered. In other words, the servitization of manufacturing enterprises is essentially the process of transformation of manufacturing enterprises from traditional commodity providers to service providers [9]. In fact, as a response to increased competition and decreased profit margins in the manufacturing sector, manufacturers have been increasingly supplementing products with value-added services so as to differentiate their products and simultaneously generate an additional revenue stream [31–35]. According to Sousa and da Silveira [36], servitization can be categorized into product-centered (basic services, hereinafter abbreviated as BAS) and customer-oriented (advanced services, hereinafter abbreviated as ADS), based on the types of services offered by manufacturers. Specifically, the characteristics of BAS are transactional and notable for low customization and limited interactions with the customers [36,37]. However, ADS are more intricate and professional, usually including help desks or other customer supports, customer training, business consultancy, product adaptations to a customer's needs, and process operations on the customers' behalf [34,38]. Therefore, ADS have a more closed interaction with customers. From this perspective, we proposed the given hypothesis:

Hypothesis 2. *IDMMS is the process of breaking the business boundaries between manufacturing and modernized services to achieve upgrading and sustainable development of manufacturing enterprises, using the advantages of advanced, digital and intelligent value.*

Different industry sectors have their own codes of conduct and norms, as well as different elements of government regulation, when providing information service content in different ways. With the deepening and restructuring of GVC division, the effective use of resources becomes a prerequisite for the servitization of manufacturing enterprises in order to achieve value co-creation. One the one hand, currently the construction of global manufacturing network is based on a regional manufacturing network. In this condition, multinational corporations transfer low value-added links, such as production and processing, to the specific regions with the most comparative advantages in the form of local outsourcing or offshored outsourcing [7]. In order to prevent technology spillover, multinational companies often use various means to hinder and inhibit the independent research and development of OEM enterprises and the climbing of the value chain, forcing OEM enterprises to be locked in the low-end processing and assembly links of the value chain for a long time. Such "path locking" by multinational companies not only restricts

their own innovation and R&D capabilities, but also deepens their "path dependence" on multinational companies. For China, there is an urgent need for independent innovation to realize the transformation and upgrading of the "OEM-ODM-OBM" model [29]. On the other hand, under the value chain-oriented networked organizational structure, the vertically integrated structure is vertically disintegrated and replaced by the contractual subcontracting cooperation. Since manufacturing servitization plays the role of "adhesive" and "modular participation" in the international production division [7], collaborative manufacturing through modular production and process optimization of products can further improve the productivity and manufacturing flexibility of enterprises while optimizing their own resources. According to the analysis above, we proposed the given hypothesis:

Hypothesis 3. *IDMMS is the process of weaking the operation boundaries between manufacturing and modernized services to form a modern industrial system with the value chain as the backbone, modularity as the structural carrier, and networking as the organizational support.*

IDMMS is a long-term interactive and collaborative evolutionary process. During this long process, IDMMS is mainly manifested in four ways: industrial association, industrial interaction, industrial coordination and industrial symbiosis, which are not only the characteristics of industrial integration, but also the performance of gradual upgrading of integration level. Explicitly, with the integration of manufacturing and modern service industry resources, the relationship between the two has become closer, and this mechanism of interactive development has promoted the joint upgrading of modern service industry and manufacturing industry. For traditional manufacturing enterprises, the embedding of manufacturing servitization in the form of distribution service helps the manufacturing enterprises establish a more perfect marketing network, shortens the distance between manufacturers and consumers, enhances the ability to obtain market information, and cuts unnecessary expenses such as coordination cost, information collection cost, and channels construction cost caused by information asymmetry [7]. In the process of industrial integration, the intersection and penetration of industry sectors with previously fixed business and market boundaries have transformed from previously non-competitive sectors into competitors, leading to a series of major mergers, acquisitions and alliances that have shaped new market structures, as well as the creation of new industries and new business models. For instance, based on the historical development experience, the productive service industry was separated from the manufacturing industry, and then produced a relatively independent modern service system, and still has a strong association, good interaction, coordinated development and mutually beneficial symbiosis with the manufacturing industry. Considering the existing research, we proposed the given hypothesis:

Hypothesis 4. *IDMMS is the process of changing the market boundaries between manufacturing and modernized services, which may enhance competitiveness, reshape market structure and create new industries or new business models.*

2.2. Degree of IDMMS

Perceived as the motivation for the optimization and upgrade of industrial structure, IDMMS has aroused widespread discussion in academic areas in recent years. The existing scholarship mainly draws on theories of industrial upgrading, entropy, GVC, coupling, and industrial structure, and uses the Herfindahl-Hirschman index [39,40], technological patents [41,42], entropy index [43], input-output analysis [44–48], coupling degree model [49–51], and aggregative indicator [52] to measure industrial integration. However, these methods have some shortcomings in the measurement of IDMMS.

First, the Herfindahl-Hirschman index mainly measures the degree of industrial integration by taking the proportion of the number of patents or investments, or product sales of an enterprise to the number of social patents or total investment or total product

sales in all industries [53]. Likewise, both technological patents and the entropy index require the patent data of the enterprises, which are difficult to obtain and primarily used to measure the degree of technological integration. Second, the coupling degree model method needs to determine the optimal value of each index, which is highly subjective, therefore, the conclusions drawn may be relatively limited. In contrast, based on general equilibrium theory, the input-output analysis method is an important method to describe the interdependence between various sectors in the economic system through a linear equation system (matrix) and to deeply reveal the internal mechanism of industrial structure changes [54]. But the traditional input-output approach mostly uses intermediate inputs and influence coefficients to measure the degree of integration and correlation between the two industries. Both reflect the inputs and impacts of specific sectors on the entire industry, including agriculture, extractive industries, etc. Hence, it is difficult to decipher the "systematic bias" and distorts the conclusions. Therefore, exploring an effective method to reflect the degree of IDMMS is crucial.

2.3. Industry Chain and the Path of IDMMS

In terms of value chain theory, an enterprise is a collection of integrated design, production, sales, operation, and management activities. To survive and grow, an enterprise must create value for its shareholders and other stakeholders (employees, customers, suppliers, retailers, etc.). As the deepening of labor division within the industry, different types of value-creating activities within the traditional industries are gradually separated from one-enterprise-led to multiple enterprises' activities. These enterprises form an upstream and downstream relationship with each other and create value together. Generally, a complete industrial chain is divided into three major links: design and development (R&D), production and manufacturing, as well as marketing and services. This mainly includes five categories of value-creating activities: R&D, procurement, operation, sales and service. Such value-creating activities objectively put forward the demand for service links, which inevitably require the addition of many related service links to the above manufacturing process. This further causes profits in the industry chain to move from their previous manufacturing role to the R&D, design or marketing and after-sales services at both ends of the value chain [29], as shown in Figure 2. Therefore, the correlation between manufacturing and service is also gradually increasing in the context of the deepening division of labor.

Several scholars have explored the path of industrial integration from the perspective of value co-creation and the industry chain, believing that the path of IDMMS should be investigated as "industry chain". Peng, etc. [55] proposed that the integration of China's equipment manufacturing industry and modernized services has four high-level integration paths, including balanced development type, service-led type, manufacturing-led type, and government-driven type. Based on the value chain, Jian and Wu [56] proposed four service-oriented transformation paths for the manufacturing industry: downstream, upstream, and downstream and upstream industrial chain service-oriented development and de-manufacturing-oriented development. Deng [57] proposed that IDMMS required specific integration paths, such as optimizing the structure of elements, enhancing user value, and improving manufacturing efficiency. Based on the above, we proposed the given hypothesis:

Hypothesis 5. *Grounding in independent innovation and value network, the linkage and upgrade of industrial value fundamentally determines sustainable development of enterprises, industries and economies.*

Based on the above argument, we present a research framework in Figure 3, which summarizes all the hypothesis in this section.

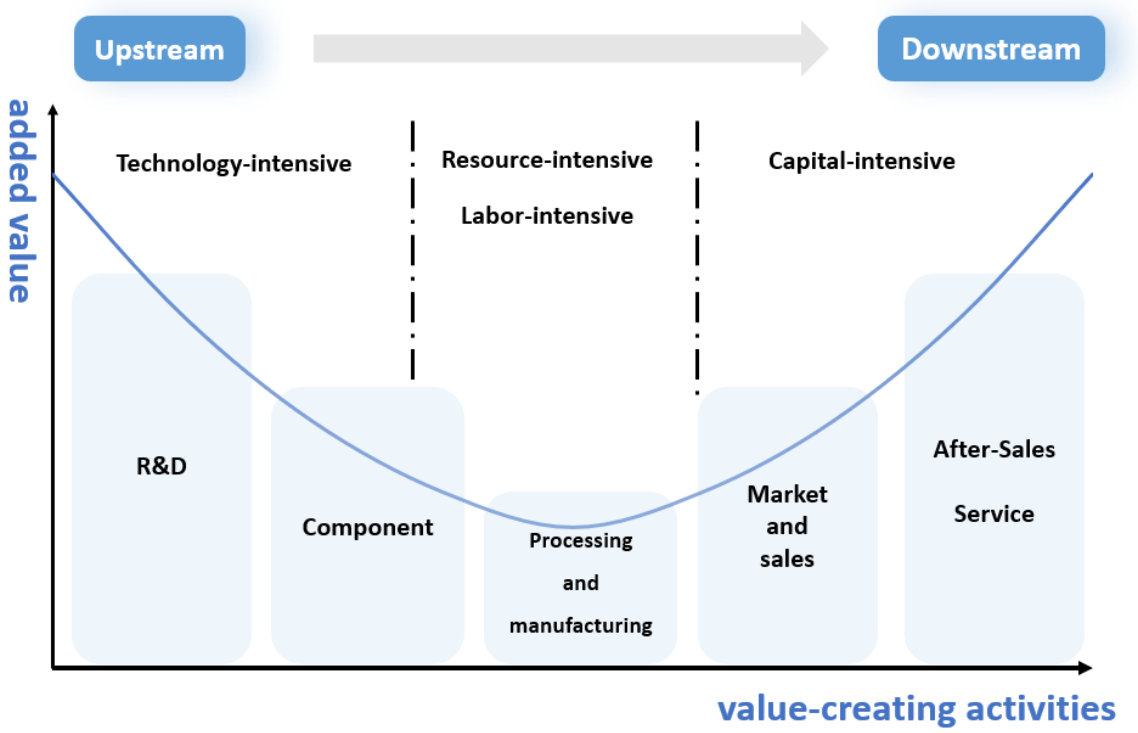

Figure 2. A smile curve of industry chain.

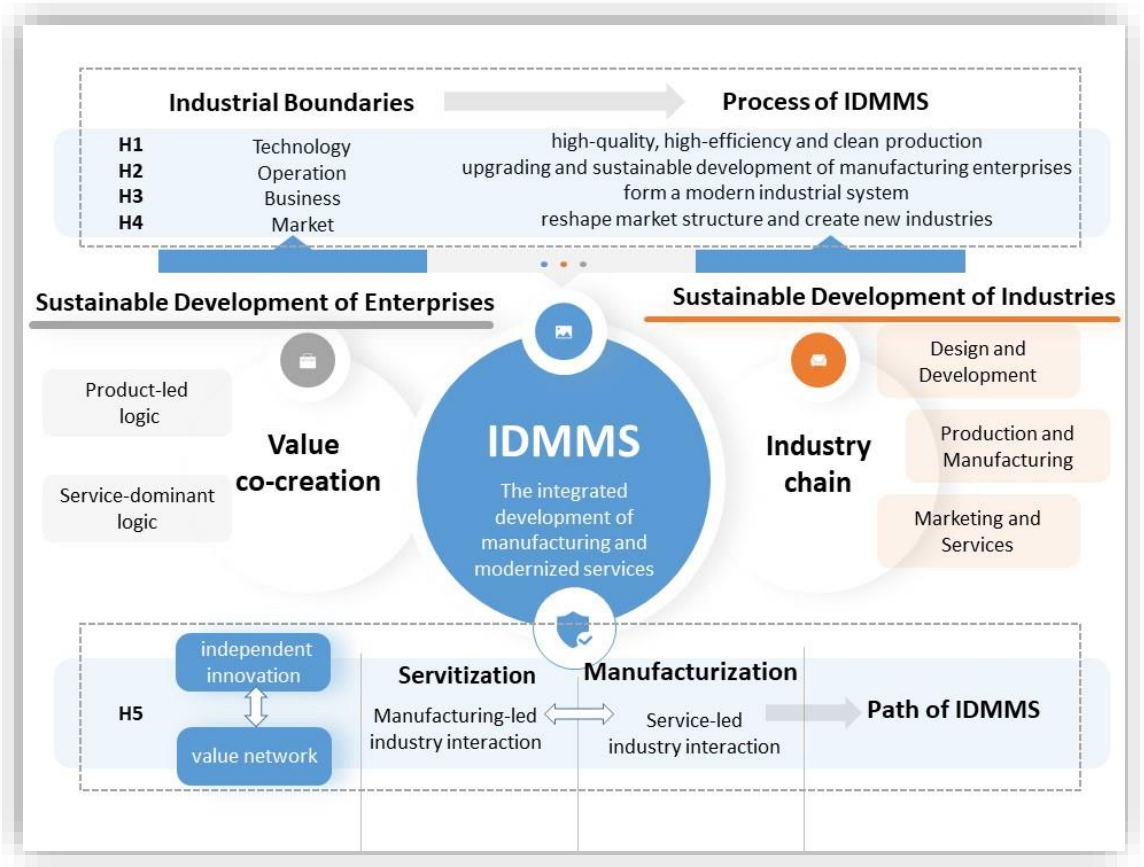

Figure 3. Conceptual framework.

3. Materials and Methods

3.1. Study Area

Located in China's eastern region (see Figure 4), Shandong has a complete range of industrial categories as a major industrial and manufacturing province. To overcome the lack of development momentum, Shandong has continued to accelerate the development of the deep integration of manufacturing and service industry, implementing service-oriented manufacturing industry action plans to promote the manufacturing industry to creative incubation, research and development, design, after-sales service and other industry chain extension at both ends, to enhance the manufacturing industry value chain.



Figure 4. Location of study area.

Firstly, Shandong has taken some steps in the aspect of fostering new industries and new models of integrated development. On the one hand, Shandong has promoted the construction of intelligent development of the total integration of general contracting pilot demonstration and supported qualified enterprises in changing from the provision of equipment to providing system integration of general contracting services, and also to transfer from the provision of products to provide total solutions. On the other hand, Shandong has accelerated the innovative application of industrial Internet, promoted flexible customization, developed a shared production platform, strengthened the whole life cycle management, optimized supply chain management, developed service derived manufacturing, and promoted industrial culture tourism and other new business models.

Secondly, several measures have been sought in terms of exploring new paths of integration development in key industries and key areas. For key industries in both the manufacturing and service industries, Shandong has proposed to accelerate the development of two-way integration of key industries such as raw materials industry, consumer goods industry, equipment manufacturing, automobile manufacturing and other possible paths.

Thirdly, Shandong has done something to promote the deep integration of consumer goods industry and service industry. It has proposed to focus on differentiation, quality, green consumer demand, and to promote the upgrading of consumer goods industry services. In the first half of 2020, the service industry in Shandong in the three industries in the proportion of added value reached 54.37%, service industry innovation and development vitality were effectively stimulated, and "Internet +" development environment more optimized. Therefore, digitization has become an important engine for the upgrading of manufacturing and high-quality economic development in Shandong.

3.2. Research Method

3.2.1. Input-Output Analysis Method

The input-output approach is an effective tool for supporting the analysis of the structural relationship between national or regional economic sectors [1]. It starts by capturing masses of observed economic data on outputs, activities, transactions, or other flows, and then organizes them in matrices representative of the economic system. Its basic idea is that to obtain a certain output, there must be a certain amount of input. Therefore, in the process of input and output between various sectors of the national economy, there are close production technology links and economic links. The interdependence between different industries and sectors can be described by the input-output table (IOT) (see Table 1), and can reveal the internal mechanism of industrial structure changes.

Table 1. Basic Input-Output Framework.

		Buying Sectors		**Final Demand**				**Total Outputs**
		s_1	**s_2**					**(x)**
Selling sectors	s_1	z_{11}	z_{12}	c_1	i_1	g_1	e_1	x_1
	s_2	z_{21}	z_{22}	c_2	i_2	g_2	e2	x_2
Primary inputs	Value-added	l_1	l_2					L
		n_1	n_2					N
	imports	m_1	m_2	m_c	m_i	m_g	m_e	M
Total inputs (x′)				C	I	G	E	X

Source: Adopted from R.E. Miller and P.D. Blair. 2009. Input-Output Analysis: Foundations and Extensions (2nd Edition). Cambridge, United Kingdom: Cambridge University Press.

As previously mentioned, essentially based on a highly specialized division of labor, IDMMS aims to improve the efficiency of production and operation, reduce obstacles between various links in the industrial chain, and transform the socialized division of labor into the internalized division of labor, which finally makes the originally independent industrial chains staggered and merged to form a symbiotic development relationship on the industrial chain [21]. It is worth noting that the symbiotic relationship between manufacturing and modern service industry integration is mainly based on the mechanism of supply and demand, which are manifested in the following aspects:

- The servitization of manufacturing-input, indicating the proportion of services as an intermediate product in manufacturing inputs, shows a trend of gradually increasing with the increased interaction between manufacturing and modern service industry.
- The servitization of manufacturing-output. The "output" here involves two main meanings: firstly, the benefits and value of the services provided in the tangible products produced by manufacturing gradually increases; secondly, the manufacturing companies directly regard the services as products to provide.
- The manufacturization of service, that is, service companies expand their value chain into different manufacturing or production segments.

Therefore, the degree of integration and correlation between the manufacturing industry and modernized services can be reflected in the promotion effect and interaction

between the two industries with the input and output relationship as the core. Hence, with the analysis of IOT, the degree of IDMMS can be sorted out.

3.2.2. Index System Construction

The input-output approach depends on the measurement of various coefficients, among which the most common indicators are the direct consumption coefficient, intermediate input rate, influence coefficient, and induction coefficient. However, in the traditional calculation process of the above indicators, the sum of all sectors of the national economy is used as the denominator to measure the degree IDMMS. The data of other industries are not excluded, which will bring interference with results and cause "systematic bias". Therefore, drawing on the research of Peng [58], this paper first unified the IOTs of Shandong Province in 2012 and 2017 to calculate the caliber, provided by the Shandong Provincial Bureau of Statistics. Considering the changes in the statistical caliber of manufacturing industry subdivisions in IOTs of 2012 and 2017, to ensure the continuity and rigor of the data, this paper selects the subdivision standard of 2017 and merges other manufacturing products and scrap and waste industries into one sector for the empirical study of this paper. Then we preprocessed the data, removed the sectors that do not belong to the manufacturing industry and modernized services, and formed the improved IOT, used as the calculation data basis of this paper (see Table 2).

The complex internal relationship between various sectors of the national economy is first manifested in the quantitative relationship of products consumed by each sector. The most basic concepts reflecting this relationship are the direct consumption coefficient and the complete consumption coefficient. The former is also called the direct input coefficient or technical coefficient, which is used to reveal the direct economic and technical connection between various production sectors under a certain technical level and production organization and management conditions [59]. Its economic meaning is the consumption of a certain product by a production unit of another product. The calculation formula is:

$$a_{ij} = x_{ij} / x_j \tag{1}$$

In the formula: x_{ij} is the element of the intermediate transactions matrix, and its meaning is the consumption of product i per unit output of sector j. x_j is the total input of sector j.

Based on Table 1, there are the following equations: $\sum_{j=1}^{n} x_{ij} + y_i = x_i$. From the direct consumption coefficient, it can be known: $x_{ij} = a_{ij} x_j$. Introducing the above model, there are: $\sum_{j=1}^{n} a_{ij} x_j + y_i = x_i$, which is expressed in matrix form as: $Ax + y = x$. Among them, A is the direct consumption coefficient matrix; x and y are the column vectors of the total product and the final product, respectively, that is:

$$A = \begin{bmatrix} a_{N1N1} & a_{N1N2} & \cdots & a_{N1N18} & a_{N1M1} & a_{N1M2} & \cdots & a_{N1M11} \\ a_{N2N1} & a_{N2N2} & \cdots & a_{N2N18} & a_{N2M1} & a_{N2M2} & \cdots & a_{N2M11} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{N18N1} & a_{N18N2} & \cdots & a_{N18N18} & a_{N18M1} & a_{N18M2} & \cdots & a_{N18M11} \\ a_{M1N1} & a_{M1N2} & \cdots & a_{M1N18} & a_{M1M1} & a_{M1M2} & \cdots & a_{M1M11} \\ a_{M2N1} & a_{M2N2} & \cdots & a_{M2N18} & a_{M2M1} & a_{M2M2} & \cdots & a_{M2M11} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{M11N1} & a_{M11N2} & \cdots & a_{M11N18} & a_{M11M1} & a_{M11M2} & \cdots & a_{M11M11} \end{bmatrix} \quad x = \begin{bmatrix} x_{N1} \\ x_{N2} \\ \cdots \\ x_{N18} \\ x_{M1} \\ x_{M2} \\ \cdots \\ x_{M11} \end{bmatrix} \quad y = \begin{bmatrix} y_{N1} \\ y_{N2} \\ \cdots \\ y_{N18} \\ y_{M1} \\ y_{M2} \\ \cdots \\ y_{M11} \end{bmatrix}$$

Table 2. Shandong's improved IOT.

		Buying Sectors								Final Demand	Import	Inflows from Other Provinces	Others	Total Outputs
		Manufacturing N1	**Manufacturing N2**	…	**Manufacturing N18**	**Modernized services M1**	**Modernized services M2**	…	**Modernized Services M11**					
Selling sectors	**Manufacturing N1**	X_{N1N1}	X_{N1N2}	…	X_{N1N18}	X_{N1M1}	X_{N1M2}	…	X_{N1M11}	F_{N1}	I_{N1}	P_{N1}	E_{N1}	X_{N1}
	Manufacturing N2	X_{N2N1}	X_{N2N2}	…	X_{N2N18}	X_{N2M1}	X_{N2M2}	…	X_{N2M11}	F_{N2}	I_{N2}	P_{N2}	E_{N2}	X_{N2}
	…	…	…	…	…	…	…	…	…	…	…	…	…	…
	Manufacturing N18	X_{N18N1}	X_{N18N2}	…	X_{N18N18}	X_{N18M1}	X_{N18M2}	…	X_{N18M11}	F_{N18}	I_{N18}	P_{N18}	E_{N18}	X_{N18}
	Modernized services M1	X_{M1N1}	X_{M1N2}	…	X_{M1N18}	X_{M1M1}	X_{M1M2}	…	X_{M1M11}	F_{M1}	I_{M1}	P_{M1}	E_{M1}	X_{M1}
	Modernized services M2	X_{M2N1}	X_{M2N2}	…	X_{M2N18}	X_{M2M1}	X_{M2M2}	…	X_{M2M11}	F_{M2}	I_{M2}	P_{M2}	E_{M2}	X_{M2}
	…	…	…	…	…	…	…	…	…	…	…	…	…	…
	Modernized services M11	X_{M11N1}	X_{M11N2}	…	X_{M11N18}	X_{M11M1}	X_{M11M2}	…	X_{M11M11}	F_{M11}	I_{M11}	P_{M11}	E_{M11}	X_{M11}
	Value-added	V_{N1}	V_{N2}	…	V_{N18}	V_{M1}	V_{M2}	…	V_{M11}					
	Total inputs	X_{N1}	X_{N2}	…	X_{N18}	X_{M1}	X_{M2}	…	X_{M11}					

Source: Self-drawn by authors.

From an economic point of view, the total of the columns of the direct consumption coefficient in the input-output matrix reflects the proportion of the intermediate input in each industrial sector to the total input. In other words, this indicator reveals the proportion of raw materials that need to be purchased from other industries in the production activities of each industry to produce a unit of output value, which can more intuitively reflect the input-driven relationship between industries. In the input-output approach, it is called the intermediate input rate, and the calculation formula is:

$$F_j = \sum_{i=1}^{n} a_{ij} \tag{2}$$

The above relationship can also be expressed as $x = (1 - A)^{-1} y$. Mathematically, this relationship reveals the relationship between the total product and the final product, where $(1 - A)^{-1}$ is called the Leontief inverse matrix, also known as the complete need coefficient matrix, and it is completely displayed, that is:

$$L = \begin{bmatrix} l_{N1N1} & l_{N1N2} & \cdots & l_{N1N18} & l_{N1M1} & l_{N1M2} & \cdots & l_{N1M11} \\ l_{N2N1} & l_{N2N2} & \cdots & l_{N2N18} & l_{N2M1} & l_{N2M2} & \cdots & l_{N2M11} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ l_{N18N1} & l_{N18N2} & \cdots & l_{N18N18} & l_{N18M1} & l_{N18M2} & \cdots & l_{N18M11} \\ l_{M1N1} & l_{M1N2} & \cdots & l_{M1N18} & l_{M1M1} & l_{M1M2} & \cdots & l_{M1M11} \\ l_{M2N1} & l_{M2N2} & \cdots & l_{M2N18} & l_{M2M1} & l_{M2M2} & \cdots & l_{M2M11} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ l_{M11N1} & l_{M11N2} & \cdots & l_{M11N18} & l_{M11M1} & l_{M11M2} & \cdots & l_{M11M11} \end{bmatrix} = (1 - A)^{-1}$$

$$= \begin{bmatrix} 1-a_{N1N1} & -a_{N1N2} & \cdots & -a_{N1N18} & -a_{N1M1} & -a_{N1M2} & \cdots & -a_{N1M11} \\ -a_{N2N1} & 1-a_{N2N2} & \cdots & -a_{N2N18} & -a_{N2M1} & -a_{N2M2} & \cdots & -a_{N2M11} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ -a_{N18N1} & -a_{N18N2} & \cdots & 1-a_{N18N18} & -a_{N18M1} & -a_{N18M2} & \cdots & -a_{N18M11} \\ -a_{M1N1} & -a_{M1N2} & \cdots & -a_{M1N18} & 1-a_{M1M1} & -a_{M1M2} & \cdots & -a_{M1M11} \\ -a_{M2N1} & -a_{M2N2} & \cdots & -a_{M2N18} & -a_{M2M1} & 1-a_{M2M2} & \cdots & -a_{M2M11} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ -a_{M11N1} & -a_{M11N2} & \cdots & -a_{M11N18} & -a_{M11M1} & -a_{M11M2} & \cdots & 1-a_{M11M11} \end{bmatrix}^{-1}$$

Element l_{ij} represents the complete demand for product i of the final product of the production unit of the j sector.

From an economic point of view, the column total of the Leontief inverse matrix reflects the absolute level of the ripple and pull of the production demand generated by the sector for all sectors, that is, when a sector increases the final demand of a unit, the production volume required by each sector through direct and indirect correlation, which can be called the degree of influence. The ratio of the average value obtained by dividing the total sum of each column by the number of sectors to the column sum of each sector reflects the relative level of the production demand ripple generated by the sector to all sectors, which is called the influence coefficient, and the calculation formula is:

$$F_j = \sum_{i=1}^{n} l_{ij} \Big/ \left(1/n \sum_{j=1}^{n} \sum_{i=1}^{m} l_{ij} \right) \tag{3}$$

Therefore, we build an index system as follows:

① Degree of Endogenous Fusion

The degree of endogenous integration is measured by the intermediate investment rate between manufacturing (a total of N sectors, N = 18) and modernized services (a total of M sectors, M = 11) in the production process. From the perspective of the value chain, manufacturing services, namely service industries, increase the value of products and realize the transformation and upgrading of traditional manufacturing by adding supporting services such as R&D design, marketing management, and extended services

in the product development process and production process. Therefore, the higher the endogenous integration of the modernized services with the manufacturing industry, the more conducive the value chain of the manufacturing industry is to climb. On the contrary, the more high-end a modernized service sector is, the more knowledge and technology-intensive it is, and the less dependent it is on intermediate industrial products. Therefore, the lower the degree of endogenous integration of the manufacturing industry with modernized services, the more conducive to the development and upgrading of modernized services. Consequently, the lower the degree of endogenous integration of the manufacturing industry with modernized services, the more conducive to the development and upgrading of modernized services.

SW_j represents the intermediate input degree of each modernized service sector as the manufacturing sector j, and the calculation formula is as follows:

$$SW_j = \sum_{i=1}^{11} a_{MiNj} \tag{4}$$

In the formula, a_{MiNj} is the direct consumption coefficient of modernized services i to manufacturing j, and the larger SW_j is, the greater the intermediate input of modernized services to the manufacturing, the more conducive to the industrial upgrading of the manufacturing industry.

MW_j represents the intermediate input degree of each manufacturing sector to the modernized services j sector, and its calculation formula is as follows:

$$MW_j = \sum_{i=1}^{18} a_{NiMj} \tag{5}$$

In the formula, a_{NiMj} is the direct consumption coefficient of the manufacturing industry i to the modernized services j. The larger MW_j is, the higher the dependence on the manufacturing industry in the production of the modernized services, which means the modernized services is at the lower end.

② Degree of Exogenous correlation

The exogenous correlation degree is used to measure the impact of production demand on each other when manufacturing (a total of N sectors, N = 18) and modernized service (a total of M sectors, M = 11) add a unit to their final use.

M_j to represents the influence coefficient of the manufacturing j industry on the modernized services, and its calculation formula is as follows:

$$M_j = \frac{\sum_{i=1}^{11} l_{MiNj}}{\frac{1}{18}\sum_{j=1}^{18}\sum_{i=1}^{11} l_{MiNj}} \tag{6}$$

In the formula, the value of M_j is greater than 1, indicating that the active integration ability of manufacturing sector j into the modernized services is greater than the average level; less than 1, indicating that the active integration ability is less than the average level. And the larger M_j is, the stronger the pulling degree of the manufacturing sector j to the modernized services.

S_j represents the influence coefficient of modernized services j on manufacturing, and its calculation formula is as follows:

$$S_j = \frac{\sum_{i=1}^{18} l_{NiMj}}{\frac{1}{11}\sum_{j=1}^{11}\sum_{i=1}^{18} l_{NiMj}} \tag{7}$$

In the formula, the value of S_j is greater than 1, indicating that the active integration ability of the modernized services j sector to the manufacturing industry is greater than the average level; less than 1, indicates that the active integration ability is lower than

the average level. The larger S_j is, the stronger the pulling degree of the j sector of the modernized services is to the manufacturing industry.

It is necessary to add that modernized services corresponds to the traditional services, which use new technologies, and new models, as well as uphold new service concepts. This paper made some adjustments according to the scope of modernized services defined in *Hebei's Modernized Services Statistical Survey Report System* released by the National Bureau of Statistics in 2020. In this report, the sales and mail order and TV telephone retail services realized through public networks in the wholesale and retail industry, and the sales services realized through public networks in the lodging and catering industry are included in the modernized services. However, because it is difficult to extract parts of the input and output of specific industries in the input-output table, this paper didn't include these parts in the calculation, so the 11 sectors in Figure 5 were included in the categories of modernized services.

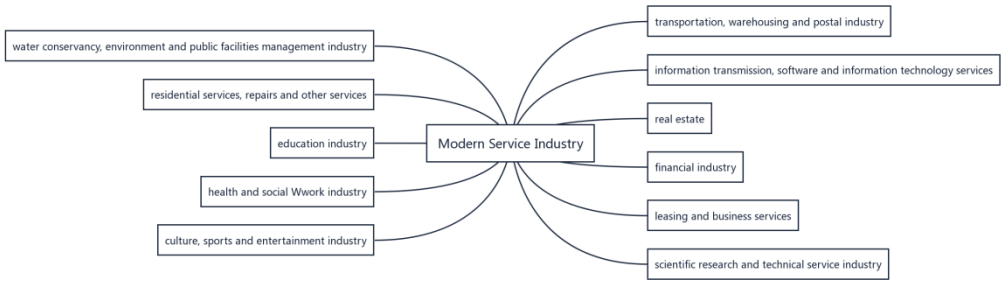

Figure 5. Scope of Modernized services.

Likewise, in view of the changes in the statistical caliber of service industry subdivisions in IOTs of 2012 and 2017, to ensure the continuity and rigor of data, this paper selects the subdivision standard of 2012 and regards scientific research and technical service industry as one sector for the empirical study.

4. Results and Analysis

4.1. Results of Endogenous Fusion Degree

According to the IOTs of Shandong Province in 2012 and 2017, the intermediate input rate between the two industries was calculated, and the endogenous integration and interaction between the manufacturing and the modernized services were obtained (see Tables 3 and 4).

As shown in Table 3, from a static point of view, in 2017, the servitization extent of manufacturing in five sectors in Shandong Province are higher, including wood products and furniture, chemical products, non-metallic mineral products, metal products, communication equipment, computers, and other electronic equipment industries, and their endogenous fusion degrees are all more than 5%. From the perspective of dynamic changes, from 2012 to 2017, the intermediate input rate of modernized services in Shandong Province to various manufacturing sectors showed a slight downward trend, indicating that the driving effect of modernized services on the overall manufacturing industry has weakened. In order of rising degree from high to low, in 2017, the modernized services' interest in nine sectors were increased, including wood products and furniture, transportation equipment, general equipment, special equipment, metal products, other manufacturing products and waste, chemical products, instrumentation, communication equipment, computers, and other electronic equipment industry. Among them, wood products and furniture industry saw the largest increase, from 3.8 percent in 2012 to 6.5 percent in 2017, an increase of 2.73 percentage points. The intermediate input rate for the remaining nine manufacturing sectors all declined, with the non-metallic mineral products industry showing the largest decline, dropping 5.57 percentage points from 11.0 percent in 2012 to 5.5 percent in 2017.

Table 3. The endogenous integration of various industries in the modernized services to manufacturing.

The Intermediate Input Rate of Modernized Service to Various Manufacturing Industries	2012	2017	2017–2012
Food and tobacco industry	3.18%	2.29%	−0.89%
Textile industry	3.50%	1.95%	−1.56%
Textiles, garments, shoes, hats, leather, down feather, and their products	3.48%	2.31%	−1.17%
Wood products and furniture industry	3.81%	6.55%	2.73%
Paper printing and cultural, educational, and sporting goods	4.60%	2.85%	−1.74%
Petroleum, coking products, and nuclear fuel processed products	2.92%	1.30%	−1.62%
Chemical products industry	4.40%	5.20%	0.80%
Non-metallic mineral products industry	11.05%	5.47%	−5.57%
The metal smelting and rolling of processed products	5.41%	4.13%	−1.27%
Metal smelting and rolling processed products industry	4.27%	5.29%	1.02%
General equipment industry	3.92%	4.47%	0.55%
Special equipment industry	2.49%	4.19%	1.70%
Transportation equipment industry	1.97%	3.98%	2.01%
Electrical machinery and equipment industry	4.90%	4.01%	−0.89%
Communication equipment, computer, and other electronic equipment industry	3.41%	5.23%	1.81%
Instrumentation industry	1.84%	2.39%	0.56%
Other manufactured products and scrap industry	2.58%	3.45%	0.87%
Metal products, machinery, and equipment repair services	3.43%	0.90%	−2.53%
All manufacturing	4.27%	3.92%	−0.35%

Table 4. The endogenous integration of various manufacturing industries to modernized services.

The Intermediate Input Rate of Manufacturing to Various Modernized Services	2012	2017	2017–2012
Transportation, warehousing, and postal industry	19.74%	12.04%	−7.71%
Information transmission, software and information technology services	23.97%	30.52%	6.56%
Real estate	19.50%	12.47%	−7.03%
Financial industry	2.85%	4.65%	1.80%
Leasing and business services	22.87%	13.17%	−9.70%
Scientific research and technical service industry	26.96%	25.84%	−1.12%
Water conservancy, environment, and public facilities management industry	24.05%	5.51%	−18.55%
Residential services, repairs and other services	25.44%	39.83%	14.39%
Education industry	11.39%	5.54%	−5.85%
The health and social work industry	36.20%	62.39%	26.19%
Culture, sports, and entertainment industry	20.77%	21.75%	0.98%
All modernized services industry	19.19%	18.65%	−0.53%

From the perspective of the three major industries of the manufacturing industry, in 2017, the endogenous integration of the modernized services with the raw material manufacturing industry and the equipment manufacturing industry was significantly higher than that of the consumer goods manufacturing industry, which was, respectively, 1.65 and 1.71 percentage points higher than that of the consumer goods manufacturing industry; from the perspective of dynamic changes, the servitization degree of equipment manufacturing industry has grown rapidly, from 3.40% in 2012 to 4.43% in 2017, an increase of 1.03 percentage points. In contrast, the servitization degree of consumer goods manufacturing and raw material manufacturing has decreased, respectively, by 0.81 and 1.05 percentage points (see Figure 6). The reason behind it may be closely related to the industrial structure development trend and industrial characteristics of Shandong Province. In 2012, the ratio of the three industries in Shandong Province was 8.6:51.4:40, which was still insufficient compared with the national industrial structure of 9.4:45.3:45.3. This is closely related to the high proportion of traditional industries in Shandong Province for a long time, especially heavy industry enterprises, which makes industries in Shandong Province as a whole show the characteristics of "rough, black and heavy". To accelerate the

transformation and upgrading of the industry, Shandong Province formulated and issued the "Action Plan for Promoting Industrial Transformation and Upgrading in Shandong and the Implementation Plan for Transformation and Upgrading of 22 Key Industries" (referred to as the "1 + 22" plan) in 2015. The plan determines to cultivate four emerging industries of high-end equipment manufacturing, modern medicine, a new generation of information technology, and new materials and strives to promote the industrial upgrading of Shandong Province from large to strong. The equipment manufacturing industry, especially the development of the high-end equipment manufacturing industry, has high requirements on a technical level, and R&D investment, and tends to provide professional and personalized customized solutions and integrated services. In the production process, the demand for modernized services such as scientific research and technical services, finance, transportation, and after-sales service is higher. With the policy support of the provincial government, the equipment manufacturing industry and the high-tech manufacturing industry in Shandong Province have achieved rapid growth. In 2021, the added value of the two has increased by 10.5% and 18.5%, respectively, and the intermediate investment rate of the modernized services has also increased well.

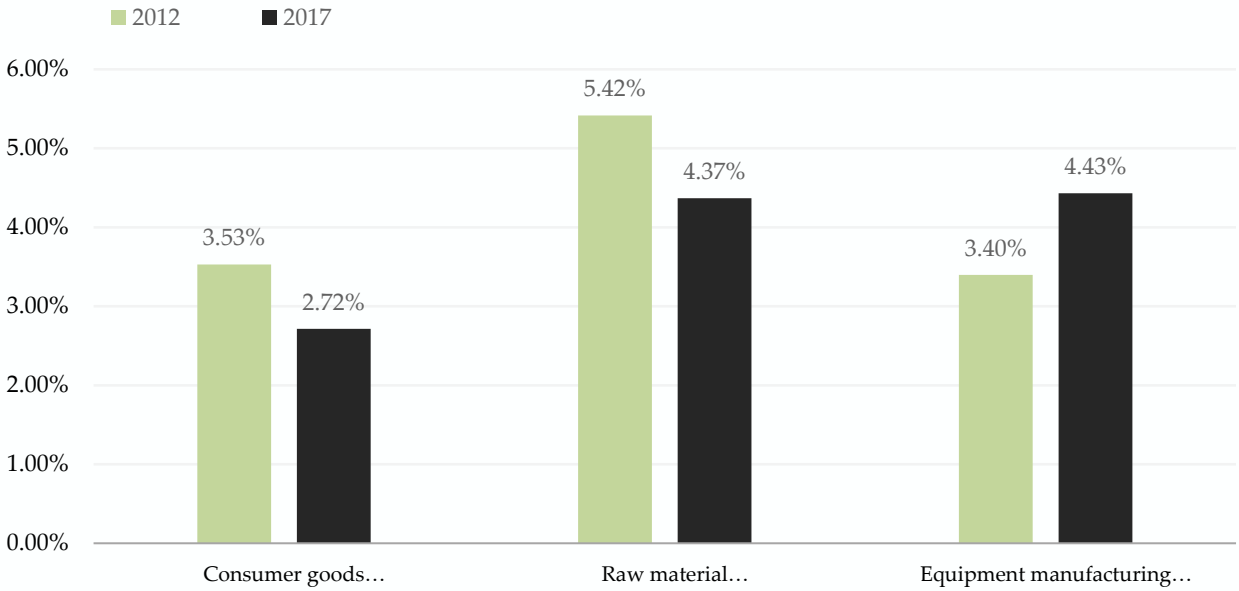

Figure 6. The degree of endogenous integration of the modernized services with the three major categories of manufacturing.

As shown in Table 4, the endogenous integration degree of the manufacturing industry in Shandong Province with modernized services decreased slightly from 2012 to 2017, which was consistent with the development trend of modernized services. With the servitization of information technology and the intensification of knowledge and talents, the dependence of modernized services on the intermediate input of the manufacturing industry in the production process decreased. From the perspective of the two major categories of modernized services, in 2017, the intermediate investment rates of manufacturing in consumer services and producer services were, respectively, 25.09% and 14.90%, with the former about 10.19 percentage points higher than the latter. From the perspective of dynamic changes, in 2017, the endogenous integration of the manufacturing industry to the producer service industry decreased from 20.87% in 2012 to 14.09%, while the endogenous integration of the consumer service industry increased from 16.28% in 2012 to 25.09% in 2017. This change revealed that the major contribution to the vigorous development of modernized services in Shandong Province from 2012 to 2017 was the producer services (see Figure 7).

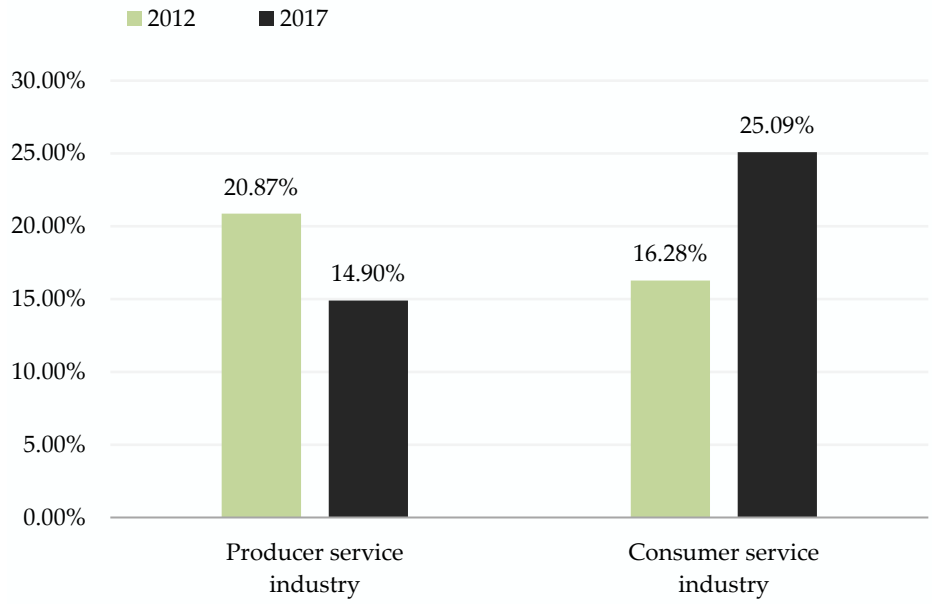

Figure 7. The endogenous integration of manufacturing with the two major categories of modernized services.

Combining Tables 2 and 3, in view of input structure, the intermediate input rate of manufacturing to modernized services in 2017 was 18.65%, while the proportion of intermediate input of modernized services to manufacturing was only single digit, 3.92%. This indicates that the manufacturing has more self-circulation, and the degree of backward correlation between the modernized services and the manufacturing was weak. The support and driving effect of the manufacturing was insufficient. From the perspective of dynamic changes in input structure, compared with 2012, the proportion of intermediate inputs between modernized services and the manufacturing in 2017 was relatively stable and showed a slight decline. The reason may be that between 2012 and 2017, the economic development of Shandong Province presented a situation from real to virtual. Although the scale of some modernized services, such as finance, were expanding, the expansion of scale was due to internalization. The integration between real industries was relatively small, and the development of manufacturing and modernized services was separated. At the same time, constrained by the traditional development of heavy chemical industrialization, Shandong Province has experienced rapid growth in raw materials and metallurgy in recent years. However, these manufacturing enterprises focus on resource investment and have limited demand for producer services. In fact, at the Central Economic Work Conference in December 2016, the issue of excessive tax burden and the financial and real estate sectors squeezing the real economy attracted significant attention, and the conference made it clear that there is a risk that the economy is shifting from real to virtual. The Shandong Provincial Economic Work Conference was held shortly thereafter, and a series of measures were put forward to revitalize the real economy, such as, deepening the "Three Reductions, One Lowering and One Compensation" (i.e., overcapacity reduction, inventory reduction, leverage reduction, cost lowering and weak link strengthening), and integrating resources to promote the leapfrog development of modernized services. After five years of exploration, the replacement of old growth drivers in Shandong has been quite effective, and the industrial structure has been continuously optimized. The composition the of three industries has changed from 6.7:45.3:48.0 in 2017 to 7.3:39.9:52.8 in 2021, and the service industry contributed as much as 59.5% to the economic growth of Shandong. The integrated development of manufacturing and the Internet has also made new achievements. In the list of "industrial Internet platform innovation leading application cases" in 2021, 23 industrial Internet application enterprises in Shandong were listed, ranking first in China.

4.2. Results of Exogenous Correlation Degree

According to the IOTs of Shandong Province in 2012 and 2017, the influence coefficient between the two industries was calculated, and the exogenous production demand ripple degree between manufacturing and modernized services was obtained (see Tables 5 and 6).

Table 5. Influence coefficient of manufacturing on modernized services.

Influence Coefficient of Manufacturing on Modernized Services	2012	2017	2017–2012
Food and tobacco industry	0.540038	0.505003	−0.035035
Textile industry	0.803648	0.793749	−0.009899
Textiles, garments, shoes, hats, leather, down feather, and their products	0.956077	0.900975	−0.055102
Wood products and furniture industry	0.879606	1.539759	0.660152
Paper printing and cultural, educational, and sporting goods	1.124759	1.085187	−0.039572
Petroleum, coking products, and nuclear fuel processed products	0.451319	0.310106	−0.141212
Chemical products industry	1.044877	1.166984	0.122107
Non-metallic mineral products industry	1.750349	1.170133	−0.580215
Metal smelting and rolling processed products	1.156702	0.826973	−0.329729
Metal smelting and rolling processed products industry	1.097578	1.213126	0.115547
General equipment industry	1.091613	1.054224	−0.037389
Special equipment industry	0.933814	1.220954	0.287139
Transportation equipment industry	0.957194	1.28014	0.322945
Electrical machinery and equipment industry	1.318665	1.14101	−0.177655
Communication equipment, computer, and other electronic equipment industry	1.320653	1.47184	0.151187
Instrumentation industry	0.86154	1.132928	0.271389
Other manufactured products and scrap industry	0.826207	0.498072	−0.328135
Metal products, machinery and equipment repair services	0.885362	0.688838	−0.196524

Table 6. Influence coefficient of modernized services on manufacturing.

Influence Coefficient of Modernized Services on Manufacturing	2012	2017	2017–2012
Transportation, warehousing and postal industry	0.807691	0.891805	0.084114
Information transmission, software and information technology services	1.361739	1.507057	0.145318
Real estate	0.982343	0.655258	−0.327086
Financial industry	0.24244	0.365747	0.123307
Leasing and business services	1.175388	0.714994	−0.460394
Scientific research and technical service industry	1.324141	1.158146	−0.165994
Water conservancy, environment and public facilities management industry	1.023389	0.326118	−0.697271
Residential services, repairs and other services	1.14084	1.676315	0.535475
Education industry	0.522078	0.274846	−0.247232
The health and social work industry	1.515445	2.31459	0.799145
Culture, sports, and entertainment industry	0.904506	1.115124	0.210618

As shown in Table 5, from the static point of view, the influence coefficient of wood products and furniture, communication equipment, computer and other electronic equipment industry on modernized services ranked first and second in 2017, at 1.54 and 1.47, respectively. It indicates that among all manufacturing sectors, these two sectors had the largest driving effect on modernized services. From the perspective of dynamic changes, most sectors in the manufacturing industry had a relatively stable impact on modernized services from 2012 to 2017. Among them, the influence coefficient of seven sectors, including communications equipment, computers and other electronic equipment, metal products and non-metallic mineral products, chemical products, electrical machinery and equipment, paper printing and stationery and sporting goods, and the general equipment industry were always higher than the average level, which showed these sector's ability to drive the modernized services have always been strong. However, the influence coefficient of seven sectors, including textile clothing, shoes, hats, leather, down feather and their products, textiles, metal products, machinery and equipment repair services, food and

tobacco, other manufacturing products and waste, petroleum, coking products and nuclear fuel processing products were always lower than the average level, which indicated that their pulling effect on the modernized services were limited. In addition, the influence coefficient of wood products and furniture, transportation equipment, special equipment, instrument and meter industry increased from less than 1 to more than 1, indicating that the driving effect of these four industrial sectors on modernized services has increased significantly in the past five years. However, the driving effect of metal smelting and rolling processing industry on modernized services declined significantly.

As shown in Table 6, from the static point of view, the exogenous correlation degree of health and social work, resident services, repair, and other services, information transmission, software, and information technology services ranked the top three in 2017 with 2.31, 1.68 and 1.51, respectively, which had a great driving effect on the manufacturing industry. From the perspective of dynamic changes, most sectors in modernized services had a relatively stable driving effect on the manufacturing industry. Among them, the four "pull functions" of the manufacturing industry sector, including residents of health and social work, service, repair, and other services, information transmission, software, and information technology services, scientific research, and technical services were always higher than the average level, and the four "pull functions" for manufacturing industry sector, including transportation, warehousing and postal service, finance, real estate, education were always below the average. In addition, the influence coefficient of the culture, sports, and entertainment industry increased from less than 1 in 2012 to more than 1 in 2017, indicating a significant increase in the driving effect on the manufacturing industry. On the contrary, leasing and business services, water conservancy, environment, and public facilities management industries didn't have more industrial advantages in promoting the transformation and upgrading of manufacturing industries.

According to Tables 5 and 6, the driving effect of wood products, and furniture industry and equipment manufacturing sectors, including communication equipment, computer and other electronic equipment industry, transportation equipment, special equipment, instrument, and meter industry on modernized services has been significantly improved. The underlying reasons may be related to the characteristics of the industry. In recent years, driven by new applications and service forms such as e-commerce and customized production, wood products and furniture in the consumer goods manufacturing industry has an increasingly high demand for technical services, human resource services, modern logistics, and after-sales services. The equipment manufacturing industry often has a long industrial chain and higher requirements for system integration services, so the demand for modernized services such as scientific and technological services, financial services, modern logistics, and after-sales services is also gradually expanding. In addition, health and social work, resident services, repair, and other services, information transmission, software, and information technology services all have a strong driving effect on the overall manufacturing industry and are closely related to the development of the manufacturing industry. They should be prioritized as key industries in Shandong, so as to promote the integration and development of more industrial sectors.

5. Discussion

5.1. Existing Problems of Shandong's IDMMS

Research results strongly suggest that there exist three problems with the integrated development of manufacturing and modernized services in Shandong Province.

In terms of industry level, the integration of manufacturing and modernized services is not wide and sufficient. From the angle of the fusion area, the fusion development in home appliance and equipment manufacturing industries started relatively early, such as Haier Group. As a leading enterprise in the home appliance industry, with the help of "Internet+" to realize the transformation and upgrading of traditional manufacturing industry, it has begun to work in IDMMS, but most of the industries and enterprises have few breakthroughs. According to the value chain theory (see Figure 2), the more the

manufacturing industry extends to both ends of the "smile curve", the higher its added value will be, which is bound to be accompanied by the investment growth of modernized service industries such as front-end R&D design and terminal marketing services. For a long time, the manufacturing industry in Shandong Province has been a mostly labor-intensive and heavy chemical industry with low production efficiency, technical content, and added value. In this stage of development, especially with "coarse, black and heavy" as the main characteristics, it focuses on resource input, lags behind industrial upgrading, and has relatively insufficient demand for information, financial and technical services, resulting in low intermediate input of modernized services.

From the perspective of enterprise level, as the manufacturing enterprises in Shandong Province are still in the middle and low end of the value chain on the whole, and even a large number of enterprises are still mainly OEM, the industrial chain is relatively short, and the high-end design, research, and development and service links depend on foreign multinational companies for a long time. They are accustomed to the self-enclosed development path of "service build-in" and lack the cooperative thinking of "outsourcing non-core business to focus on improving core competitiveness", presenting the production and operation mode of "large and complete" and "small and complete". This lacks the specialized division of labor and coordination among enterprises, and also compresses the development space of modernized services. Such "path locking" and "path dependence" formed for a long time places a large number of manufacturing enterprises, especially private enterprises, in a dilemma, which is that there exists a high risk, large investment and slow effect for these enterprises to transform from traditional manufacturing enterprises to the integration of two industries.

5.2. Value Co-Creation and the Mechanism of IDMMS

Fundamentally, the process of IDMMS is a process of value creation. It emphasizes the transformation from the traditional product manufacturing as the core to the provision of products with rich service connotation and product-dependent services, until providing complete solutions to customers, which finally creates new value for enterprises. The process is the transformation of manufacturing enterprises from production to service. This process is the transformation of manufacturing enterprises from product providers to service providers, and is also the reason why most contemporary enterprises have a "dual identity" as both manufacturing enterprises and service enterprises [29]. In addition, with technological innovation and development, the interactive support of service value and tangible product value has become more obvious, and each value co-creation subject has an increasing impact on overall value [9]. This section begins to give some suggestions by the following facts (see Figure 8):

First, information technology and knowledge are integrated into all aspects of the service, and collaborative manufacturing is achieved through the modular production of products and process optimization. Hence, digital empowerment should be strengthened and the information barriers and industrial boundaries (see Figure 1) of the integration of the two industries should be eliminated. In the era of traditional industrial economy, limited by the level of technology, massive data acquisition, processing and sharing cannot be realized, which leads to a large number of information barriers between upstream and downstream enterprises in the industrial chain, between enterprises and users, and even within enterprises, blocking the integration and development of industries. Currently, the Internet, big data, the Internet of Things and other new technological means should be made use of to give full play to the "self-value adding effect" and "integrated value adding effect" of data and to build a sharing platform based on the interactive connection of all kinds of data and achieve value creation.

Second, the modern service industry's integration and customization of customer service allows companies to create value for their customers by better co-producing with them. Therefore, intelligent production should be promoted and the business model and industrial form of the integration of the two industries should be innovated. The effective

combination of information technology and manufacturing industry can not only improve the traditional production process, but also meet the individual needs of consumers, and realize the dual improvement of production efficiency and product quality. Through years of scientific research and practice, Kutesmart, the original Red Collar Group, has built an industrial Internet platform dominated by C2M (customer to factory) business model, and accomplished the service of intelligent and flexible intelligent and efficient solutions from the whole industry chain, such as intelligent body measurement, intelligent R&D design, marketing planning, independent ordering, flexible production, intelligent manufacturing, logistics and distribution. It provides a useful reference for the promotion and application of the new business form and mode of intelligent production and flexible customization in various fields.

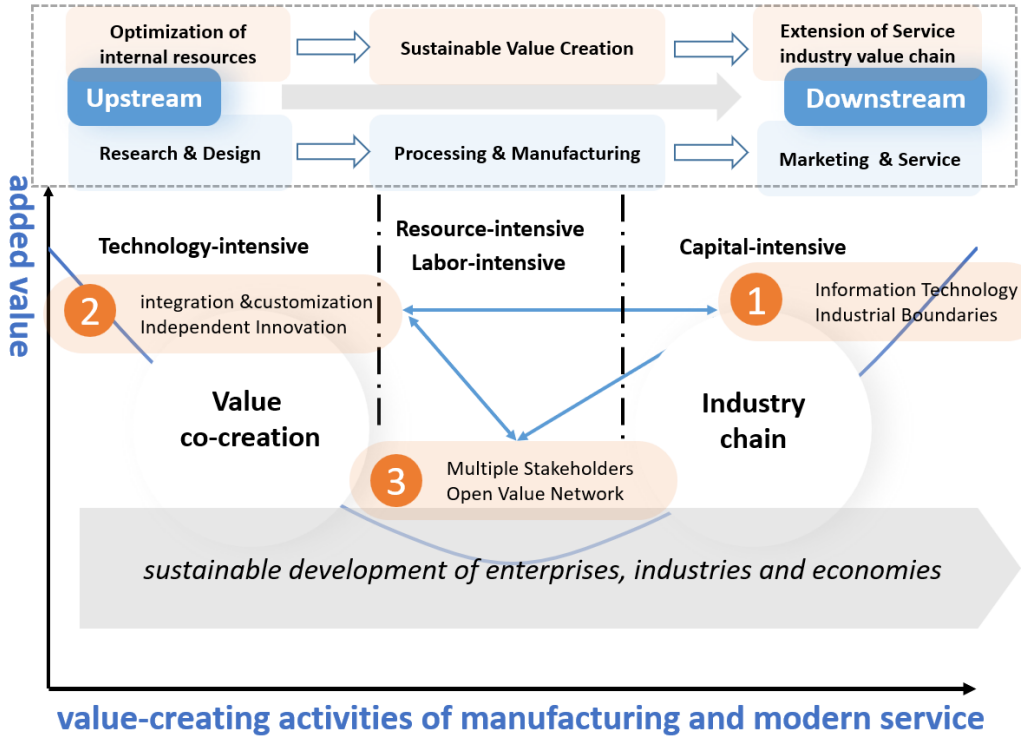

Figure 8. The mechanism of IDMMS based on value co-creation and industry chain.

Finally, with the gradual replacement of commodity-driven logic by service-dominant logic [60], the value creation method in the process of servitization of manufacturing has shifted from the traditional "enterprise–customer" and "enterprise–stakeholder" binary relationship to an ecosystem that includes more value-creation subjects. Hence, more and more stakeholders participate in the process of value co-creation, including enterprises, governments, the media as well as customers. Hence, the degree of servitization and degree of resource integration of enterprises impact the upgrade path and the sustainable development of manufacturing enterprises.

6. Conclusions

Since IDMMS has positive effects on the sustainable development of the micro firms, the macro economy, as well as the environment, it has been a hot topic for both scholars and practitioners. Building upon value co-creation, industry chain theory and the industrial boundary literature, this paper explored an analytical framework combining theoretical and empirical evidence, using Shandong's latest input-output table data. The establishment of this framework is scientific and reasonable, because it not only figures out the existing problems in the evolution process of Shandong's IDMMS by empirical analysis, but also provides a fine-grained understanding of the relationship among different industrial boundaries (i.e., technology boundary, business boundary, operation boundary,

and market boundary), various value-creating activities of manufacturing and modern service industries (i.e., R&D, procurement, processing & manufacturing, market & sales, and after-sale service), a smile curve of industry chain and industrial integration.

The findings can be summarized as follows: first, the analysis of the degree of endogenous fusion indicates that the manufacturing has more self-circulation, the degree of backward correlation between the modernized services and the manufacturing was weak, and the support and driving effect of the manufacturing was insufficient. Compared with 2012, the proportion of intermediate inputs between modernized services and manufacturing in 2017 was relatively stable and showed a slight decline. In view of the three major industries of the manufacturing industry, the servitization degree of equipment manufacturing industry has grown rapidly, whereas the servitization degree of consumer goods manufacturing and raw material manufacturing has decreased. Second, the driving effect of wood products and furniture industry, and equipment manufacturing sectors, including communication equipment, computer and other electronic equipment industry, transportation equipment, special equipment, instrument, and meter industry on modernized services has been significantly improved. Simultaneously, health and social work, resident services, repair, and other services, information transmission, software, and information technology services all have a strong driving effect on the overall manufacturing industry and are closely related to the development of the manufacturing industry. They should be prioritized as key industries in Shandong, so as to promote the integration and development of more industrial sectors.

This paper breaks through the limitations of two aspects:

In terms of theoretical contributions, drawing on the value co-creation theory and industrial integration literature, this paper has developed a comprehensive framework linking IDMMS, sustainable development and firm performance. Few studies have been conducted to analyze the mechanism and path of deeper integration between manufacturing and modern service industry from three dimensions: macroeconomic-sustainable-development, meso-industrial-integration, and micro-enterprise-performance-improvement. From the perspective of managemental significance, this paper addresses the gap, that is, the industrial integration and its relationship with sustainable development within the region is still not clear.

Despite its contributions, our study has several limitations. On the one hand, the final possible limitation of this study is that the input–output table provided by Shandong Bureau of Statistics has inconsistencies in the number of industrial sectors each year, yet the names of industry sectors are also different. Consequently, some important industrial sectors, whose internal structure changes greatly each year, cannot perform the time-series analysis of their status. On the other hand, the industrial boundaries of advanced manufacturing and modern service industries will change with the continuous development of the economy, and some traditional industries will be transformed into "advanced" or "modernized" industries with the integration of AI technology, so the definition and boundaries of the industries still deserve further exploration. Further research should consider alternative approaches to identify the mechanisms of IDMMS and to measure the degree of industrial integration between manufacturing and modern service.

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References

1. Jin, Y.; Xu, Y.; Li, R.; Zhao, C.; Yuan, Z. Comprehensive Evaluation of China's Input–Output Sector Status Based on the Entropy Weight-Social Network Analysis Method. *Sustainability* **2022**, *14*, 14588. [CrossRef]
2. Wang, Q.; Su, M. A Preliminary Assessment of the Impact of COVID-19 on Environment—A Case Study of China. *Sci. Total Environ.* **2020**, *728*, 138915. [CrossRef]
3. Wang, Q.; Zhang, F. What Does the China's Economic Recovery after COVID-19 Pandemic Mean for the Economic Growth and Energy Consumption of Other Countries? *J. Clean. Prod.* **2021**, *295*, 126265. [CrossRef]
4. Chen, Y.; Wu, Z.; Yi, W.; Wang, B.; Yao, J.; Pei, Z.; Chen, J. Bibliometric Method for Manufacturing Servitization: A Review and Future Research Directions. *Sustainability* **2022**, *14*, 8743. [CrossRef]
5. Zhou, R.; Tang, D.; Da, D.; Chen, W.; Kong, L.; Boamah, V. Research on China's Manufacturing Industry Moving towards the Middle and High-End of the GVC Driven by Digital Economy. *Sustainability* **2022**, *14*, 7717. [CrossRef]
6. Szirmai, A.; Verspagen, B. Manufacturing and Economic Growth in Developing Countries, 1950–2005. *Struct. Chang. Econ. Dyn.* **2015**, *34*, 46–59. [CrossRef]
7. Zhang, J. Impact of Manufacturing Servitization on Factor Productivity of Industrial Sector Using Global Value Chain. *Sustainability* **2022**, *14*, 5354. [CrossRef]
8. Peng, B.; Wang, Y.; Zahid, S.; Wei, G.; Elahi, E. Platform Ecological Circle for Cold Chain Logistics Enterprises: The Value Co-Creation Analysis. *Ind. Manag. Data Syst.* **2020**, *120*, 675–691. [CrossRef]
9. Li, G.; Wu, J.; Li, N. Identifying the Value Co-Creation Model and Upgrading Path of Manufacturing Enterprises from the Value Network Perspective. *Sustainability* **2022**, *14*, 16008. [CrossRef]
10. Vandermerwe, S.; Rada, J. Servitization of Business: Adding Value by Adding Services. *Eur. Manag. J.* **1988**, *6*, 314–324. [CrossRef]
11. Francois, J.; Woerz, J. Producer Services, Manufacturing Linkages, and Trade. *J. Ind. Compet. Trade* **2008**, *8*, 199–229. [CrossRef]
12. Greenstein, S.; Khanna, T. What Does Industry Mean? In *Competing in the Age of Digital Convergence*; The President and Fellows of Harvard Press: Boston, MA, USA, 1997; pp. 14–28.
13. Yoffie, D.B. Service-Led Growth: The Role of the Service Sector in World Development. By Dorothy I. Riddle. New York: Praeger Publishers, 1986. Pp. xiv, 289. Index. $37.95. *Am. J. Int. Law* **1988**, *82*, 224–225. [CrossRef]
14. Eichengreen, B.; Gupta, P. The Two Waves of Service-Sector Growth. *Oxf. Econ. Pap.* **2013**, *65*, 96–123. [CrossRef]
15. Legewie, J. The Political Economy of Industrial Integration in ASEAN: The Role of Japanese Companies. *J. Asia Pac. Econ.* **2000**, *5*, 204–233. [CrossRef]
16. Li, T.; Liu, X.; Li, X. Some Theoretical Analysis About the Service of Manufacturing Industry. *Forum Sci. Technol. China* **2018**, *0*, 75–82.
17. Li, W.; Xia, J. Integration of Manufacturing and Service Industries Based on Independent Innovation: Mechanism and Path. *J. Nanjing Univ. (Philos. Humanit. Soc. Sci.)* **2012**, *49*, 60–67.
18. Qi, L.; Cai, Y.; Wang, C. Study on the Influence Factors of the Convergence of China's Equipment Manufacturing Industry. *Sci. Technol. Prog. Policy* **2017**, *34*, 92–97.
19. Zhao, X.; Zhang, Y. Technological Progress and Industrial Performance: A Case Study of Solar Photovoltaic Industry. *Renew. Sustain. Energy Rev.* **2018**, *81*, 929–936. [CrossRef]
20. Mattila, A.S.; Wirtz, J. Congruency of Scent and Music as a Driver of In-Store Evaluations and Behavior. *J. Retail.* **2001**, *77*, 273–289. [CrossRef]
21. Hong, Q. Current Situation of the Convergence of Advanced Manufacturing and Modern Service in China and the Strategic Focus of the "14th Five-Year Plan". *Contemp. Econ. Manag.* **2021**, *43*, 74–81.
22. Zhou, Z. Industrial Convergence: New Power of Industrial Development and Economic Growth. *China Ind. Econ.* **2003**, *4*, 46–52.
23. Bastas, A. Sustainable Manufacturing Technologies: A Systematic Review of Latest Trends and Themes. *Sustainability* **2021**, *13*, 4271. [CrossRef]
24. United Nations Infrastructure and Industrialization–United Nations Sustainable Development. Available online: https://www.un.org/sustainabledevelopment/infrastructure-industrialization/ (accessed on 14 December 2022).
25. Chen, W.; Huang, X.; Liu, Y.; Song, Y. Does Industry Integration Improve the Competitiveness of China's Electronic Information Industry?—Evidence from the Integration of the Electronic Information Industry and Financial Industry. *Sustainability* **2019**, *11*, 2695. [CrossRef]

26. Uekusa, M. Some Policy and Regulatory Issues in the Japanese Electric Power Industry. In *Electricity 21: Power Industry Technology and Management Strategies for the Twenty-First Century*; OECD Publications and Information Centre: Washington, DC, USA, 1993; pp. 319–324.
27. Xia, L. Spatial Effect of Industrial Integration on Total Factor Productivity: From the Perspective of the Integration of Advanced Manufacturing Industry and Modern Service Industry. *J. Beijing Univ. Aeronaut. Astronaut. (Soc. Sci. Ed.)* **2022**. [CrossRef]
28. Yoffie, B.D. Competing in the Age of Digital Convergence. *Calif. Manag. Rev.* **1996**, *38*, 31–53. [CrossRef]
29. Liu, J.; Dai, M.; Yi, S. Integration of Advanced Manufacturing and Modern Service Industry: Mechanism and Path. *Study Pract.* **2014**, 23–34. [CrossRef]
30. Wang, W.; Lai, K.-H.; Shou, Y. The Impact of Servitization on Firm Performance: A Meta-Analysis. *Int. J. Oper. Prod. Manag.* **2018**, *38*, 1562–1588. [CrossRef]
31. Zhang, Y.; Wang, Y.; Li, Y. Facilitating Servitization in Manufacturing Firms: The Influence of Strategic Orientation. *Sustainability* **2021**, *13*, 13541. [CrossRef]
32. Benedettini, O.; Neely, A.; Swink, M. Why Do Servitized Firms Fail? A Risk-Based Explanation. *Int. J. Oper. Prod. Manag.* **2015**, *35*, 946–979. [CrossRef]
33. Neely, A. Exploring the Financial Consequences of the Servitization of Manufacturing. *Oper. Manag. Res.* **2008**, *1*, 103–118. [CrossRef]
34. Baines, T.S.; Lightfoot, H.W.; Benedettini, O.; Kay, J.M. The Servitization of Manufacturing: A Review of Literature and Reflection on Future Challenges. *J. Manuf. Technol. Manag.* **2009**, *20*, 547–567. [CrossRef]
35. Shah, S.A.A.; Jajja, M.S.S.; Chatha, K.A.; Farooq, S. Servitization and Supply Chain Integration: An Empirical Analysis. *Int. J. Prod. Econ.* **2020**, *229*, 107765. [CrossRef]
36. Sousa, R.; da Silveira, G.J.C. Capability Antecedents and Performance Outcomes of Servitization. *Int. J. Oper. Prod. Manag.* **2017**, *37*, 444–467. [CrossRef]
37. Mathieu, V. Product Services: From a Service Supporting the Product to a Service Supporting the Client. *J. Bus. Ind. Mark.* **2001**, *16*, 39–61. [CrossRef]
38. Szász, L.; Demeter, K.; Boer, H.; Cheng, Y. Servitization of Manufacturing: The Effect of Economic Context. *J. Manuf. Technol. Manag.* **2017**, *28*, 1011–1034. [CrossRef]
39. Gambardella, A.; Torrisi, S. Does Technological Convergence Imply Convergence in Markets? Evidence from The Electronics Industry. *Res. Policy* **1998**, *27*, 445–463. [CrossRef]
40. Helleno, A.L.; Simon, A.T.; Papa, M.C.O.; Ceglio, W.E.; Rossa Neto, A.S.; Mourad, R.B.A. Integration University-Industry: Laboratory Model for Learning Lean Manufacturing Concepts in the Academic and Industrial Environments. *Int. J. Eng. Educ.* **2013**, *29*, 1387–1399.
41. Curran, C.-S.; Bröring, S.; Leker, J. Anticipating Converging Industries Using Publicly Available Data. *Technol. Forecast. Soc. Chang.* **2010**, *77*, 385–395. [CrossRef]
42. Fai, F.; von Tunzelmann, N. Industry-Specific Competencies and Converging Technological Systems: Evidence from Patents. *Struct. Change Econ. Dyn.* **2001**, *12*, 141–170. [CrossRef]
43. Cheng, G.; Yang, C. China's Provincial Industry Convergence Capability: Theoretical Deconstruction, Evaluation Methods and Spatiotemporal Differentiation. *Sci. Technol. Prog. Policy* **2019**, *36*, 61–67.
44. Chu, M. Study on Convergence Degree between Producer Services and Equipment Manufacturing Industry in the Yang-Tze River Delta—Based on the Comparative Analysis of Input-Output Table. *Shanghai J. Econ.* **2015**, 94–100. [CrossRef]
45. Li, L.; Zhao, Y. Research on the Industrial Linkage-Development between Manufacturing and Information Service Industry of Hubei Province. *Wuhan Univ. Technol. (Soc. Sci. Ed.)* **2017**, *30*, 24–31.
46. Zhang, Z. The Influence of Information Industry on Manufacturing Industry: An Empirical Analysis Based on Chongqing Data. *Sci. Technol. Manag. Res.* **2019**, *39*, 110–117.
47. Zhang, J.; Yan, X. Latest Trend of the Integration of Beijing's Producer Services and Manufacturing: From the Perspective of Ex-Panding Opening-Up. *J. Cap. Univ. Econ. Bus.* **2022**, *24*, 18–31.
48. Yao, X.; Pu, Y.; Wu, G.; Wang, B.; Wang, L. China's Level and Status of Industry Convergence in the Belt and Road Initiative: Industry Comparisons, Regional Gaps and Associated Factors. *Econ. Res. J.* **2019**, *54*, 172–186.
49. Barry, P.B.; Jack, E.T. The Early 21st Century U.S. Productivity Expansion Is Still in Services. *Int. Product. Monit.* **2007**, *14*, 3–19.
50. Cao, D.; Yu, C.; Xu, B. The Collaborative Mechanisms between High-End Services and Advanced Manufacturing and the Empirical Analysis—Research on the Yangtze River Delta. *Res. Econ. Manag.* **2014**, 76–86. [CrossRef]
51. Tang, X.; Zhang, X.; Li, Y. Dynamic Coordination Development in China's Manufacturing and Manufacturing-Related Service Industries. *Econ. Res. J.* **2018**, *53*, 79–93.
52. Cao, X. Study on Integration of Informatization and Industrialization Characteristics and Its Interation Relationship with Industrial Design. *Int. J. Technol. Manag.* **2015**, *5*, 829–833.
53. Li, X.; Chen, H.; Zhang, X. Research on the Industrial Performance of the Covergence of Information Industry with Manufacturing Industry Based on the Data of Zhejiang Province. *China Soft Sci.* **2017**, *32*, 22–30.
54. Hiroshi, I. *Introduction to Input-Output Analysis*; China Statitics Press: Beijing, China, 1990; ISBN 7-5037-0401-2.
55. Peng, Y.; Hou, Y.; Luo, J.; Li, Y. Research on Configuration of Integration of Equipment Manufacturing Industry and Modernized Services Based on TOE Framework. *Chin. J. Manag.* **2022**, *19*, 333–341.

56. Jian, Z.; Wu, Z. A Research on the Paths Selection of Servitization in Manufacturing: Based on the Viewpoint of Smiling Curve. *Sci. Sci. Manag. S. T.* **2011**, *32*, 137–143.
57. Deng, Z. Historical Logic, Practical Significance and Path Exploration of the Integration and Development of Manufac-Turing Industry and Service Industry. *J. Beijing Univ. Technol. (Soc. Sci. Ed.)* **2019**, *19*, 61–69.
58. Peng, H.; Kuang, X. To What Extent Does China's Manufacturing and Productive Services Integrate—Base on 2010–2014 International Input-Output Analysis and Comparison. *J. Int. Trade* **2019**, *10*, 100–116.
59. Wang, Y.; Ge, Y. Analysis on Characteristic of Input-Output Relation of Chinese Industrial Structure. *J. Manag. World* **2007**, 61–68. [CrossRef]
60. Vargo, S.L.; Maglio, P.P.; Akaka, M.A. On Value and Value Co-Creation: A Service Systems and Service Logic Perspective. *Eur. Manag. J.* **2008**, *26*, 145–152. [CrossRef]

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