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Research on measurement of service-oriented development level of manufacturing industry in Henan Province, China

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ABSTRACT

This study examines the service-oriented development level of Henan Province's manufacturing sector to understand regional servitization patterns and inform industrial transformation policies in central China. The research employs a mixed-methods approach combining cross-sectional and longitudinal analyses. Input-output analysis using 2017 regional data from China's 31 provincial-level regions measures servitization through direct and complete consumption coefficients. A ten-year longitudinal study (2011-2020) analyzes 62 listed manufacturing enterprises using service revenue ratios as proxy indicators for temporal development patterns. Henan's manufacturing servitization level (0.39) surpasses the national average (0.29), ranking fifth nationally. Sixteen of 17 manufacturing industries rank within the top eight, with non-metallic mineral products, textiles, and electrical machinery leading. Longitudinal analysis reveals bifurcated development: steady growth (2011-2016) followed by volatility (2016-2020), with significant decline during COVID-19. Henan demonstrates robust servitization capacity with comprehensive multi-sectoral development, though external vulnerabilities persist during economic shocks and policy transitions. Strategic recommendations include establishing provincial servitization funds, building digital service platforms, strengthening talent development systems, implementing tax incentives for high-service enterprises, and creating monitoring frameworks to enhance policy effectiveness and industrial competitiveness.

Contribution/Originality: This study uniquely examines manufacturing servitization in central China's traditional industrial regions, employing dual analytical frameworks (horizontal cross-regional and vertical temporal analysis) to reveal servitization vulnerabilities during external shocks such as COVID-19, addressing methodological gaps in previous coastal-focused research.

1. INTRODUCTION

Since the reform and opening-up, China has developed a relatively comprehensive industrial system through prolonged, arduous efforts, encompassing all 41 major industrial categories. As a pivotal province in central China, Henan currently possesses 40 major industrial categories, 197 medium industrial sectors, and 583 minor industrial subsectors (Shen & Wang, 2018). Over the years, Henan's industrial output has consistently ranked among the top nationwide, solidifying its status as a genuine industrial powerhouse where manufacturing increasingly serves as the "primary engine" of economic growth. However, objective analysis reveals that the majority of manufacturing enterprises still adhere to conventional production approaches, characterized by low technological sophistication, high energy intensity, significant environmental pollution, and limited economic efficiency, occupying the low-end segment of the value chain (Wang, Zhang, & Wang, 2024). Consequently, industrial restructuring and upgrading have become imperative for Henan. The province must enhance industrial competitiveness, prioritize the development of advanced manufacturing, and transition towards a model emphasizing technological sophistication, value-added production, energy efficiency, and environmental sustainability. This transformation represents the most important step for Henan to become a leader in advanced manufacturing and industries.

Servitization is established as a service-centered competitive approach in the realm of manufacturing. This is because it associates with the planning efforts of manufacturers to administer in-depth knowledge services throughout the value chain for competitive gain (Gomes, Lehman, Vendrell-Herrero, & Bustinza, 2021) effectively changing value chains from being manufacturing-focused to service-oriented. Therefore, businesses move from producing products to offering integrated solutions that encompass both services and products (Kowalkowski, Gebauer, Kamp, & Parry, 2017a). This strategic change also focuses on the interaction and engagement with the customer and the provision of advanced tailored service fulfils (Martinez, Neely, Velu, Leinster-Evans, & Bisessar, 2017; Raja & Frandsen, 2017; Sjödin, Parida, Kohtamäki, & Wincent, 2020). The general uptake of this approach allows firms to capture and use customer data systematically (Tóth et al., 2020) while at the same time improving customer retention and market differentiation all of which enhance both financial and non-financial performance indicators (Matthyssens & Vandenbempt, 2008; Wang, Lai, & Shou, 2018). Newer forms of technology, including big data analytics, artificial intelligence, cloud computing, and the Internet of Things (IoT), facilitate the compartmentalization of products and their integration with services (Lim & Maglio, 2018). This transformative innovative business model offers services to preserve manufacturing enterprises' fundamentally defined operational domain (Rymaszewska, Helo, & Gunasekaran, 2017).

Object-oriented programming (OOP) is a fundamental aspect of the software development curriculum, providing pedagogical tools for reasoning, abstraction, encapsulation, and class hierarchy. Many OOP languages and advanced development tools not only embody these principles but also include robust user-interface design features such as exploration, animation, and online help. The purpose of this study is to analyze problems encountered when teaching class hierarchies to undergraduate students and to develop effective solutions tailored to their specific needs. We conducted lessons on class hierarchy over two sessions. As our results indicated, using visual aids improved students' understanding of the relationships within a class hierarchy. Ensuring that the relationships among classes depicted in these diagrams are accurately defined is essential.

While regions of more advanced economies and coastal regions of China have been studied in depth, China's central regions, which are distinctly constrained by structural challenges in transforming their manufacturing units, remain underexplored. This study offers novel insights into the literature and practices concerning manufacturing servitization. The analysis addresses methodological gaps in previous studies with its vertical and horizontal temporal frameworks for assessing servitization development. The study focused on Henan province as a representative case of a traditional manufacturing empire transitioning in the center of China, aiming to highlight servitization pathways constrained by available resources, limited technological sophistication, and an immature industrial shift. The longitudinal study covering the years 2020 to 2021 revealed new vulnerabilities related to policies and external shocks, such as the COVID-19 pandemic, which severely impacted destabilized servitization pathways. These findings help in striking the right balance for planned efforts to accelerate service orientation in the transitional manufacturing sector at a global level.

2. THEORETICAL FRAMEWORK

2.1. Conceptualization and Characteristics of Manufacturing Servitization

Ever since Vandermerwe and Rada (1988) introduced the notion of "servitization" 35 years ago, its conceptual limits and theoretical ramifications have been enriched and dynamically evolved over time. In particular, business enterprises enhance products with ancillary services using multiple techniques, shifting their focus toward customer retention to develop service-based production lines (Levitt, 1972). Specifically, manufacturing servitization is described as a delineated strategy of embedding service components into a product, which changes the role of the manufacturer from a seller of goods to offering integrated "product-service" packages and complete solutions Vandermerwe and Rada (1988). This shift fundamentally alters the paradigm by positioning services as primary drivers throughout the product life cycle, enabling them to capture and create value instead of merely adding value.

Thus, the progression is clear: producers shift from being product-centric entities to service providers (White, Stoughton, & Feng, 1999) and from offering physical products as the core offering to providing them alongside associated product functionalities and services (Fishbein, McGarry, & Dillon, 2000; Makower, 2001). Increased market competition has compelled manufacturers to add service components along two dimensions: internal services regarding organizational efficiency create significant competitive advantage, while external services increasingly address the complex and customer-focused nature of modern products (Stieglitz, 2003). Servitization, in conceptual terms, is a process of transformation where manufacturers shift to a service-dominant logic, using services as a main resource through servitization in order to satisfy shifts in demand, improve competitive positioning, and organizational performance (Ren & Gregory, 2007). Shifts in competitive strategy from offering products to services require the conversion of business structures and aims, and fundamentally, business models and corporate missions (Rabetino, Harmsen, Kohtamäki, & Sihvonen, 2018; Raddats, Kowalkowski, Benedettini, Burton, & Gebauer, 2019). The resulting transformations, referred to in the literature as 'multilevel transformation dynamics,' accompany changes in strategic level objectives for various organizational participants constituting an industrial ecosystem (Sousa & da Silveira, 2020).

Academics have studied the meaning of manufacturing servitization from various scholarly angles. Some researchers have framed its essence from an input-output perspective, suggesting that services increasingly penetrate manufacturing processes as production inputs (Lanz & Maurer, 2015; Liu, 2008). This has resulted in the formulation of servitization measurement indicators that aim to assess the level of servitization through intermediate service inputs (Heuser, Mattoo, & Ruta, 2017). Another academic cohort interprets servitization as an outcome of knowledge economy development, where technological advancements, particularly in information technology, drive the transition from product-oriented manufacturing to service-oriented manufacturing (Xu, Mo, & Chen, 2016). Empirical studies demonstrate that digital technologies facilitate the creation of sophisticated and innovative services that enhance manufacturing servitization (Grubic, 2018; Lerch & Gotsch, 2015). Emerging as a novel paradigm in manufacturing servitization, cloud manufacturing characterized by service-oriented architecture and cloud computing provides comprehensive solutions encompassing product development, manufacturing processes, testing, and lifecycle management (Talhi, Huet, Fortineau, & Lamouri, 2015). This technological framework exemplifies the progressive integration of service elements throughout manufacturing value chains.

In summary, the servitization of manufacturing drives transformations in the functional roles and industrial structures of manufacturing enterprises (Reiskin, White, Kauffman Johnson, & Votta, 1999). It enables firms to maintain customer relationships through distinctive approaches and methodologies (Tukker, 2004) and has evidently emerged as a strategic option for corporate innovation and development (Carlborg, Kindström, & Kowalkowski, 2013). Numerous manufacturers recognize that implementing servitization strategies yields benefits across multiple dimensions, including financial performance (Neely, 2008) strategic growth (Kowalkowski, Gebauer, & Oliva, 2017b) marketing effectiveness (Gebauer, Saul, Haldimann, & Gustafsson, 2017) and technological innovation (Rabetino et al., 2018) ultimately generating super profits for enterprises. The conceptual understanding of manufacturing servitization requires objective and in-depth analysis, rather than simplistically equating "servitization" with "de-manufacturing" (Cheng, Zhang, Sun, Rong, & Zhang, 2020). However, it must be acknowledged that servitization constitutes a complex research domain. Evolving global development environments present new challenges to manufacturing servitization while simultaneously enabling servitization to play crucial roles within emerging interdependent stakeholder relationships.

The characteristics of servitization in manufacturing are perceived differently by various scholars, who focus on distinct aspects. Specifically, these characteristics can be summarized from three perspectives: the input perspective (Jiang & Shu, 2023) the output perspective (Baines et al., 2017) and the product-service provision perspective (Gölgeci, Gligor, Lacka, & Raja, 2021). The specific features are compiled in Table 1 as follows:

Table 1. A Comparative analysis of traditional manufacturing and servitization models in the manufacturing industry.

Comparison items	Traditional manufacturing model characteristics	Servitization development model characteristics
Final products provided by enterprises	Predominantly tangible products	Predominantly services.
Method of final product provision	Actively provide products and services in a supplementary position.	Actively provide services to meet customer needs.
Types and intensity of service elements	Labor-intensive	Knowledge and technology-intensive.
Relationships with upstream and downstream enterprises in the industry chain.	Horizontal or vertical integration	Network-based equal partnership.
Input-output relationship	Ultimately achieving economies of scale	Ultimately achieving economies of scope.

2.2. Measurement of Manufacturing Servitization Level

Servitization, as a critical strategic choice for manufacturing enterprises, exerts profound influences on internal organizational dynamics, corporate growth, and decision-making processes. Empirical evidence suggests a correlation between the level of manufacturing servitization and corporate profitability, with service-oriented inputs demonstrating lower resource intensity compared to physical production factors (Rothenberg, 2007). Such service-driven substitutions foster innovation in production models, enabling 11.1% of manufacturing firms to derive over 40% of their revenue from service offerings (Gebauer, Fleisch, & Friedli, 2005). However, the relationship between servitization and corporate performance is not uniformly linear Neely (2008) identified an inverted U-shaped relationship, where escalating human capital and operational costs at advanced servitization stages may erode profitability. This nonlinearity is further corroborated by Kastalli and Van Looy (2013) who observed negative correlations between servitization and financial returns in heavy equipment manufacturers and listed industrial firms. The magnitude and direction of these effects vary across servitization phases:

- Initial phase: enterprises adopt basic service differentiation strategies (e.g., outsourced maintenance or customized solutions) to reduce production and transaction costs (Xu, Cheng, & Sun, 2017). while early adopters generate technological spillovers that accelerate industry-wide servitization, constrained investments in intangible assets (e.g., R&D, skilled labor) often trap firms in low-value service segments.
- Transitional phase: organizations face escalating complexity in value proposition redesign, pricing model adaptation, and structural realignment. The deepening integration of production and service systems frequently leads to cost overruns and transient performance declines, a phenomenon termed the "servitization paradox"(Gebauer et al., 2005).
- Maturity Phase: Advanced digital platforms and knowledge-intensive service innovations enhance product-service synergies, driving demand-supply alignment and value capture. Cross-industry resource sharing in R&D and design, as evidenced by Dai (2021), enables sustainable profitability resurgence and sector-wide servitization acceleration.

Heterogeneous servitization trajectories across industries and developmental stages underscore the necessity for systematic measurement frameworks. Quantifying servitization levels facilitates the identification of phase-specific challenges, benchmarking of best practices, and the avoidance of strategic pitfalls inherent in service-oriented transformation.

The quantification of servitization development levels is a critical component of empirical research on manufacturing servitization. Scholars predominantly adopt macro- and micro-level perspectives to assess servitization intensity, with enterprise-level micro-analyses being the most prevalent approach in both theoretical and practical applications. From a microeconomic perspective, manufacturing firms establish measurement dimensions and systems based on service activity typologies, service quality parameters, and strategic service positioning (Bowen, Siehl, & Schneider, 1989). The concept of servitization strategic orientation significantly influences service intensity, where stronger strategic commitments correlate with increased resource allocation to service elements, broader service portfolios, and expanded service coverage. Consequently, Homburg, Hoyer, and Fassnacht (2002) proposed a tripartite measurement framework integrating service quantity, service intensity, and service breadth to operationalize servitization levels. Complementary approaches incorporate strategic service types, product-service configurations, and supply chain positioning as evaluative criteria (Gunter, 2010). A representative methodology involves analyzing listed manufacturing enterprises through global databases such as OSIRIS. Neely (2008) exemplified this approach by examining 10,028 listed manufacturers across 25 countries, utilizing service project metrics including scale, quantity, and revenue contributions. Financial disclosure analysis further enables researchers to calculate service revenue ratios by isolating "other operating income" items under prevailing accounting standards (Fang, Palmatier, & Steenkamp, 2008; Skaggs, 2004). Industry-specific empirical measurements frequently employ mixed methods. Guo, Li, Zuo, Liu, and Wang (2015) study of Chinese CT manufacturers combined survey data and interviews to assess servitization through four dimensions: customer performance, product-service scale, financial metrics, and service revenue ratios. Human capital metrics also prove instrumental, with Martin and Fei (2011) advocating workforce composition analysis particularly the proportion of dedicated service professionals and technical personnel as a pragmatic indicator of servitization maturity.

From a macro perspective, the primary scholars and experts conducting research on the measurement of servitization levels in the manufacturing industry are Chinese. The data for measurement is primarily sourced from the World Input-Output Database (WIOD), the Organisation for Economic Co-operation and Development (OECD) Inter-country Input-Output Tables, the Global Supply Chain Database, the Multi-regional Environmentally Extended Supply and Use Table and Input-Output Table, and the Input-Output data from China's National Statistical Yearbook. Relevant data are extracted from these databases, and servitization levels are measured by constructing Input-Output models. Cui (2015) applied this method to calculate and compare the servitization levels of China, the United States, and India. Measuring servitization levels from the perspective of service innovation performance is an innovative approach, based on the Cobb-Douglas production function to construct a mathematical model for measuring servitization levels (Yang, 2009). Some scholars use Input-Output tables to calculate correlation coefficients as indicators for measuring the servitization levels of various manufacturing sectors (Du & Jin, 2020). Other studies measure servitization levels from an output perspective, calculating the proportion of production services in manufacturing output as a measure of servitization levels (Xiao, Nie, & Liu, 2014).

2.3. The Convergence Trend of Manufacturing and Service Industries

Over the past few decades, changes have occurred in various aspects such as technology, institutions, management, and the trade environment. Innovation no longer takes place solely within individual organizations. Customer demands also extend beyond specific major fields. All these factors have prompted changes in an increasing number of industrial structures, leading enterprises to make significant adjustments in management strategies, organizational structures, and process flows. Against the backdrop of a new competitive landscape, industry boundaries have begun to blur and are even being redefined (Bettis & Hitt, 1995; Bröring, Cloutier, & Leker, 2006; Sampler, 1998). For example, the automotive industry now involves not only the mechanical field but also communication technology; nanotechnology encompasses multiple disciplines, including physics and chemistry (Battard, 2012). The integration of education and artificial intelligence has given rise to various forms of educational services. Scholars have closely monitored this ever-changing phenomenon of industry convergence, explored the concepts and theories of industrial convergence, and conducted qualitative analyses based on specific industry cases (Bröring et al., 2006; Chon, Choi, Barnett, Danowski, & Joo, 2003; Duysters & Hagedoorn, 1998; Gambardella & Torrisi, 1998; Stieglitz, 2002; Wirtz, 2001). Early discussions on industrial convergence mainly focused on the information technology, communication (ITC), and media industries (Lei, 2000; Stieglitz, 2003). Nowadays, the technological convergence triggered by the information technology revolution has permeated various industries, leading to a major convergence of sectors. Technological innovation and technological convergence have become catalysts for the development of industrial convergence. The industrial convergence based on technological innovation and technological fusion is not only a fundamental change to the traditional industrial system but also a historical milestone of a new industrial revolution, becoming a new driving force for industrial development and economic growth.

A review of the historical development of manufacturing servitization reveals that this process inherently represents the integration between manufacturing and modern service industries. The servitization level demonstrates a significant positive correlation with the degree of industry convergence. Generally speaking, the servitization process has evolved through three distinct phases characterized by different levels of integration: shallow integration, general collaboration, and deep convergence. As detailed in Table 2, each developmental stage exhibits unique patterns and defining characteristics that reflect progressive advancement in service-oriented transformation.

Table 2. Process and manifestations of integration development in manufacturing and service industries.

Integration dimension	Shallow integration	General collaboration	Deep convergence
Input integration	• Simple service elements provided internally within manufacturing	• Specialized producer services spun off from manufacturing enterprises.	• Reintegration and integrated development between manufacturing enterprises and modern service industries.
Output integration	• Enhanced product/component reliability • Promoted product diversification and portfolio expansion	Value-added services include: - Post-sales support - Personalized experiences - Product design customization - Financial service integration	Holistic integration of manufacturing and service operations through: - Systematic convergence - Full-spectrum service-manufacturing integration - Closed-loop value chain optimization

Based on extensive empirical studies, the current servitization level of China's manufacturing sector remains relatively low overall, with significant disparities across different industries. Advanced manufacturing sectors, including high-end equipment manufacturing, electronic information manufacturing, new energy vehicles, and biopharmaceuticals, demonstrate relatively higher servitization levels, showing better integration with knowledge-intensive service industries such as software and information services, financial services, and scientific R&D sectors. In contrast, other manufacturing industries still maintain elementary-level servitization development.

Current industry observations reveal that most manufacturing enterprises remain at the rudimentary collaboration stage in industrial convergence with service sectors, indicating substantial potential for growth and development. Particularly noteworthy is that the global economic crisis and COVID-19 pandemic have profoundly impacted traditional manufacturing worldwide, simultaneously exposing critical bottlenecks and obstacles in conventional manufacturing development patterns. These challenges have accelerated the imperative for manufacturing servitization transformation, compelling enterprises to align with emerging service-oriented trends. The evolutionary trajectory of manufacturing servitization manifests four distinct developmental trends:

- Input Servitization: Progressive adoption of service-oriented production factors and intermediate inputs throughout manufacturing processes.
- Output Servitization: Strategic expansion from tangible product offerings to comprehensive service-solution packages, enhancing value-added services.
- Value Chain Enhancement: Methodical extension and deepening of service-embedded nodes within enterprise value chains, optimizing value creation mechanisms.
- Accelerated Convergence: China's intensified efforts to narrow the servitization gap with developed economies through policy support and industrial upgrading initiatives.

3. METHODOLOGY

3.1. Selection of Research Methods

A systematic review of existing literature reveals three primary methodological frameworks for measuring manufacturing servitization levels:

3.1.1. Input-Output Analysis

This method uses the available regional input–output table to compute direct and full-service consumption coefficients for each unit of manufacturing output. This approach measures servitization through interindustry dependencies by computing service sector inputs (direct consumption coefficient) and the total supply chain service-related inputs (complete consumption coefficient) (Cui, 2015; Du & Jin, 2020). This approach concerns the integration of the service factor into production inputs and is sometimes referred to as the Input Servitization Measurement.

3.1.2. Service Revenue Ratio Method

This micro-level metric measures the proportion of service-related income (referred to as "other operating income" in contemporary accounting) to total revenue for the enterprise. Firm-level data are aggregated to construct regional or sectoral servitization levels, which depict the portion of service outputs in total value-added production in manufacturing (Fang et al., 2008; Skaggs, 2004). Thus, it is widely accepted as the measurement of output servitization.

3.1.3. Comprehensive Survey Approach

Using both qualitative and quantitative techniques, this approach develops multi-faceted evaluation frameworks via enterprise questionnaires. Indicators can comprise the range of services provided (Bowen et al., 1989; Homburg et al., 2002) where greater breadth of service provision reflects higher levels of servitization maturity. This blended approach enhances the understanding of firm-level practices of servitization, guiding strategists to make informed decisions. Its combination of these features enhances contextual relevance and supports precise adjustments at the micro-level within an organization.

3.1.4. Methodological Comparison

- Input-Output Analysis: Captures macro-level structural interdependencies but lacks firm-specific granularity.
- Service Revenue Ratio: Enables meso-level benchmarking but faces accounting standardization challenges.
- Comprehensive survey: Provides micro-level operational insights at the expense of increased implementation complexity.

This triadic structure concerns servitization measurement at macro, meso, and micro levels. It adopts a particular technique based on the research aims, the data available, and the level of detail required in the analysis. The latest developments indicate there is now increasing adoption of administrative validity and empirical reliability.

3.2. Data Collection and Research Design

This study employs a mixed-methods research design, combining cross-sectional and longitudinal analyses to comprehensively evaluate manufacturing servitization in Henan Province. The research utilizes an integrated data triangulation framework, drawing from multiple authoritative sources to ensure analytical robustness and reliability.

For the cross-regional comparative analysis, we extracted data from China's official 2017 regional input-output tables, the most recent comprehensive dataset available from the National Bureau of Statistics. These standardized tables provide detailed inter-industry transaction matrices across 42 sectors for all 31 provincial-level administrative regions, enabling systematic benchmarking of Henan's servitization performance against national counterparts. The five-year publication cycle of these tables presents an inherent constraint; however, the structural stability of industrial configurations suggests continued relevance for contemporary assessments.

For the longitudinal analysis (2011-2020), we constructed a stratified sample of 62 publicly listed manufacturing enterprises headquartered in Henan Province, selected based on three criteria: (1) continuous operation throughout the entire study period; (2) proportional representation across 17 manufacturing subsectors to ensure sectoral diversity; and (3) market capitalization exceeding 500 million RMB to capture economically significant firms. Financial data was extracted from audited annual reports filed with the Shanghai and Shenzhen Stock Exchanges, with a specific focus on "other operating income" line items as proxy indicators for service revenue streams.

3.3. Analytical Framework and Procedures

The study implements a dual-pronged analytical strategy:

For horizontal assessment, we apply the Leontief input-output model to calculate both direct consumption coefficients ($aij = zij/xj$) and complete consumption coefficients ($bij = \Sigma k\ aik \cdot bkj + aij$) for service inputs across manufacturing subsectors. These coefficients quantify the immediate and total (direct plus indirect) service factor intensities per unit of manufacturing output, enabling provincial rankings and sectoral comparisons. Statistical significance of interprovincial differences was verified through ANOVA testing with post-hoc Bonferroni adjustments ($p < 0.05$).

When analyzing vertically, we aggregate computed annual service revenue ratios (SRR: Other Operating Income/Total Revenue) for scoped enterprises to their industry and provincial levels using market share-weighted averaging. We assess temporal consistency through variation coefficient (VC) calculations and segmented regression analysis to detect structural breaks in servitization pathways.

This multi-step set enhances traditional methodologies focused on Henan's manufacturing servitization features by employing diverse methods through a holistic lens with minimal integration challenges from individual subordinating methods. The disparity between macro-level input-output datasets and micro-level financial metrics at the enterprise scale is reconciled through method triangulation, although low-resolution data granularity can raise issues, and potential service income classification interdisciplinary overlap is acknowledged.

4. EMPIRICAL RESULTS ANALYSIS

4.1. Cross-Regional Comparative Analysis of Manufacturing Servitization in Henan Province

Before performing a comparative assessment of the servitization level in the manufacturing sector in Henan Province, I need to build a sound measurement framework by methodically choosing the approaches and verifying the scientific integrity of the data sources. This methodological foundation serves as a critical prerequisite for guaranteeing the reliability and cross-regional comparability of analytical outcomes. Building upon the input-output analysis framework constructed in the preceding section, this study systematically examines the relative positioning and sectoral characteristics of Henan's manufacturing servitization through comparative empirical evidence from provincial-level data. The transitional analysis presented herein bridges the theoretical-methodological discussion with subsequent empirical investigations, establishing a coherent analytical continuum for this research.

4.1.1. Methodology Application and Data Description

This section employs input-output analysis to measure manufacturing servitization levels across China's 31 provincial-level regions, with a focus on Henan's industrial performance and national ranking. Utilizing direct and complete consumption coefficients derived from 2017 regional input-output tables, the study quantifies service factor integration in manufacturing processes. The direct consumption coefficient reflects the immediate service inputs required per unit of manufacturing output, while the complete consumption coefficient accounts for both direct and indirect service dependencies across supply chains, offering a more comprehensive metric of servitization intensity. Given its superior capacity to capture systemic interdependencies, the complete consumption coefficient serves as the primary indicator for interprovincial comparisons.

Notably, China's regional input-output tables are published quinquennially, with data typically lagging by five years (e.g., tables released in years ending with 3 or 8 correspond to economic data from years ending with 2 or 7). While the 2017 dataset represents the latest available provincial-level information, its structural stability ensures continued relevance for benchmarking Henan's servitization status against national peers. This methodological approach balances temporal limitations with analytical validity, providing critical insights into spatial disparities in service-oriented manufacturing transformation.

4.1.2. Analysis of Measurement Results

Leveraging 2017 input-output tables from 31 provincial-level regions, this study calculates complete consumption coefficients for 17 manufacturing subsectors (Table 3), including food and tobacco, textiles, chemical products, transportation equipment, and electronic devices. Aggregated provincial averages of these coefficients (Table 4 and Figure 1) reveal Henan's manufacturing servitization index at 0.39, significantly exceeding the national average of 0.29 and securing 5th place nationally. This performance aligns with Zhengzhou's 16th ranking among China's top 100 advanced manufacturing cities (Sun, 2025) underscoring Henan's competitive positioning in service-oriented industrial transformation.

Table 3. Sectoral complete consumption coefficients of manufacturing industries in 31 Chinese provincial regions (2017).

Region	Food and tobacco	Textiles	Apparel, leather, and down products	Wood products and furniture	Paper, printing, and stationery	Petroleum, coking, and nuclear fuel processing	Chemical products	Non-metallic mineral products	Metal smelting and processing	Metal products	General equipment	Specialized equipment	Transportation equipment	Electrical machinery	Communication, computer, and electronic equipment	Instruments	Other manufacturing and waste products
National Average	0.52	0.1	0.08	0.06	0.47	0.59	0.78	0.09	0.49	0.24	0.12	0.07	0.23	0.21	0.5	0.1	0.2
Henan	0.65	0.22	0.1	0.15	0.62	0.33	1.04	0.17	0.62	0.33	0.24	0.11	0.4	0.42	0.85	0.15	0.27
Beijing	0.43	0.07	0.05	0.05	0.74	0.46	1.1	0.09	1.59	0.48	0.08	0.03	0.17	0.24	1.01	0.17	0.03
Tianjin	0.65	0.07	0.04	0.04	0.62	0.95	1.2	0.11	0.82	0.28	0.26	0.12	0.5	0.4	0.68	0.22	0.23
Hebei	0.33	0.05	0.04	0.03	0.32	0.7	0.62	0.06	0.86	0.63	0.1	0.06	0.1	0.17	0.2	0.04	0.68
Shanxi	0.4	0.04	0.05	0.02	0.34	0.23	0.51	0.03	0.36	0.05	0.09	0.1	0.27	0.12	0.17	0.01	0.33
Inner Mongolia	0.32	0.02	0.04	0.03	0.33	0.51	0.45	0.06	0.3	0.27	0.11	0.04	0.05	0.27	0.29	0.05	0.2
Liaoning	0.56	0.1	0.05	0.06	0.58	0.56	0.92	0.07	0.45	0.22	0.19	0.1	0.37	0.29	0.5	0.1	0.13
Jilin	0.51	0.05	0.12	0.06	0.45	0.35	0.44	0.08	0.77	0.11	0.08	0.06	0.05	0.19	0.37	0.02	0.52
Heilongjiang	0.25	0.02	0.02	0.03	0.27	0.82	0.36	0.05	0.17	0.06	0.05	0.03	0.11	0.08	0.25	0.03	0.06
Shanghai	0.44	0.09	0.09	0.03	0.48	1.42	0.94	0.08	0.54	0.41	0.21	0.08	0.29	0.21	0.71	0.13	0.53
Jiangsu	0.48	0.14	0.05	0.06	0.5	0.46	1.01	0.08	0.6	0.32	0.16	0.08	0.51	0.18	0.63	0.14	0.31
Zhejiang	0.43	0.14	0.07	0.05	0.47	0.47	1.13	0.07	0.56	0.17	0.08	0.06	0.12	0.12	0.37	0.35	0.42
Anhui	0.58	0.15	0.05	0.06	0.63	0.42	1.05	0.1	0.78	0.32	0.2	0.08	0.35	0.29	0.84	0.19	0.22
Fujian	0.8	0.21	0.55	0.1	0.48	0.62	0.68	0.1	0.34	0.16	0.06	0.03	0.16	0.06	0.31	0.04	0.08
Jiangxi	0.42	0.1	0.08	0.08	0.43	0.56	0.63	0.11	0.58	0.45	0.11	0.12	0.18	0.42	0.5	0.08	0.23
Shandong	1.16	0.36	0.15	0.29	0.93	0.88	1.86	0.15	0.6	0.4	0.31	0.19	0.67	0.44	1.36	0.15	0.14
Hubei	0.88	0.2	0.09	0.05	0.4	0.21	0.79	0.09	0.18	0.2	0.07	0.02	0.51	0.21	0.3	0.1	0.1
Hunan	0.59	0.07	0.08	0.04	0.35	0.33	0.58	0.07	0.28	0.21	0.1	0.04	0.17	0.19	0.29	0.04	0.15
Guangdong	0.57	0.08	0.06	0.04	0.35	0.39	0.73	0.08	0.7	0.29	0.06	0.03	0.04	0.24	0.44	0.14	0.39
Guangxi	0.51	0.07	0.09	0.07	0.37	0.59	0.86	0.09	0.39	0.14	0.14	0.08	0.26	0.26	0.73	0.11	0.12
Hainan	0.46	0.04	0.04	0.16	0.47	1.26	0.65	0.09	0.25	0.23	0.08	0.02	0.21	0.17	0.53	0.03	0.1
Chongqing	0.48	0.07	0.07	0.06	0.34	0.5	0.7	0.12	0.42	0.14	0.09	0.05	0.04	0.22	0.84	0.19	0.23
Sichuan	0.93	0.14	0.11	0.1	0.47	0.37	1.13	0.11	0.44	0.23	0.19	0.1	0.41	0.3	0.89	0.16	0.11
Guizhou	0.41	0.05	0.07	0.04	0.49	0.95	0.72	0.09	0.38	0.17	0.17	0.05	0.24	0.09	0.31	0.05	0.06
Yunnan	0.52	0.09	0.14	0.03	0.35	0.5	0.5	0.07	0.39	0.12	0.12	0.04	0.3	0.2	0.39	0.05	0.08
Xizang	0.34	0.08	0.06	0.03	0.57	0.8	0.34	0.16	0.08	0.11	0.03	0.05	0.03	0.03	0.17	0.07	0.02
Shaanxi	0.41	0.09	0.07	0.05	0.54	0.48	0.68	0.1	0.48	0.28	0.12	0.09	0.08	0.12	0.26	0.07	0.07
Gansu	0.57	0.04	0.03	0.05	0.59	0.46	0.73	0.07	0.3	0.26	0.09	0.05	0.09	0.12	0.22	0.06	0.11
Qinghai	0.31	0.19	0.05	0.05	0.27	0.44	0.65	0.05	0.39	0.15	0.05	0.02	0.07	0.1	0.1	0.05	0.06
Ningxia	0.19	0.03	0.05	0.03	0.45	0.38	0.26	0.03	0.12	0.1	0.06	0.04	0.04	0.06	0.13	0.04	0.13
Xinjiang	0.68	0.14	0.06	0.03	0.44	0.87	0.81	0.07	0.3	0.17	0.17	0.1	0.43	0.25	0.78	0.07	0.09

Sectoral analysis demonstrates Henan's exceptional performance: 16 of 17 subsectors (excluding petroleum and coking products) surpass the national average coefficients, matching Shandong Province for the highest number of above-average industries. This multi-sectoral superiority indicates comprehensive servitization development compared to peer regions. Further stratification of Henan's subsector rankings (Figures 2) reveals.

- Top-tier industries (Rank 1-5): Electronics, specialized equipment, and chemical manufacturing exhibit service integration levels comparable to coastal innovation hubs.
- Mid-tier industries (Ranks 6-8): Traditional sectors such as textiles and metal processing show moderate but stable progress in servitization.
- Emerging industries (Rank 9+): Resource-intensive sectors display nascent servitization, suggesting untapped potential for service infusion.

This tripartite classification highlights both the breadth and heterogeneity of Henan's servitization achievements, with advanced manufacturing sectors driving regional competitiveness, while traditional industries await deeper service integration. The findings collectively affirm Henan's strategic transition from production-centric to service-enhanced manufacturing ecosystems.

Table 4. Total consumption coefficients of manufacturing industry in 31 provinces/Municipalities.

Region	Total consumption coefficient	Region	Total consumption coefficient
Shandong	0.59	Guangdong	0.27
Tianjin	0.42	Chongqing	0.27
Beijing	0.4	Hubei	0.26
Shanghai	0.39	Guizhou	0.25
Henan	0.39	Jilin	0.25
Anhui	0.37	Shaanxi	0.23
Sichuan	0.36	Yunnan	0.23
Jiangsu	0.34	Gansu	0.23
Xinjiang	0.32	Hunan	0.21
Liaoning	0.31	Inner Mongolia	0.2
Zhejiang	0.3	Shanxi	0.18
Jiangxi	0.3	Qinghai	0.18
Hebei	0.29	Xizang	0.17
Guangxi	0.29	Heilongjiang	0.16
Hainan	0.28	Ningxia	0.13
Fujian	0.28		

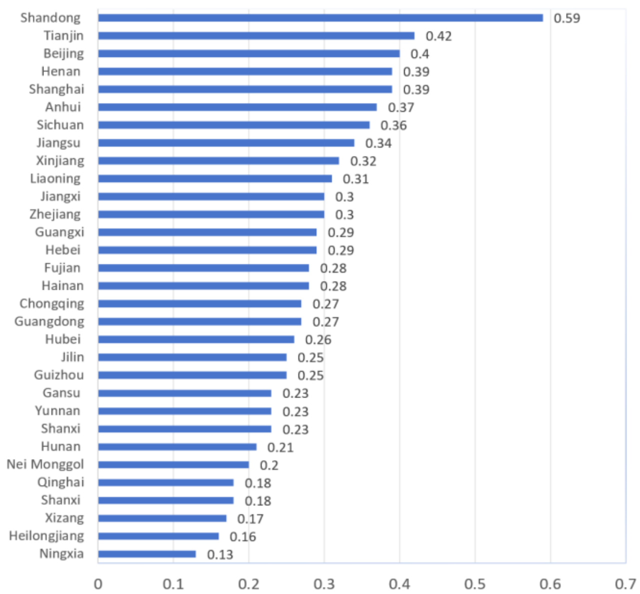

Figure 1. Ranking of total consumption coefficients in the manufacturing industry across 31 provinces/Municipalities in China.

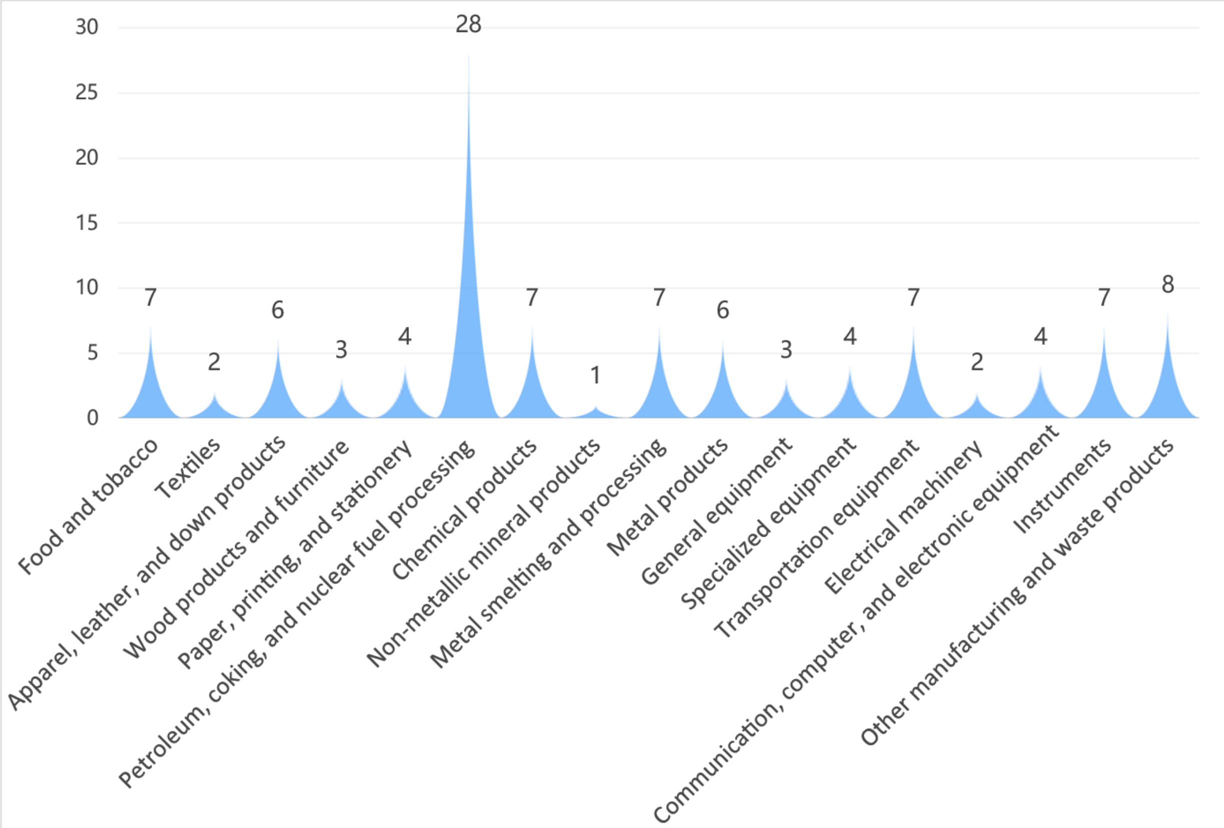

Figure 2. Ranking of complete consumption coefficients across manufacturing sectors in Henan province.

As depicted in the sectoral distribution of total consumption coefficients for manufacturing industries in Henan Province (Figure 2), the region exhibits a robust servitization capacity, with eight sectors achieving top-tier performance (Ranks 1–5). These include non-metallic mineral products, textiles, electrical machinery and equipment, wood processing and furniture, general equipment, paper/printing and stationery/sports goods, specialized equipment, and communication equipment/computers/other electronic devices. Sectors with moderate servitization levels (Ranks 6–8) encompass apparel, leather and down products, metal products, food and tobacco, chemical products, metal smelting and processing, transportation equipment, instruments, and other manufacturing/waste materials. Notably, petroleum, coking, and nuclear fuel processing rank lowest (28th), likely due to Henan's limited natural resource reserves and underdeveloped industrial infrastructure in these sectors.

Henan Province ranks fifth nationally in comprehensive manufacturing servitization, reflecting its advanced integration of service-oriented activities. Among high-performing sectors, non-metallic mineral products lead significantly, followed closely by textiles and electrical machinery, all demonstrating exceptional servitization metrics. Secondary sectors such as apparel, metal products, and chemical products also show strong competitiveness, securing positions within the top ten. In contrast, petroleum and coking industries lag markedly, highlighting structural bottlenecks associated with resource dependency and delayed technological adoption. This divergence underscores the necessity for strategic investments in innovation and industrial upgrading to mitigate regional disparities and foster sustainable growth.

4.2. Longitudinal Development Analysis of Servitization Level in Henan's Manufacturing Sector

This section aims to analyze the decadal evolution (2011–2020) of servitization in Henan's manufacturing industry, exploring its developmental patterns to lay the groundwork for subsequent pathway selection and strategic discussions.

4.2.1. Methodology Application and Data Description

To achieve the research objectives, a longitudinal analysis spanning ten consecutive years (2011–2020) was conducted. Given the lack of continuity in China's input-output tables (published quinquennially), the service revenue share method was adopted as a supplementary approach to evaluate servitization trends. Due to data accessibility constraints operational service revenues are often categorized under "other business income" in financial statements the ratio of other business income to total revenue was selected as the proxy indicator for servitization.

To approximate Henan's manufacturing servitization level, a comprehensive list of listed manufacturing firms in Henan was compiled from authoritative databases. After rigorous screening based on industry representativeness and data continuity, 62 listed firms were identified as a representative sample. Their servitization metrics were aggregated to derive provincial-level estimates. While this approach does not fully capture the servitization dynamics of all manufacturing entities, it offers a feasible proxy for analyzing developmental trends. Notably, shifts in provincial servitization levels are inherently linked to changes in firm-level practices, particularly among dominant and representative listed enterprises. Thus, the servitization trajectories of these firms reflect broader provincial patterns with reasonable validity. The list of sampled firms is provided in Table 5.

Table 5. List of measured listed manufacturing enterprises in Henan Province.

No.	Company name	No.	Company name	No.	Company name	No.	Company name
1	Muyuan Co., Ltd.	17	Pingmei Co., Ltd.	33	Punan shares	49	Beibao shares
2	Luoyang Molybdenum	18	Shenhuo Co., Ltd.	34	Zhongfu industrial	50	Linzhou Heavy Machinery
3	Shuanghui development	19	Furen pharmaceutical	35	Luoyang glass	51	Tongda shares
4	Hualan biological	20	Anyang iron & steel	36	Pulike bio	52	Neway open source
5	Longbo group	21	Sanquan food	37	Xintian Technology	53	Sanhui electric
6	AVIC optoelectronics	22	Lida Optoelectronics	38	Ancaigao technology	54	Feilong shares
7	Yutong bus	23	Mingtai Aluminum	39	Zhong optics	55	Pinggao electric
8	Autobio diagnostics	24	Jingang (Diamond)	40	Lianhua (Lotus)	56	Xinye textile
9	Zhongyuan special steel	25	Huanghe Whirlwind	41	Rebecca Co., Ltd.	57	Kedi dairy
10	CITIC heavy industry	26	Jiaozuo Wanfang	42	Sifangda	58	Hengxing technology
11	ST Senyuan	27	Shenma shares	43	Senba Sensing	59	Zhongyuan Neipei
12	Pinggao electric	28	Yingge investment	44	Huaying agriculture	60	Zhouyan technology
13	XJ electric	29	Yuguang gold & lead	45	Tailong pharmaceutical	61	Aeolus Tyre
14	Do-fluoride chemicals	30	Haoxiangni	46	Huanghe Whirlwind	62	Yituo group
15	Zhengzhou coal mining machinery	31	Lingrui pharmaceutical	47	Huihuang technology		
16	CRRC times new material	32	Mengshi	48	Puyang Huicheng		

4.2.2. Analysis of Measurement Results

Based on annual report data from the 62 listed enterprises, the ratio of other business income to total revenue was calculated annually from 2011 to 2020. The mean values, serving as proxies for Henan's manufacturing servitization level (Table 6 and Figure 3), reveal a bifurcated trajectory.

- Phase I (2011–2016): Servitization rose steadily from 2011 to 2013, peaked during 2013–2015, and maintained elevated levels through 2016.
- Phase II (2016–2020): A marked decline occurred in 2016–2017, followed by a partial recovery in 2018–2019, and a significant contraction in 2020.

This pattern aligns with broader economic shifts in Henan. The post-2016 downturn corresponds to stringent real estate market controls and the transition to a "quality-first" growth paradigm under China's economic "new normal." The temporary rebound in 2018–2019 likely reflects stimulus-driven industrial diversification efforts, while the 2020 collapse underscores the acute vulnerability of servitization to exogenous shocks, particularly the COVID-19 pandemic, which disrupted supply chains and suppressed service-oriented activities. These observations highlight the dual role of policy frameworks and global crises in shaping regional industrial evolution.

Table 6. Longitudinal measurement values of servitization level in Henan's manufacturing industry.

Year	Servitization level of the manufacturing industry	Year	Servitization level of the manufacturing industry
2011	4.27%	2016	4.71%
2012	4.84%	2017	4.07%
2013	5.62%	2018	4.54%
2014	5.45%	2019	5.20%
2015	5.68%	2020	4.28%

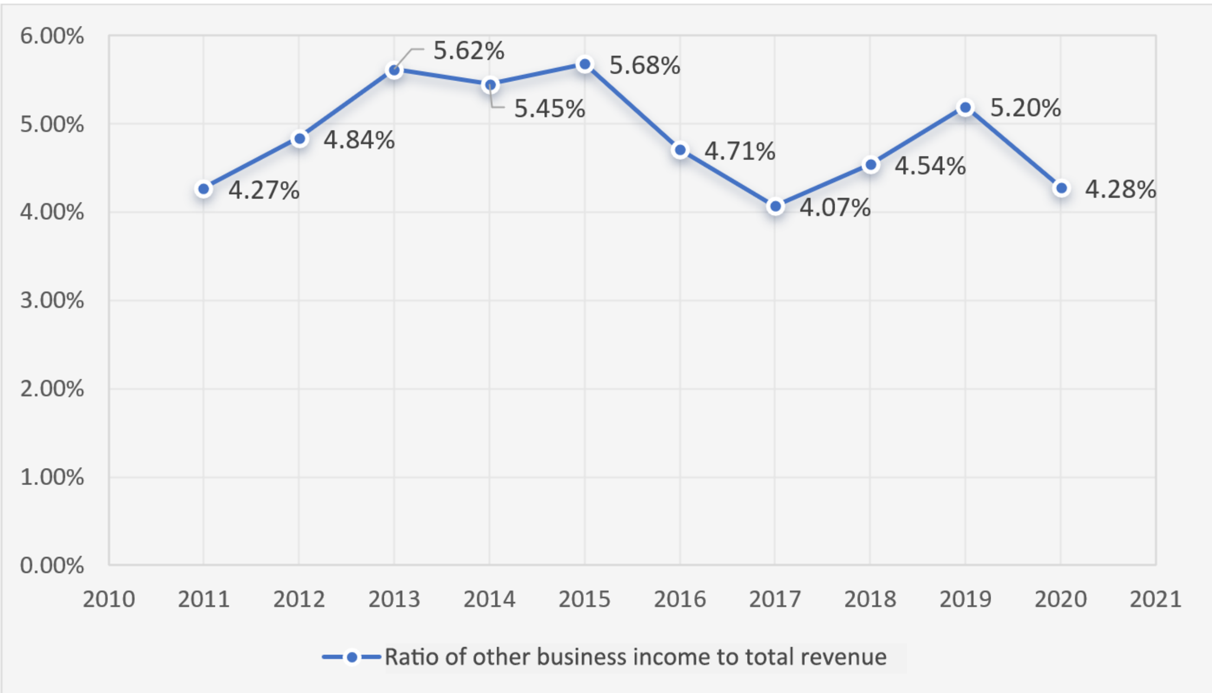

Figure 3. Trend distribution of servitization measurement values in Henan's manufacturing industry.

5. CONCLUSIONS

Henan Province's manufacturing sector demonstrates a robust servitization capacity, ranking fifth nationally a performance driven by advanced service integration across most industries. Sectoral disparities reveal that only petroleum, coking, and nuclear fuel processing lag critically (rank 28), attributable to Henan's resource scarcity and insufficient industrial clustering in this sector. Conversely, eight industries non-metallic mineral products, textiles, electrical machinery, wood processing/furniture, general equipment, paper/printing/stationery, specialized equipment, and communication/computer/electronic devices achieve top-tier servitization (rank 1–5), with non-metallic mineral products dominating as the leader, followed by textiles and electrical machinery.

Longitudinal analysis (2011–2020, Figure 3) identifies two phases: (1) a growth phase (2011–2016) peaking in 2015, and (2) a volatile phase (2016–2020) marked by post-regulation declines and pandemic-induced contractions. The 2016–2017 downturn correlates with China's supply-side structural reforms targeting overcapacity in traditional industries, while the 2020 collapse highlights systemic risks in service-dependent manufacturing during global crises. These findings suggest servitization is both policy-sensitive and externally vulnerable, necessitating adaptive strategies to balance service innovation with supply chain resilience. Based on the research findings, Henan Province should adopt the following policy measures: (1) establish a provincial servitization development fund focusing on supporting the top eight ranked advantageous industries; (2) build digital service platforms to promote integration between manufacturing and modern service industries; (3) strengthen talent development by establishing a servitization talent training system; (4) improve incentive mechanisms by providing tax benefits to enterprises with service revenue exceeding 30% of total revenue; (5) establish monitoring and evaluation systems to regularly track servitization development levels across industries, ensuring policy effectiveness and adaptability.

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