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Research on the Upgrading Path of Foshan Ceramic Industry Based on Data Elements

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Abstract: As data becomes a key force reshaping industrial organization and resource allocation mechanisms, traditional manufacturing faces an urgent need to upgrade its governance structures in the digital economy era. Drawing on the typical practices of the Foshan ceramics industry, this paper constructs a three-mechanism model of "data standardization—platform-based collaboration—data public goods supply," systematically revealing how data drives traditional industrial upgrading. The Foshan practice demonstrates that data has become a core driving force for the high-quality development of traditional manufacturing. The study further proposes an upgrading path driven by standardization, supply chain collaboration, public goods orientation, and ecosystem-based sustainable development, providing a reference for the digital and data-driven transformation of traditional industries.

Keywords: Data Elements; Ceramics Industry; Industrial Upgrading; Path Research
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1.Introduction

1.1 Research Background and Problem Statement

As the global digital economy enters a phase of rapid development, data has transformed from a traditional information resource into a new type of production factor capable of directly creating value and shaping competitive advantage. Compared with traditional production factors such as labor, capital, and land, data exhibits non-consumable, replicable, combinable, and highly spillover-oriented characteristics, enabling it to reshape industrial organization and resource allocation mechanisms on a larger scale and at a deeper level. Since the state first explicitly identified "data as a new type of production factor," market-oriented reforms of data factor allocation have continued to deepen, and data's strategic position in promoting the digital, intelligent, and green transformation of traditional industries has been continuously rising.

The ceramics industry is one of the traditional manufacturing sectors in my country with the most complete industrial chain, the largest scale, and the most significant regional agglomeration. Foshan, as the core base of the national ceramics industry, possesses a complete industrial chain system encompassing raw material supply, production and manufacturing, equipment manufacturing, logistics and transportation, and marketing channels. However, the long industrial chain, numerous participants, complex supply chain structure, and fragmented transaction links have led to long-standing structural problems in the industry, such as information opacity, insufficient transaction credibility, low collaborative efficiency, weak technological innovation capabilities, and financing difficulties for small and medium-sized enterprises. The root cause of these problems lies in the lack of unified data standards and interfaces within the industry. Severe data silos exist between enterprises, making it difficult to collect, verify, and share real production and operational data, resulting in inefficient resource allocation and limited industrial chain governance capabilities.

Faced with the aforementioned pain points, data has become a crucial tool for the ceramics industry to overcome bottlenecks. In recent years, with the implementation of the national "Data Elements ×" Three-Year Action Plan (2024-2026), Foshan has actively responded to policy requirements by building a data element market environment, promoting data platform construction, developing data public goods, and exploring the circulation of data assets, giving rise to a number of innovative "Data Elements × Ceramic Industry" application cases. In particular, Foshan Zhongtaolian Supply Chain Service Co., Ltd. (hereinafter referred to as "Zhongtaolian Supply Chain Company") has significantly improved resource allocation efficiency and governance capabilities in the ceramics industry by building an industry-wide data standard system, developing data public goods such as tax payment assistance and inclusive finance, and promoting the circulation and application of data in multiple scenarios across the industrial chain through a "scenario + standard + technology + data" model.

However, despite the pioneering breakthroughs achieved by Foshan's ceramics industry in the application of data elements, existing academic research focuses more on the macro-level development of the digital economy or the application of specific technologies, lacking a systematic analysis of the specific mechanisms, governance logic, and upgrading paths of data elements in the traditional manufacturing industry chain. Especially in traditional industries like ceramics, with their complex structures and diverse chains, in-depth theoretical explanations are still lacking regarding how data functions within the industrial chain, how it reshapes industrial organization, and how it evolves into a public good that enhances governance effectiveness."

Therefore, it is necessary to construct an explanatory theoretical framework based on summarizing the Foshan practice, to answer the question of how data elements drive the ceramic industry to upgrade from "experience-driven" to "data-driven", thereby providing a scientific basis for the digital transformation of traditional manufacturing industry.

1.2 Research Objectives and Significance

The overall goal of this study is to systematically analyze, based on the typical practices of the Foshan ceramics industry, how data elements can reshape the governance structure of the traditional industrial chain through standardization, platformization, and public goods mechanisms, thereby promoting the high-quality development of the ceramics industry. Specifically, this study aims to achieve three aspects:

1.2.1 Constructing the Mechanism of Data-Driven Transformation in Traditional Industries from a Theoretical Perspective

Existing research lacks a mechanistic analysis of the application of data elements in traditional manufacturing. Based on the characteristics of the ceramic industry chain and the attributes of data elements, this study proposes a three-mechanism model of "data standardization—collaborative platformization—public goods supply," which systematically explains the value formation logic of data elements within the industry chain from a micro-governance perspective, and helps to enrich the existing theoretical system of data elements.

1.2.2 Summarizing the experience of data elements in Foshan's ceramic industry from a practical perspective

The digital transformation practices of Foshan's ceramics industry are typical and representative. This study integrates key cases from Foshan, including data platform construction, data public goods development, and data asset circulation, to extract replicable and scalable industrial digitalization solutions, providing practical guidance for the transformation of traditional industries in other regions.

1.2.3 Propose feasible industrial upgrading paths from a policy perspective

By summarizing the governance value of data elements for traditional industries, this study proposes an upgrade path that prioritizes standardization, empowers through platforms, emphasizes public goods, and promotes ecological development, providing policy support for governments to build a data element market and promote the development of digital manufacturing.

Overall, this study not only makes theoretical contributions (mechanism innovation), practical contributions (summarizing cases), and policy contributions (proposing pathways), but also provides important insights into how China's traditional manufacturing industry can maintain its competitive advantage in the digital economy era.

1.3 Research Questions and Main Contents

Based on the research background and objectives, this study focuses on the following three core questions:

(1) How do data elements play a role within the traditional ceramic industry chain? That is, how can data reduce transaction costs and enhance the industry's credit foundation through mechanisms such as standardization, credibility, and traceability?

(2) How can digital platforms become a new type of infrastructure for collaborative governance of the ceramic industry chain? That is, how can platforms improve the overall collaborative capabilities and resource allocation efficiency of the industry chain through data sharing, real-time interaction and intelligent scheduling?

(3) How can data public goods evolve into public goods in the ceramics industry and enhance industry governance capabilities? That is, how can data be transformed into public governance tools in scenarios such as tax payment, finance, and certification to improve regulatory efficiency and industry transparency?

2.Literature Review

2.1 Research Progress on Data Elements

With the rapid development of the digital economy, data, as a new type of production factor, has become an important topic in academia and policy circles. The "Data Factor White Paper (2022)" released by the China Academy of Information and Communications Technology (CAICT) systematically proposed for the first time that "data factors" should be regarded as a resource form that can directly participate in production activities and create economic benefits, emphasizing its resource-based, asset-based, and scenario-dependent characteristics. With the gradual refinement of this definition, the academic community has conducted extensive discussions on the value formation logic, operational mechanisms, and institutional arrangements of data elements.

From a macro perspective, the rise of data elements has driven the reshaping of resource allocation logic. Zhang Yihui and Liu Cheng systematically deconstructed the resource allocation theory of the digital economy era from four dimensions: data, information, organizational form and market competition. They pointed out that digitalization has brought about a triple effect of "technology-driven, platform competition and institutional change", which has caused profound changes in the traditional resource allocation rules in three scenarios: labor, industry and government governance [1]. This analysis reveals that data elements are not only technical tools but also carry institutional implications for reshaping economic governance systems.

In addition, Chen Menggen et al. sorted out the development path of China's data element market and pointed out that although the current data element market has made significant progress in the construction of trading platforms and institutional supply, it still faces problems such as imperfect trading rules, insufficient infrastructure and unsound regulatory system. It is necessary to work together from three aspects: institutional foundation, market operation and technical support to further advance the market-oriented allocation reform of data elements [2]. Ouyang Rihui and Xu Yuanbin started from the reform path of the "15th Five-Year Plan" and emphasized that the reform of data elements should follow the principle of "establishing before breaking down" and build a data management system, data basic system, data circulation and trading model and asset management system to form a sustainable reform promotion mechanism [3].

Overall, existing research has extensively explored the connotation, market-based allocation, institutional guarantees, and development paths of data elements, but it still lacks detailed analysis on how data elements are implemented within specific industrial chains and how they are transformed into production and governance capabilities.

2.2 Research on Data Elements and Industrial Development

At the micro-enterprise level, a series of studies have demonstrated that data elements have significant performance improvement and efficiency enhancement effects. Zhang Xiaofei et al. found through multi-period difference test of A-share listed companies that the market-oriented allocation of data elements can significantly promote the specialization of enterprises. Its mechanism of action includes reducing external transaction costs, alleviating financing constraints and expanding market size [4]. This effect of data elements is more significant for small and medium-sized enterprises, non-state-owned enterprises and enterprises with high degree of supply chain information asymmetry, indicating that data elements have a governance effect of "reducing uncertainty and improving the operating environment of weak entities".

At the industry level, the relationship between data elements and high-quality industrial development has been systematically demonstrated. Wang Xiaowen et al. used listed manufacturing companies as samples and found that digital industry agglomeration accelerates the formation of new quality productivity in manufacturing through mechanisms such as technology integration, supply chain collaboration and industrial chain efficiency optimization [5]. This study reveals that data elements play an important role in improving the overall efficiency and innovation momentum of the industry.

Another line of research emphasizes the mechanism by which data assets release value through industrial-chain linkages. Zhang Benxiu et al. pointed out from the perspective of industrial chain information linkage that enterprises can improve total factor productivity by expanding the scale of data assets, and this productivity improvement depends on environmental conditions such as the degree of digitalization of upstream and downstream industries, market competition level and customer concentration [6]. This study shows that data assets function as a form of "networked asset," whose value depends on the level of industrial-chain collaboration.

From the perspective of supply chain resilience, Li Yili et al. constructed a theoretical framework of "data elements - supply chain resilience - new quality productivity" and found that data elements can further promote the digital transformation of enterprises and improve new quality productivity by enhancing the agility, responsiveness and resilience of the supply chain [7]. This study provides an important reference for understanding how data elements play a governance role in complex industrial chains.

In addition, Zeng Hao et al. pointed out from the perspective of data element governance that data element governance can significantly improve the new quality productivity of enterprises through optimizing talent allocation, improving the efficiency of capital financing and promoting digital transformation, and further bring about the spillover effect of total factor productivity and enterprise value growth [8].

Based on the above research, the academic community generally believes that the role of data elements in industrial development is mainly reflected in reducing transaction costs, enhancing supply chain resilience, promoting specialization, improving innovation capabilities, and improving governance structures. However, most existing studies use macro-level or cross-industry samples, lacking in-depth scenario-based research on specific sub-sectors of traditional manufacturing, and even more so, lacking a mechanistic analysis of how data elements form value within a single industrial chain.

2.3 Definition of Data Elements

In order to ensure the theoretical consistency of the research and the rigor of the model construction, it is necessary to clearly define the "data elements". According to the authoritative definition of the Data Elements White Paper (2022) of the China Academy of Information and Communications Technology, data elements refer to data resources that are recorded electronically in the production and operation process and can create economic benefits for users or owners, including datasets, data public goods , and information generated based on data , which are collected, organized, and processed according to specific production needs [9].

Three core characteristics can be extracted from this definition:

(1) Data elements are highly processable and structured. Only data that has been collected, cleaned, processed, and structured can enter production activities and have economic value.

(2) Data elements have asset value and are tradable. Data elements not only have internal use value, but can also form data public goods, data reports and data services, and realize asset value through market transactions.

(3) Data elements are subject to both scenario-dependent and institutional-dependent characteristics. Data itself does not generate value; its value is realized through specific scenarios such as tax payment verification, supply chain collaboration, production scheduling, and financial services, and depends on data standards, data governance, and circulation mechanisms.

Based on this, this paper understands data elements as "complex resources that can reduce information asymmetry, improve governance capabilities, enhance collaborative efficiency, and be transformed into public goods through platform mechanisms." This definition will serve as the foundation for subsequent theoretical model construction and case analysis.

2.4 Literature Review and Research Gaps

Existing literature has extensively discussed the connotation, institutional role, industrial function, and governance mechanisms of data elements, reaching the following consensus:

First, data elements have become an important force in the reshaping of resource allocation and industrial organization. Their mechanism of action involves reducing transaction costs, improving information transparency, strengthening supply chain resilience, and improving industrial chain collaboration [1, 4-7].

Second, the value of data elements depends significantly on the industrial structure and institutional environment. Their assetization, productization and marketization processes all require the support of supporting data standards, governance mechanisms and circulation systems [2,3].

Third, data elements have a stronger empowering effect on SMEs and long-chain industries with multiple participants, especially in reducing uncertainty and improving the foundation of trust [4,7].

However, from the perspective of this study, existing research still has three obvious shortcomings:

First, there is a lack of in-depth research on the segmented industrial chains of traditional manufacturing. Existing literature mostly focuses on high-tech industries or manufacturing as a whole, and there is insufficient discussion on the specific role and mechanism of data elements in traditional industrial chains such as ceramics, which are complex in structure, have long chains, and involve many entities.

Second, there is a lack of a "mechanistic" theoretical framework. Although existing research has explored the role of data elements, there is still a lack of theoretical models that can systematically explain "how data elements drive industrial chain upgrading," especially a framework that combines data elements with elements such as industrial chain collaboration, transaction credibility, and public governance.

Third, there is a lack of contextualized and case-based research. Most data element studies emphasize statistical significance, while paying less attention to institutional innovation and governance practices in specific cities and industrial clusters. For example, the application of data elements in the Foshan ceramics industry has not been systematically studied in academia.

Based on the aforementioned literature gaps, this paper will take the Foshan ceramics industry as the research object, construct a three-mechanism theoretical model of "data standardization- platform-based collaboration-public goods supply", systematically analyze the role path of data elements in the traditional industrial chain, and verify the theoretical model through typical practical cases, so as to provide new theoretical explanations and policy implications for the digital upgrading of traditional manufacturing industry.

3.A Three-Mechanism Model for Data-Driven Upgrading of Traditional Industries

Data has become a core force driving the digital transformation of traditional manufacturing and the restructuring of the industrial chain governance system. However, in specific industry contexts, the value of data is not naturally presented, but rather gradually manifested, structured, and tradable through multiple mechanisms such as institutionalization, platformization, and productization, thereby forming a sustainable driving force within the industrial chain. The traditional ceramic industry chain is long, involves many entities, has fragmented links, and has a complex governance structure. It is a typical industry characterized by "weak digital foundation, weak collaborative capabilities, and a weak credit system," thus better reflecting the deep-seated governance value of data. Based on the research questions raised above, this chapter constructs a three-mechanism model of "data standardization, platform-based collaboration, and public goods provision" to systematically explain how data plays a role within the ceramic industry chain, how platform infrastructure enhances collaborative capabilities, and how data public goods provide governance and public goods value, laying a theoretical foundation for the subsequent analysis of the Foshan ceramic industry case.

3.1 Mechanism 1: Data Standardization to Build a Trustworthy Transaction System

Data standardization is the starting point for data elements to enter the industrial chain. The traditional ceramics industrial chain has long suffered from problems such as information silos, discrepancies between accounts and actual products, and disconnected processes. The core challenge lies in the lack of verifiable, comparable, and traceable data formats and interfaces, leading to high transaction costs, a lack of trust, and difficulties in supervision. The ceramics industry suffers from inconsistencies in multi-source data in raw material transactions, logistics, contract performance, and fund settlement. Enterprises often cannot form a stable understanding of each other's production and transaction information, making it difficult to establish a foundation of trust and a verifiable transaction chain.

In this context, data standardization mechanisms, through unified coding systems, data structures, interface specifications, and collection rules, enable the organization, alignment, and verification of previously scattered, heterogeneous, and unconnected data. The primary benefit of data standardization lies in improved verifiability. For example, by structuring data such as raw material delivery orders, logistics tracks, warehousing records, payment records, and invoice information, and establishing unified field formats and verification rules, automatic data comparison across enterprises and processes can be achieved, thereby reducing information asymmetry and verification costs during transactions.

Secondly, data standardization enhances authenticity and credibility. When logistics, information flow, capital flow, and invoice flow can be cross-verified under a unified data standard, businesses and regulatory authorities can identify abnormal transactions, fraudulent shipments, and falsified invoices in real time. This "four-flow integration" verification mechanism essentially establishes an industry-level, authentic business chain through data standardization, ensuring that any anomalies in any link are exposed within the chain.

Secondly, data standardization provides a stable data foundation for subsequent collaborative platforms. Platform-based collaboration relies on high-quality data, and the foundation of high-quality data is unified standards. Without standardization, platforms cannot implement algorithm scheduling, regulators cannot achieve penetrating supervision, and financial institutions cannot conduct data-driven risk control assessments. Therefore, data standardization not only improves transaction efficiency but also reshapes the credit foundation of the entire industry, making it the most fundamental and crucial link in the entire three-mechanism model.

In summary, the data standardization mechanism directly addresses one of the research questions: How do data elements play a role within the traditional ceramic industry chain?

Its core contribution lies in:

(1) Improve the comparability, verifiability and traceability of data;

(2) Establish an industry-level credit system to reduce uncertainty;

(3) Reduce transaction friction and verification costs;

Provide the underlying data foundation for subsequent collaboration and data public goods.

3.2 Mechanism Two: Platform-based Collaboration to Reconstruct the Governance Structure of the Industrial Chain

Once data standardization is achieved, the second layer of value created by data elements is reflected in platform-based collaboration. Collaboration in the traditional ceramics industry mainly relies on methods such as manual telephone communication, WeChat group communication, and experience-based judgment, leading to lagging production scheduling, disconnected logistics plans, large inventory fluctuations, and low efficiency in supply and demand matching. Because the chain is long and enterprises are highly dispersed, the absence of a real-time and transparent information-sharing mechanism keeps the entire industrial chain in a state of "local optimization but overall inefficiency."

The introduction of digital platforms has transformed this governance structure. Through the real-time collection, cleaning, and integration of standardized data, digital platforms enable information from all stages to be uploaded to the blockchain, shared, and visualized in real time. For example, on the platform, data such as production plans, inventory status, logistics conditions, and raw material requirements of various enterprises can be integrated in real time, thereby achieving real-time supply and demand matching, intelligent scheduling, and predictive decision-making. The core logic of platform-based collaboration includes the following three aspects.

First, information transparency leads to improved collaborative efficiency. When the supply, production, logistics, and sales ends can share real-time information on a unified platform, demand forecasting becomes more accurate, production planning more forward-looking, inventory management more refined, and resource waste significantly reduced. Enterprises no longer rely on manual communication but instead leverage the platform's data visualization tools to achieve a "visible supply chain."

Second, algorithmic governance is reshaping the supply chain scheduling mechanism. Based on structured data and predictive algorithms, the platform can automatically generate logistics routes, production scheduling plans, and raw material replenishment plans, thereby reducing erroneous decisions caused by human experience. For industries like ceramics, which are highly volatile and experience rapid demand changes, algorithmic scheduling enhances the resilience of the supply chain, enabling the industry to respond to market changes more quickly.

Third, the construction of collaborative networks enhances the resilience of the industrial chain. The platform connects suppliers, manufacturers, logistics providers, distributors, and financial institutions, transforming the industrial chain from a “linear structure” to a “network structure.” The network structure offers higher redundancy and more pathways between nodes, helping to reduce the risk of single points of failure and improve the overall stability of the industrial chain.

The platform-based collaboration mechanism addresses the second research question: How can digital platforms become a new type of infrastructure for collaborative governance of the ceramic industry chain?

Through data sharing, real-time interaction, algorithm scheduling, and cross-entity collaboration, platform-based governance has achieved:

(1) Reduce chain uncertainty;

(2) Improve the efficiency of production and logistics coordination;

(3) Improve the accuracy of supply and demand matching;

(4) Enhance the resilience of the industrial chain;

(5) Achieve systematic governance across enterprises and across processes.

3.3 Mechanism Three: The Public Goods Supply Mechanism of Data- Driven Public Goods

The value of data elements in the industrial chain is ultimately reflected in “productization,” that is, developing tradable, verifiable, and replicable data public goods based on high-quality data, thus forming public goods for industrial governance. The traditional ceramics industry faces typical industrial public problems such as difficulty in paying taxes, weak credit, difficulty in financial risk control, and high costs of quality certification. These public problems are characterized by strong externalities and the lack of incentive for private enterprises to bear them alone. Therefore, it is necessary to achieve the supply of industry-level public goods through data public goods.

A data public goods further processes standardized platform data into products with governance effectiveness, such as “chain of evidence certificates,” “data credit reports,” “risk control models,” and “quality credibility certificates.” These products have the following four characteristics.

First, replicability. Data public goods can be quickly replicated and used in multiple enterprises and scenarios with low marginal costs, which is conducive to improving the overall governance efficiency of the industry.

Second, there are public governance effects. For example, chain-of-evidence certificates can help regulators identify genuine transactions, data credit reports can improve corporate financing capabilities, and risk control models can reduce risks for financial institutions. This means that data public goods possess the attributes of public goods, which can enhance the transparency and standardization of the entire industry.

Third, it has strong industry adaptability. The traditional ceramic industry has a complex supply chain and highly fragmented information. Data public goods, by being deeply embedded in industry logic, enable governance to shift from “experience-driven” to “data-driven”.

Fourth, cross-scenario scalability. A mature data public goods can typically be replicated from the ceramics industry to adjacent industries such as glass, construction, and stone, further enhancing the economies of scale and scope of data elements.

The data public goods mechanism addresses the third research question: How can data public goods evolve into public goods for the ceramics industry and enhance governance capabilities?

Its core values include:

(1) Enhance corporate credit rating;

(2) Improve government regulatory efficiency and tax transparency;

(3) Improve the risk control capabilities of financial institutions and promote capital flow;

(4) Enhance industry transparency and compliance;

(5) Reduce the cost of public governance at the industry level.

By making data public goods, data elements are transformed from “raw materials” into “governance tools” and from “corporate assets” into “industry public goods,” thereby achieving a profound reshaping of the traditional industrial chain governance structure.

3.4 The overall logic of the three mechanisms: from data structuring to supply chain governance restructuring

In response to the research questions raised earlier, the three-mechanism model constructed in this chapter has a complete logical progression:

(1) Data standardization answers the question of “how data can have an effect”. By reducing transaction costs, improving authenticity, and establishing an industry-level credit system, data can become a reliable means of production.

(2) Platform-based collaboration answers the question of “how a platform becomes infrastructure”. Through data sharing, real-time interaction and algorithm governance, collaborative methods are reconstructed to achieve efficient resource allocation.

(3) Data public goods, answering the question of “how data can improve governance capabilities”. By making data public goods, industry governance tools are provided, making data elements an industry-level public good.

The three mechanisms work together to transform traditional industries from “experience-driven” to “data-driven” and from “decentralized governance structure” to “platform-based collaborative structure,” thereby achieving systemic industrial upgrading.

4.Contextual Analysis of Foshan Ceramic Industry

4.1 Context of Digital Transformation in Foshan Ceramics

Foshan, as one of the core industrial clusters of China’s ceramics industry, has formed a highly complete industrial chain system since the reform and opening up. However, the inherent problems of the traditional ceramics industry, such as long chains, numerous participants, fragmented data, and inconsistent standards, continue to constrain the industry’s efficiency and governance capabilities. The structural pain points long faced by the ceramics industry, such as information opacity, difficulty in verifying the authenticity of transactions, isolated logistics data, weak corporate credit, and difficulties in financial risk control, are highly compatible with the “ownership-circulation-application” system of data elements. Problems such as the separation of invoices and cash flow in raw material transactions, untraceable logistics nodes, and the inability to present production processes in real time significantly restrict ceramic enterprises in tax payment, financing, and supply chain collaboration. For example, different enterprises have different data formats and business standards, resulting in a lack of a unified “real data language” in the industry; regulatory authorities struggle to obtain continuous and traceable data chains; financial institutions find it difficult to identify the true operating conditions of ceramic enterprises, leading to a long-term weakening of the financing structure; and supply chain collaboration relies more on experience, personal relationships, and reputation, making it difficult to form efficient and transparent chain governance.

Against this backdrop, Foshan’s “data elements × ceramics industry” practice is not solely driven by government initiatives, but rather a two-way resonance between “institutional supply” and “industry demand.” On the one hand, policies have established institutional guarantees for the ceramics industry by clarifying data standards, promoting the construction of industry data platforms, and encouraging the compliant listing of data public goods on exchanges. On the other hand, due to operational pressures and intensified competition, companies in the industrial chain urgently need to reduce transaction costs, strengthen credit foundations, and improve collaborative efficiency through data, thereby breaking away from the old model of “capacity competition—low-price competition.” Under this dual impetus, the digitalization process of Foshan’s ceramics industry has shifted from the past “small-scale digitalization” where companies operated independently to a systematic, platform-based, and institutionalized transformation, laying the foundation for the subsequent formation of industry-level data public goods and governance structure reforms.

Overall, the digital landscape of Foshan’s ceramics industry exhibits three significant characteristics: First, the transformation is strongly linked to the “policy-market,” driven by both industrial policies and enterprise needs; second, data elements are no longer limited to internal enterprise management but are extending to external scenarios such as supply chain collaboration, regulatory governance, and financial services; and third, policies, platforms, and enterprises have formed a tiered evolutionary path of "institutional environment—technology platform—application scenario," providing the ceramics industry with the basic conditions for developing a digital industrial ecosystem.

4.2 The Formation Logic of the Trustworthy Data Foundation for the Ceramic Industry

Zhongtaolian Supply Chain Company was the first in the ceramics industry to propose a "scenario–standard–technology–data" framework. Its essence is to take the deep pain points of the industry as the entry point, take data standardization as the core technology, and achieve data credibility through a variety of technologies, ultimately forming an industry-level data foundation.

First, scenario-driven approaches are a key breakthrough in data collection. The complexity of the ceramic industry chain dictates that data cannot be systematically collected through administrative orders or voluntary action by enterprises. It must rely on actual business scenarios, embedding data processes into enterprises' "strong demand points." For example, the lack of credible evidence chains for verifying the authenticity of raw material transactions forces the creation of "tax payment assistance scenarios"; frequent changes in logistics and transportation nodes necessitate "logistics visualization scenarios"; the weak credit of small and medium-sized ceramic enterprises drives the development of "supply chain finance risk model scenarios"; and the high cost and insufficient credibility of product quality certification fosters "credible quality certification scenarios." These scenarios constitute the data entry points of the ceramic industry chain, making data collection a natural by-product of enterprise operations.

Secondly, the standardization system has solved the fundamental problems of "data silos" and "system fragmentation" in the ceramics industry. The industry operation standards and data format standards developed by Zhongtaolian Supply Chain Company enable cross-entity mutual recognition of data such as contracts, logistics, invoices, payments, and production processes among different enterprises. For example, a series of standards, such as "raw material specification data standards," "logistics node timestamp standards," "transaction contract format standards," and "platform data interface standards," transform the multi-source heterogeneous data generated daily by ceramic enterprises into structured and fusionable data assets. This step is of great significance for industry governance because only by achieving "data comparability, verifiability, and traceability" through standardization can the ceramics industry chain move from experience-based governance to data-based governance.

Secondly, the technological system ensures that the data is "credible, accurate, and verifiable." The ceramic industry chain has long faced risks of data falsification and data gaps; therefore, simply collecting and standardizing data cannot meet the industry's demand for trust. Zhongtaolian Supply Chain Company uses technologies such as AI cross-validation, blockchain notarization, and trusted computing to link and compare the flow of goods, funds, invoices, and information. For example, the system automatically issues warnings when waybill data and logistics tracks are inconsistent; it triggers anomaly detection when payment vouchers do not match contract amounts; and it forms a "risk warning chain" when the invoice issuance time and logistics information are completely mismatched. These technologies construct the core "trustworthy data chain" for the ceramic industry.

Ultimately, the 2.2 billion multi-dimensional industry data points accumulated by 2024 formed the ceramics industry's "largest data foundation." This data foundation is not simply a collection of data, but rather "high-quality data assets" processed through standardization, verification, and systematization, covering information across the entire supply chain, including supply, logistics, production, and finance. This data not only supports enterprises' digital operations but also provides a systematic data foundation for supply chain collaboration, tax verification, financial credit, and industry regulation, achieving a fundamental leap from "enterprise data" to "industry data."

From policy guidance to scenario-driven development, from standards systems to technology verification, and from data collection to data assetization, Foshan's ceramics industry has successfully built a leading industry-level data foundation in China, providing strong support for upgrading industry governance models and resource allocation methods.

4.3 The formation of the public goods system in the ceramics industry

Based on a trusted data foundation, the biggest breakthrough for Foshan's ceramics industry lies not in the improvement of enterprises' digital management level, but in the successful evolution of data public goods into industry public goods, which significantly enhances the industry's governance capabilities and reflects the practical application of the "data public goods supply mechanism" proposed in Chapter 3.

One of the most representative institutional innovations in the ceramics industry is the "Transaction Evidence Chain Certificate." In traditional ceramic raw material transactions, tax authorities struggle to ascertain the true nature of transactions, and enterprises lack the incentive for passive compliance. Difficulties in tax payment, verification, and traceability have long plagued both tax authorities and businesses. The Evidence Chain Certificate, as the first data public goods in the building ceramics industry nationwide, integrates a "four-flow-in-one" data chain, AI-powered automatic verification, and blockchain evidence storage mechanisms to form a "data certificate" that can be used for tax audits, compliance verification, and business proof. Its institutional significance lies in transforming data that was originally internal to enterprises into a governance tool that the government can accept, thus becoming an industry public good. Data from the Foshan Municipal Government Service and Data Management Bureau in 2024 shows that this product has served over 1,200 enterprises, supported over 10,000 transactions, assisted in tax payment exceeding 800 million yuan, and has been replicated in 18 industries, including glass and building materials, becoming a typical example of the diffusion of data public goods.

In the financial services sector, ceramic enterprises have long faced problems such as weak credit, high financing costs, and difficulty in obtaining financing. Zhongtaolian Supply Chain Company has built a "behavioral credit system" for enterprises by accumulating real transaction chain data. Financial institutions no longer rely solely on reports and collateral during the credit granting process, but rather on the actual performance and operational data generated by enterprises on the platform. Thanks to this data public goods, the ceramic industry has achieved a breakthrough in financing improvements: 264 enterprises have obtained financing exceeding 1.633 billion yuan, financing costs have decreased by 18.79%, post-loan risk warnings have been issued 30 days earlier, bank customer acquisition efficiency has increased by 46.67%, and loan matching accuracy has improved to 89.47%. This process demonstrates the value of data public goods as a public good: it not only serves individual enterprises but also changes the financing ecosystem of the entire industry.

On the product side, the "Trusted Quality Certificate" provides a digital upgrade path for quality certification in the ceramics industry. Previously, ceramic product certification was costly, time-consuming, and lacked credibility, hindering its effective entry into public procurement and high-end markets. By storing production processes and testing indicators on the blockchain, the Trusted Quality Certificate becomes a quality identifier that customers, regulatory agencies, and the market can trust, making ceramic product quality certification more transparent and reliable. To date, over 300 related data asset transactions have been completed, marking the official entry of the ceramics industry's quality certification system into the data-driven era.

Overall, the data public goods in Foshan's ceramics industry exhibit clear characteristics of public goods:

(1) Replicability: low marginal cost and rapid scalability;

(2) Reusability: It can be shared and coordinated across multiple scenarios and departments;

(3) Public governance effect: It fosters cross-departmental collaboration among taxation, finance, and regulation;

(4) Industry spillover: It can be replicated and promoted to other industries;

Through the institutionalized application of data public goods, the ceramics industry has achieved a leap from "corporate tools" to "industry public goods," promoting the upgrading of industry governance from "point-based governance" to " platform-based collaboration " and "data governance."

4.4 Data-driven supply chain collaborative upgrading

from the Foshan Municipal Government Service and Data Management Bureau shows that the application of data elements in the ceramic industry chain has gone beyond single-point innovation and is forming a "multiplier effect" through multi-scenario linkage—that is, data is used for reuse, linkage and penetration of multiple links to achieve a leap in the overall collaborative efficiency of the industry chain.

In supply chain management, data platforms enable real-time sharing of previously fragmented information such as demand, capacity, and logistics, shifting supply and demand matching from reactive to proactive forecasting. For example, the logistics map update cycle has been shortened from the traditional 90–180 days to only 7–15 days, and data collection costs have been reduced to 10% of the traditional model, significantly improving the forecasting accuracy of raw material supply and production plans.

In terms of production management, the traditional production processes in the ceramics industry are slow to respond to logistics and order information, leading to imbalances in production scheduling and inventory backlogs. Through data platform-based chain visualization, companies can monitor upstream and downstream nodes in real time, achieving more precise production scheduling and inventory management, reducing waste and delays.

In terms of industry regulation, the data chain constructs a true, complete, and traceable industry profile, enabling regulatory authorities to shift from traditional "post-event review" to "pre-event warning and real-time supervision." Tax, market supervision, and industry and information technology departments can obtain real-time data through the platform, significantly reducing verification costs and improving regulatory efficiency and governance accuracy.

From the perspective of the overall effect of supply chain collaboration, the Foshan ceramics industry has achieved a structural upgrade from "experience-based collaboration" to "data-driven collaboration." This process has not only improved supply chain efficiency but also changed the industry's governance structure, gradually leading to the following characteristics in the supply chain:

(1) The collaborative approach has shifted from interpersonal collaboration to data collaboration;

(2) Information flow has shifted from opaque to visible and traceable;

(3) Risk management has shifted from passive response to proactive prediction;

(4) The operation of the industrial chain has shifted from a linear structure to a network structure;

(5) The governance subject has shifted from independent government governance to a three-party collaboration between platform, enterprise and government.

This collaborative upgrade is of great significance to the ceramics industry because it not only improves costs and efficiency, but also rebuilds the trust foundation of the industrial chain, providing the ceramics industry with the institutional and data foundation for further digital and intelligent upgrades.

4.5 Systemic Evolution and Governance Leap in the Application of Data Elements in the Ceramic Industry

In summary, the data element practices of Foshan's ceramic industry have shown a systematic evolution from data collection, data standardization, data platformization to the supply of data public goods, reflecting a multi-dimensional leap from the technical level, organizational level to the governance level.

First, it has enabled a leap from enterprise-level digitalization to supply chain digitalization. Data is no longer confined to within enterprises but has become a shared production resource across the industry.

Secondly, it has achieved a leap from data silos to standardized and trustworthy data governance. With the help of unified standards and trusted technologies, the ceramics industry has established a reliable data language and trust system for the first time.

Third, it has enabled a leap from information systems to supply chain collaboration platforms. Digital platforms have become the infrastructure for the operation of the supply chain, promoting overall collaboration among supply and demand, logistics, production, finance, and other links.

Fourth, it has achieved a leap from enterprise service tools to industry public goods. Data public goods such as "chain of evidence certificates," "data credit reports," and "trustworthy quality certificates" have become public governance tools jointly recognized by governments, financial institutions, and enterprises.

Fifth, it has achieved a leap from improving local efficiency to restructuring governance. Data elements have driven the ceramics industry to move from "experience-based governance" to "data-based governance," forming a replicable and scalable path for the digital upgrading of traditional industries.

The Foshan ceramics data element practice clearly demonstrates how a traditional industry can achieve systematic upgrading through standardization, platformization, and public goods development driven by data elements, providing a "ceramics model" that can be learned from for traditional manufacturing industries across the country.

5.Upgrading Path of Foshan Ceramic Industry

For traditional manufacturing, digital and data-driven transformation is not only a technological revolution, but also a reshaping of industrial governance structures and development models. The Foshan model of "data elements × ceramics industry" provides an empirical basis, but in order to achieve sustainable and scalable industrial upgrading, it is necessary to promote it through the following four systematic paths.

5.1 Standardization-Driven Trusted Data Infrastructure System for the Ceramic Industry

The primary prerequisite for the digitalization of the industrial chain is the reliability, uniformity, and reusability of data. The ceramics industry comprises numerous entities with varying sizes and severely heterogeneous information systems, resulting in inconsistent data formats, semantic discrepancies, and incomparable definitions. This fundamentally hinders the release of the value of data elements. Therefore, the upgrading of Foshan's ceramics industry must adhere to the principle of "standardization first" and promote the construction of fundamental industry systems.

First, establish a comprehensive data standard system. Focusing on key aspects such as raw material supply, production and manufacturing, logistics and distribution, transaction settlement, and quality inspection, develop unified data format standards, data collection specifications, and data classification and grading systems through government guidance, industry alliances, and leading enterprises. For example, standardizing raw material specifications can improve cross-regional circulation efficiency; standardizing logistics nodes facilitates real-time visualization; and standardizing contract, invoice, and fund flow formats forms the basis for transaction verification.

Second, establish data interface standards and an industry data dictionary. The ceramic industry ecosystem contains numerous heterogeneous systems such as ERP, MES, and WMS. Without a unified interface standard, these systems cannot connect smoothly, creating data silos. By establishing industry API specifications, a unified data tagging system, and a data dictionary, internal enterprise data can be read, accessed, and shared, thereby achieving industry-level data interoperability and mutual recognition.

Third, promote the standardization of regulatory data. The government's data needs in areas such as tax supervision, environmental protection supervision, and quality supervision heavily rely on real data from enterprises. Establishing unified regulatory data standards can reduce compliance costs for enterprises, improve regulatory efficiency, and enable regulatory authorities to utilize accumulated enterprise data for intelligent supervision.

Overall, the significance of standardization lies not only in the unification at the technical level, but also in building a "trustworthy data foundation " for the industry through the construction of underlying systems, enabling data elements to flow efficiently within the industrial chain, and providing a solid foundation for subsequent platformization, public goods development, and ecosystem development.

5.2 Collaborative Governance Path of Industrial Chain Digital Platform

Based on data standardization, the key to the digital upgrade of the ceramics industry lies in building a unified digital platform for the industrial chain, which enables data from multiple entities to be aggregated, integrated, interacted, and intelligently scheduled, thereby optimizing the overall efficiency of the industrial chain.

First, build an industry-level data aggregation platform. The core of platformization is to form a unified data hub, integrating internal enterprise data, platform-accumulated data, and government and external agency data through data access, data cleansing, and data governance. This platform should cover the entire supply chain, including supply, production, sales, logistics, and finance, becoming a "real-time digital mirror" of industry operations.

Second, develop an intelligent industrial scheduling system. Based on the data resources centrally accumulated on the platform, the efficiency of supply and demand matching, production planning and scheduling capabilities, and resource allocation levels in the ceramics industry can be improved through algorithm optimization, intelligent forecasting, and real-time scheduling tools. For example, by analyzing real-time data from logistics nodes, the platform can assist enterprises in optimizing transportation routes; by forecasting capacity load, the platform can provide enterprises with intelligent production scheduling suggestions; and by analyzing market demand data, the industrial chain can respond more quickly to changes in demand.

Third, platform-based collaboration enables multi-stakeholder collaborative governance. The ceramic industry chain involves multiple stakeholders, including raw material suppliers, manufacturers, logistics companies, distributors, banks, and regulatory agencies. Traditional collaboration relies on manual communication, which is inefficient and lacks transparency. Platform-based collaboration, through process digitization, access control, and data visualization, enables collaboration to occur automatically based on data, building a "digital governance consensus" within the industry. For example, the government can monitor the industry's operational status in real time; banks can conduct risk control based on platform data; and transparent collaboration can be achieved between enterprises.

Fourth, the platform serves as governance infrastructure, not a standalone system. Foshan's experience demonstrates that platformization should not be understood as an upgrade of enterprise-level information systems, but rather as a reconstruction of the infrastructure of the industrial governance system. Industry-level platforms are the core carriers for data elements to exert a multiplier effect, enabling industries to shift from "enterprise-driven" to "platform-driven," and from "point-based digitization" to "networked digitization."

In summary, platform-based empowerment is a key step for the ceramics industry to transition from traditional manufacturing to a digital governance system, and a systematic path to enhance the resilience, efficiency, and transparency of the industrial chain.

5.3 Construction of an Industry Governance System Driven by Data Public Goods

In practical applications within the ceramics industry, the most groundbreaking innovation is the elevation of data public goods from enterprise-level tools to industry-level public goods, promoting the public governance effect of data elements in areas such as taxation, finance, certification, and regulation through institutional scenarios.

First, creating a public good for tax payment verification data. The ceramics industry has long suffered from opaque raw material transactions and high difficulty in tax verification. Foshan's practice integrates, verifies, and stores data from four flows (transactions, capital, logistics, and consumer goods) on the blockchain through a "transaction evidence chain certificate," providing credible evidence to tax authorities. This type of public good not only reduces tax risks for enterprises but also improves the efficiency of regulatory departments, making it a typical "data public goods."

Second, we need to build a public data goods system for financial services. Ceramic industry enterprises generally lack collateral, making traditional credit rating methods ineffective. The platform provides highly reliable behavioral data such as real transaction data, performance records, logistics tracking, and capital flows, which can serve as important bases for bank credit granting. This enables financial institutions to conduct precise credit granting, intelligent risk control, and dynamic supervision, thereby improving inclusive finance coverage and reducing financing costs.

Third, promote the publicization of quality certification data. Quality certification for ceramic products is costly, complex, and difficult to verify. By storing production process and quality data on the blockchain using credible quality certificates, traceability of quality and credibility of certification can be achieved, thereby enhancing industry reputation and market competitiveness.

Fourth, build a public data system for intelligent regulation. A transparent, authentic, and traceable data chain enables the government to conduct intelligent and real-time industry regulation, reducing regulatory costs, improving regulatory accuracy, and achieving "data-driven regulation."

The ultimate significance of data public goods lies in: by institutionalizing data public goods , embedding data elements into the industrial governance system, enabling the ceramic industry to achieve structural breakthroughs in key areas such as taxation, finance, certification, and supervision, and promoting the modernization of the governance system.

5.4 Building a Sustainable Ecosystem of "Ceramic Industry × Data"

The ultimate goal of data-driven upgrading of the ceramics industry is to form an open ecosystem that spans industries, regions, and scenarios, enabling the ceramics industry not only to achieve digitalization but also to build future-oriented industrial competitiveness.

First, promote the cross-industry replication of data public goods. Foshan's transaction evidence chain, data credit system, and credible quality certificates have been replicated in industries such as glass and construction, extending from "applications in the ceramics industry" to "public scenarios in the manufacturing industry." In the future, it can be further expanded to the home furnishing, building materials, and engineering industrial chains, realizing the cross-industry diffusion of data public goods.

Second, build a data asset ecosystem for the ceramics industry. Industry data assets formed based on accumulated data can become new capital resources for enterprises. By promoting the market circulation of data through data trading, data services, and data cooperation, the ceramics industry can enter a development stage where "data is the core asset".

Third, promote the deep integration of the "industrial chain, innovation chain, and data chain". Under the ecological model, the ceramic industry not only uses data, but can also form new innovation scenarios around data, such as intelligent quality inspection, product design, personalized production, supply chain forecasting, and green manufacturing, so as to drive the industry towards high quality and high added value.

Fourth, build an open data collaboration network. The future industrial ecosystem needs to have the ability to participate in multiple entities, including governments, platform companies, manufacturing companies, equipment companies, research institutions, and financial institutions, to jointly form a collaborative system for data sharing, value co-creation, and benefit distribution, so as to enable the ceramic industry to have sustainable development capabilities.

The essence of ecological development is to enable the ceramics industry to move from "industrial digitalization" to "digital industrialization," embedding data elements into every link of the industrial value chain to form a new industrial ecosystem that is self-growing, self-circulating, and self-evolving.

6.Conclusions and Future Prospects

This paper takes the Foshan ceramics industry as a typical case. Based on an analysis of the national "Data Elements ×" strategy, it constructs a three-mechanism model of "data standardization—collaborative platformization—public goods supply," systematically analyzing how data elements generate governance effects within the traditional manufacturing industry chain, and verifying its operational logic through typical scenarios. The research shows that the impact of data elements on traditional industries has gone beyond the technological dimension and has become a key driving force in reshaping industrial organization, transaction patterns, and governance structures.

Firstly, in the transaction process, data standardization has enabled "credibility," "verifiability," and "circulation" within the industry chain. A unified data standard system has structurally resolved long-standing problems in the traditional ceramics industry, such as opaque raw material transactions, untraceable logistics nodes, and difficulties in comparing invoice information. Data standardization is not merely a technological reform, but also a reconstruction of the industry chain's credit, regulatory, and financial foundations, directly propelling the ceramics industry towards a more institutionalized and standardized operating model.

Secondly, in terms of supply chain collaboration, digital platforms have become a new type of industrial infrastructure. Platform-based governance, through data aggregation, algorithm scheduling, and real-time collaboration, significantly reduces the uncertainty of supply and demand matching, improves the overall efficiency of production-logistics-sales linkage, and transforms the ceramic industry chain from "fragmented enterprise decision-making" to "holistic chain optimization." This model effectively alleviates the persistent problems of information silos, high coordination costs, and severe resource misallocation in the traditional industry chain.

Third, at the industry governance level, data public goods are gradually evolving into public goods, providing institutionalized tools for collaborative governance among governments, financial institutions, and enterprises. Whether it's "transaction evidence chain certificates" improving tax payment supervision, data credit reports promoting inclusive finance, or trusted quality certificates improving product certification efficiency, all these indicate that data public goods have transcended the scope of enterprise services and become industry-wide public governance resources, strengthening industry transparency and compliance.

Overall, the data-driven practices in Foshan's ceramics industry exemplify a typical path for traditional industries to "leap from point-based innovation to systemic transformation": establishing a foundation of trust through data standardization, enhancing collaborative capabilities through digital platforms, strengthening industry governance efficiency through the supply of data public goods, and achieving cross-industry replication through ecological development. The research confirms a core viewpoint: the value of data elements lies not in the application of a single technology, but in driving the restructuring of the overall governance structure of traditional industries through the combined effects of systems, platforms, and ecosystems.

The following areas still warrant further research:

First, we need to construct a multi-dimensional quantitative indicator system for the role mechanism of data elements. Although this paper reveals the governance logic of data elements from a mechanistic perspective, the data-driven transformation of traditional industries still requires the support of quantitative models, such as transaction cost indices, collaborative efficiency indices, and data public goods effectiveness indices, to provide a quantitative basis for broader industrial chain research.

Second, conduct comparative studies across industries and regions. The ceramics industry has a highly agglomeration characteristic and a unique chain structure. In the future, it can be compared with traditional industries such as textiles, home appliances, and building materials to verify the external generalizability and boundary conditions of the three-mechanism model.

Third, we need to deepen our research on the interaction between data assetization and industrial finance. Foshan's experience shows that transaction data, performance data, and behavioral credit data can support inclusive finance, but how to price, classify, and regulate data assets in different financial scenarios still needs in-depth discussion.

Fourth, explore incentive and governance mechanisms for data sharing. In traditional industries, companies face competition and data security concerns. In the future, it is necessary to build a more mature data rights and responsibilities system, privacy computing mechanisms, and benefit-sharing mechanisms to encourage more entities to participate in data circulation.

Overall, the digital transformation of Foshan's ceramics industry provides a replicable and scalable practical model for the high-quality development of traditional manufacturing. With the continuous improvement of the data element system, technology system, and market system, data-driven industrial upgrading will have a profound and lasting impact on more industries and more regions.

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