buildings

MDPI

Article

Developing a Manufacturing Industrial Brain in a Smart City: Analysis of fsQCA Based on Yiwu Knitting Industry Platform

Jinchi Ma [1], Weidong Wang [2,*] and Cheng Zhou [1]

[1] School of Economics and Management, China Jiliang University, Hangzhou 310018, China; p23070254034@cjlu.edu.cn (J.M.); p23070254066@cjlu.edu.cn (C.Z.)
[2] School of Modern Science and Technology, China Jiliang University, Hangzhou 310018, China
* Correspondence: wwdn2002@cjlu.edu.cn

Abstract: This article explores the mechanism for constructing and the path for implementing an industrial brain in the development of smart cities, with a focus on the case of the Yiwu knitting industry platform in China. Accordingly, our study involved a literature review, questionnaire survey, data analysis, qualitative comparative analysis (QCA), and discussion. Our key finding was that the manufacturing brain evolves in three distinct stages: platform creation, growth, and expansion. The mechanisms of implementing these are functional development, trust creation, and value co-creation, respectively. Specifically, functional development marks the commencement of the industrial brain's construction, which involves enterprise demand analysis, capability bottleneck identification, data value formation, and platform architecture simplification. Trust building serves as the central mechanism of evolving the manufacturing brain, comprising institutional, relational, and computational trust. Lastly, value co-creation proceeds, which is pivotal for a business paradigm revolution, encompassing connection, linkage, and integration. The main theoretical contribution of this article is to propose a normative analytical framework for revealing the mechanism of construction and the path of implementation of industrial platforms in smart city development. Meanwhile, in its practical contribution, this article provides policy guidance, as developed through our analysis of how an industrial platform can promote the transformation and upgrading of the urban manufacturing industry, to realize smart city construction and the economy and society's coordinated development.

Keywords: industrial brain; smart city; fsQCA

Citation: Ma, J.; Wang, W.; Zhou, C. Developing a Manufacturing Industrial Brain in a Smart City: Analysis of fsQCA Based on Yiwu Knitting Industry Platform. *Buildings* **2024**, *14*, 1404. https://doi.org/10.3390/buildings14051404

Academic Editors: Haifeng Liao and Yung Yau

Received: 14 March 2024
Revised: 25 April 2024
Accepted: 10 May 2024
Published: 14 May 2024

1. Introduction

Smart cities are a form of modern cities, representing an advanced stage of development, and they have become a new driver for the growth of the urban economy [1]. The industrial brain, as an important component of the smart city framework, refers to a system that utilizes technologies such as AI, big data, and cloud computing to connect up and intelligently manage the industrial chain [2]. The core of the industrial brain lies in achieving deep data mining and value transformation through technological means, promoting industrial upgrading and innovation. In the era of smart cities, industrial cloud platforms, as concrete representations and carriers of "industrial brains", are gradually becoming the core of urban manufacturing industries [3–5]. Industrial platforms facilitate the manufacturing industry to develop efficiently, intelligently, and sustainably. In particular, their input helps to save resources and optimize resource allocation in cities, thus accelerating the construction of smart cities [6–9].

The existing literature has extensively explored the concept of smart cities, their infrastructure's construction, the application of information technology, the intelligence of smart city urban management, and the potential of industrial brains in promoting urban development [7,10]. However, there is a relative dearth of research on the specific role, construction mechanisms, and transformation pathways of industrial brains in the practical smart city environment. In particular, key questions that remain unanswered are how best to integrate advanced technologies through industrial cloud platforms, to achieve intelligent management and innovation of the industrial chain, and how these technological means specifically affect the transformation and upgrading of the urban manufacturing industry. The core research questions that this article answers are as follows: How can the industrial brain optimize the management and intelligent decision making of the industrial chain through technological means in the smart city environment, especially in promoting the transformation and upgrading of the urban manufacturing industry? What specific roles does the industrial cloud platform play? This issue is closely related to the objectives of our study, which aim to delve into and analyze the construction mechanisms and pathways of industrial brains in smart cities, based on Yiwu Knitting Industry Platform. This article attempts to fill this research gap and, in doing so, offer practical guidance and theoretical contributions regarding the application of the industrial brain in the construction of smart cities, which are of great significance for academia and industry players. In sum, this article makes a novel contribution to the research by uncovering details of the practical application of the industrial brain in the construction of a smart city through the analysis of fsQCA based on Yiwu Knitting Industry Platform, highlighting the role of technological innovation in promoting industrial transformation and upgrading.

According to the *China Digital Economy Development Report* (2023) released by the China Academy of Information and Communication Technology, the digital economy in China was booming in 2022. The scale of the digital economy had reached CNY 6.95 trillion, having increased by CNY 0.64 trillion on a year-on-year basis. This represented a year-on-year nominal growth of 10.3%, which was 4.98 percentage points higher than the nominal GDP growth rate and accounted for 41.5% of the national GDP. These figures demonstrate how the digital economy has become a key pillar of the national economy. As part of this trend, in the context of the "Internet of Everything", platforms have boomed in China and become the new engines of economic growth. Today, Zhejiang is the province with the highest level of digitization in China. Yiwu, a city in Zhejiang, is oriented as the "small commodity capital of the world", but top-level design efforts are underway to facilitate its transformation into a data-fused and innovative smart city. The aim is to establish a "Yiwu benchmark" for novel smart cities in China and to put forward a "Yiwu model" that others will follow in the development of international smart cities. Since 2021, the knitting industry in Yiwu has been part of the first batch of new intelligent manufacturing pilots for industrial clusters in Zhejiang Province. In the resulting "industrial brain", the knitting industrial platform of Yiwu Yingyun Technology Co., Ltd. (Guangzhou, China). Equipment from Santoni, Flanelli, Italy, and Lonati, located in Bologna, Italy is highly representative. We demonstrate the application of the industrial brain in the actual construction of a smart city. In recent years, officials in Yiwu have optimized and intelligently managed the knitting industrial chain by building a knitting industry platform and utilizing cloud computing and big data analysis technologies, thereby improving the industry's competitiveness and sustainable development capabilities [11]. This process not only promotes the construction of Yiwu as a smart city but also provides valuable practical experience and a theoretical reference for those considering other cities.

2. Literature Review

2.1. Smart Cities and Industrial Platforms

The idea of smart cities is to improve the operational efficiency of the city, thereby enhancing its sustainability and improving the quality of life of residents [8]. With the acceleration of global urbanization, smart city projects have spread globally and become an important trend in urban development [10]. These projects hinge on the establishment of industrial platforms, as proposed by Gawer and Cusumano, which constitute the industrial application of platform architecture [12]. Specifically, in smart cities, digital tools and service platforms serve to integrate advanced information technologies such as cloud computing, the Internet of Things, and big data analysis. The aim is to promote information sharing, efficient collaboration, innovativeness, and the optimization of various links in the industrial chain, thus raising the overall innovation, intelligence, and competitiveness of the industry. Chiefly, these efficient industrial management and service systems for cities support the digital transformation of manufacturing and related industries, and, thus, the urban economy, by providing data-driven decision support and resource integration capabilities [3,13]. Industrial platforms are different from previous platforms that only emphasized transactional efficiency. They highlight the enabling characteristics of digitization, deconstruct and reconstruct the transaction and innovation activities of various enterprises in industrial chains, and help enterprises to improve their efficiency and develop new modes of doing business. However, many platforms still use the operational logic of consumer Internet platforms and pursue rapid, unilateral growth, so they fail to create value for enterprise users and promote unsustainable development. Likewise, in the existing research, many studies focus on consumer Internet platforms for the two-sided market, mainly involving topics such as price subsidy and network effects [14,15].

Instead, in the process of building smart cities, industrial platforms act as bridges and links, connecting urban management and urban industrial development. On the one hand, industrial platforms help urban managers to optimize resource allocation and improve the efficiency and quality of public services through data analysis and intelligent decision support [6]. On the other hand, these industrial platforms provide technical support and business model innovation for enterprises, promoting industrial upgrading and economic growth [7].

2.2. Platform-Based Ecosystem and Industrial Cloud Platform

Efforts aimed at developing a platform-based ecosystem and at digitization have often blended in industrial practice, so theoretical crossover research is urgently needed [16,17]. Although the impact of the rise of platform-based enterprises on the industrial ecology has seldom been studied, some researchers put forward certain insights: for instance, Zheng found that there is a need to establish a regional innovation platform to drive innovative regional development, solving a problem that can arise of there being insufficient innovation impetus [18]. Gawer and Cusumano, meanwhile, noted an interaction between the rise of platform-based enterprises and industrial ecological innovation across levels, and they offered a perspective whereby platforms are regarded as systems aggregating many modules that can innovate independently [7]. Furthermore, Chen described how a public entrepreneurship platform oriented toward widespread entrepreneurship may facilitate the innovation of industrial technologies [19]. By combining platform theory and a case study, Wu (2016) explored the upgrading of industrial clusters, dominated by leading enterprises. Elsewhere, Wang and Cai established an ecological upgrading process model for clusters based on a dual-platform architecture (the Process Model) [20]. The model offers a new idea for the study of industrial digitization, that is, the platform and ecosystem transformation of industrial clusters in the scenario of the digital economy. Yu then enriched this mechanism by accounting for the spillover effect of the platform architecture, which resulted from their empirical research on relevant economic data [21]. As part of their findings, they noted that the rise of the platform economy is a significant force driving the implementation of policies aimed at industrial transformation and upgrading [22].

2.3. Empowering Mechanism of Industrial Platforms

Existing studies on the empowerment generated by industrial platforms have generally supposed that platforms have output capacity; however, recent research underlines the need for cooperation between multiple agents when establishing platforms. Their establishment is a co-evolutionary process of functional development (FD) and trust-building (TB) behaviors, which drive the growth of platforms [23]. Based on the concept of empowerment in psychology, platform empowerment involves co-creating value and energy through interactions between organizations and individuals, whereby skills and abilities are imparted that empower those involved [24]. Furthermore, as the Internet develops and organizational and management modes are transformed, enterprises and organizations move away from a mechanical design toward more diversified modes, and organizational empowerment comes into focus [25]. In this way, enterprises empower the production, innovation, and competition of platform participants by means of technology transfer, interactive scene expansion, and opened platform interfaces, which may eradicate information asymmetry, optimize resource allocation, and facilitate complementary and innovative activities [26]. These mechanisms have such effects as promoting resource integration and the optimal configuration of the parties in supply chains [27]. In recent years, studies on platform empowerment have gradually combined with those on platform ecology, taking note of the relationship between platforms and enterprises in the industrial ecosystem, and have discussed the potential for establishing a platform-based ecosystem with the interactions between participants at its core [28].

In summary, researchers have yet to explore the establishment mechanism and path of industrial platforms. Furthermore, different industries differ from one another, but empirical research cases remain rare. Therefore, the provision in this article of a typical case, in which we explore the action mechanism of industrial platforms in a specific industry via qualitative research, holds significant value in providing a reference for other industries.

3. Research Design

3.1. QCA

QCA is a research method in social science that was proposed by the American sociologist Charles C. Ragin in the 1980s [29]. Based on set theory and Boolean operation, QCA is case-oriented and aims to verify how different antecedents lead to specific outcomes via different paths. QCA has a particular use in dealing with complex cause-and-effect questions and offers insight into how certain configurations function, that is, by assessing the influences of different antecedent combinations on specific outcomes. QCA combines the depth of qualitative research with the systematic nature of quantitative research, making it a suitable method for exploring the configurations of variables and their relationships in studies with small and medium-sized samples. The core concept of QCA is to recognize that the causal relationships of social phenomena may be conditional and configurational, and that different combinations (configurations) of conditions can lead to the same results, with emphases on "equivalent heterogeneity" and "causal complexity" [30].

Since its proposal, the QCA method has been widely applied in various fields such as political science, sociology, and management to solve complex causal problems that traditional quantitative methods struggle to handle. Furthermore, Ragin developed the QCA method into the fuzzy-set QCA (fsQCA), which can handle more complex social science research problems, thus demonstrating increased flexibility and applicability [31]. Data sources that may be used in fsQCA include textual cases, questionnaires, and secondary data. Researchers should select their sources according to the research topic and the likely effectiveness of data acquisition in each case. Then, fsQCA provides a systematic analytical framework for exploring the data in order to gain an understanding of how relevant antecedents interact to yield specific outcomes.

After comparing the traditional quantitative methods with QCA, we chose to use QCA in this study owing to its suitability for investigating the action mechanism by which platforms empower the digital transformation of industrial clusters. Our analysis of the applicability of the method was as follows:

(1) QCA provides a novel research idea, emphasizes the multiple concurrent relations between antecedents and outcomes, and breaks through the limitation of traditional quantitative methods in exploring only the influence of a single dependent variable. In particular, when solving problems with complex antecedents, QCA has the unique advantage of being unimpaired by the correlations between multiple antecedents. In comparison, traditional quantitative methods can only show the cumulative effect of multiple antecedents on the outcome, meaning they can fail to provide a comprehensive explanation in practical scenarios. In this case, previous analytic results based on

grounded theory have revealed diverse and complex factors influencing the mechanism empowering the digital transformation of industrial clusters via platform-based organizations, so QCA is highly applicable to the present research.

(2) QCA considers that not only one path can cause specific outcomes and highlights diversity and globality. Furthermore, unlike traditional quantitative methods that can only explain simple paths, QCA ascertains all antecedents that cause a certain outcome through use of the set theory and Boolean operation based on configuration theory. This renders the research results more realistic and provides more practical guidance for corporate governance. Accordingly, in this case, using QCA in the research may serve to construct all antecedent combinations influencing the mechanism by which platform-based organizations empower the digital transformation of industrial clusters, allowing us to understand the relationships between influencing factors comprehensively.

(3) A factor influencing the mechanism of empowerment in this case may plausibly change through its combination with other factors. QCA is suitable for investigating such a scenario because it breaks the traditional assumption of causal consistency. As such, by using QCA, we may come to understand how the empowering mechanism in this case functions and shifts under combinations of different factors, thus gaining a comprehensive perspective.

(4) The core idea of QCA—namely, asymmetric causalities—offers a new way of thinking in research. This holds that in many actual scenarios, causalities are asymmetric, and so QCA allows for analyses of these causalities through Boolean operation and the degree of membership to sets, which subverts the traditional concept of symmetrical causalities. Accordingly, in this case, selecting QCA as the method for investigating the factors influencing the empowering mechanism offers the possibility of accurately charting their complex correlations.

3.2. Variables' Selection and Measurement

The industrial Internet platform, as a driving force of industrial digital transformation and upgrading, serves to empower platform users on both the supply and demand sides of the industrial chain. According to the existing research results, three factors can be identified for the mechanism empowering the digital transformation of industrial clusters via platform-based organizations: Function Development (FD), Trust Building (TB), and value co-creation (VCC) [23,32–34]. These were adopted as the antecedents of our fsQCA. To determine how to target these, we referred to the items measured in previous studies from China or abroad that adopted the same or similar variables. These were combined with the open-coding results based on grounded theory, specifically, the characteristics they highlighted of empowering mechanisms. Finally, scales applicable to this research were designed. The specific backgrounds of the variables are as follows:

(1) Function Development (FD)

According to Kagermann, the development of an industrial platform's functionality may be measured in three sub-dimensions: platform technological innovation, service diversity, and user experience [13].

(2) Trust Building (TB)

According to Pavlou, P. A.'s (2003) e-commerce trust model, trust building may be measured through platform security, transparency, and interaction quality [35].

(3) Value Co-creation (VCC)

The theory of value co-creation, proposed by Prahalad, C.K. and Ramaswamy, V. (2004), is measured through three aspects: user involvement, innovation sharing, and feedback mechanisms. Furthermore, the authors developed a scale for their measurement [36].

3.3. Questionnaire Survey

We adopted a mixed-methods approach, combining qualitative interviews with quantitative surveys to ensure the comprehensiveness and depth of the data collected. In practice, interviews were used to gain a preliminary understanding of the role and impact of industry platforms in smart cities, while the survey was then used to quantitatively analyze the relationships between variables already identified. The questionnaire was strictly designed to probe the variables introduced above according to their defined measurement dimensions, ensuring the accuracy and relevance of the questions. The survey allowed us to collect data from different perspectives; for instance, we sought not only to gain an understanding of the technological and policy background of smart cities and industry platforms but also to obtain direct information on user experiences and needs. Together, these methods allowed us to build a comprehensive framework of understanding, in line with the discussions in the literature review on the multidimensional construction of smart cities. Furthermore, through our survey, we could collect data from a wide range of target groups in a short period, which was particularly useful for exploring and analyzing the construction of industry platforms in smart cities. Moreover, the survey data were suitable for statistical analysis, allowing for the quantification of different groups' viewpoints and differences in needs, which facilitated our formulation of specific recommendations on improvement measures.

3.3.1. Target Audiences

Our survey was directed toward the following groups:

(1) Planners and decision makers of smart city projects

This group includes government officials, urban planners, and managers of smart city projects, who have a comprehensive understanding of and direct influence on the construction and operation of smart cities.

(2) Developers and operators of industrial platforms

Representatives of technology companies, IT experts, and development and operation teams of related industry platforms, who have a thorough understanding of the technical characteristics, operational models, and market strategies of industry platforms.

(3) Industrial users and service beneficiaries

This includes both businesses and ordinary citizens who utilize industry platform services; they are able to provide evaluations of industry platforms' functionality and smart city services from a user perspective.

Through a questionnaire designed for these target audiences, we sought to validate and extend the theoretical viewpoints noted in the literature review, such as the empowering role of industrial platforms and the user acceptance of smart city services, thus strengthening the connection and feedback between theory and practice.

3.3.2. Pre-Survey for Questionnaire

Our questionnaire was used as the data collection method for the fsQCA, with each completed questionnaire taken to represent a case. Before releasing the formal questionnaire, a pre-survey of its questions was conducted on a small scale through the Wenjuanxing platform.

The questionnaire comprised three parts: questionnaire description, basic information, and measured items. In part two, to guarantee the quality of the questionnaire data, we included relevant questions that screened the respondents, allowing us to ensure they were from one of the target audiences relating to the knitting industry Internet platform of Yingyun Tech. Then, in part three, all items were measured using a five-point Likert scale to ensure we acquired detailed ideas from the interviewees and captured their attitudes.

Negatively worded items were also included in the questionnaire design, to verify the accuracy of the responses. Furthermore, questionnaires that were answered in the absence of relevant experience, had contradictory replies, had identical answers, or were answered too quickly were all deemed invalid. After screening, we were left with 50 appropriate completed questionnaires.

Some respondents noted that they had faced difficulty in understanding certain items or they questioned the descriptive accuracy of some items. The questionnaire was modified accordingly, with extensive consideration of the corrections that were appropriate. The formal questionnaire was then released using the Wenjuanxing online platform, which was utilized to ensure the reliability and effectiveness of the data collected (Table 1).

Table 1. Design of measurement items for each conditional variable.

Variable	Code	Measured Item
FD	FD1	The supply chain service platform of Yingyun Tech can accurately identify the common demands and pain points of the industry.
	FD2	The supply chain service platform of Yingyun Tech can meet the demands of enterprises in clusters.
	FD3	The knitting industrial Internet platform of Yingyun Tech helps enterprises to break through their capacity bottleneck.
	FD4	The knitting industrial Internet platform of Yingyun Tech has an optimized architecture and gives a positive user experience.
	FD5	The value proposition of the knitting industrial Internet platform of Yingyun Tech tallies with the user demand.
	FD6	The digital and intelligent manufacturing service platform of Yingyun Tech increases the operating efficiency of enterprises in clusters.
TB	TB1	The knitting industrial Internet platform of Yingyun Tech has a well-established system.
	TB2	Users trust Yingyun’s financial services and use them as needed or under the conditions allowed.
	TB3	Users are willing to share their real business data on the knitting industrial Internet platform of Yingyun Tech.
	TB4	The knitting industrial Internet platform of Yingyun Tech maintains a close interaction with users.
	TB5	The services offered by the knitting industrial Internet platform of Yingyun Tech are reliable.
	TB6	The knitting industrial Internet platform of Yingyun Tech has appeal in the industry.
VCC	VCC1	The joint R&D platform of Yingyun Tech raises the R&D efficiency of the knitting industry.
	VCC2	The talent training platform of the Yingyun Institute meets the talent demand of the knitting industry.
	VCC3	The Yingyun Youfu talent-sharing platform facilitates the sharing of human resources in the knitting industry.
	VCC4	The knitting industrial Internet platform of Yingyun Tech contributes to sustaining tight connections in the knitting industry.
	VCC5	The knitting industrial Internet platform of Yingyun Tech allows timely measures to be taken and responses given to feedback.
Effects	E	The knitting industrial Internet platform of Yingyun Tech drives the overall development of the knitting industry.

3.4. Data Collection

We released 150 questionnaire URLs to the target research group via social media including WeChat and microblogs on 10 and 20 January 2024, and all questionnaires were returned (a recovery rate of 100%). Through careful screening of these questionnaires according to the inclusion principles described above for the pre-survey, 123 valid questionnaires were retained as the sources of data for our analysis, so the effective recovery rate was 82%. Since the number of cases needed in QCA relates to the number of selected conditions, and theoretically there are 2^k combinations under k conditions, three antecedents were selected in this research. The number of actual cases (123) was larger than the number theoretically required (2^3 (8)), which helped us to avoid the common research problem of a limited diversity of samples (wherein the cases do not necessarily satisfy all combinations).

4. Data Analysis

4.1. Descriptive Statistical Analysis of Samples

There were more males (65.04%) than females (34.96%) in our sample, and interviewees with a bachelor's degree accounted for the largest educational group (65.85%), followed successively by those with a master's degree (14.63%), college degree (8.94%), high school degree or below (7.32%), and doctoral degree (3.25%). On the whole, a good majority of the interviewees had a bachelor's degree or above, reaching 83.73% (Table 2).

Table 2. Demographic characteristics of sample.

Sample Characteristics	Measured Item	Sample Size	Percentage
Gender	Male	80	65.04%
	Female	43	34.96%
Educational background	High school degree or below	9	7.32%
	College degree	11	8.94%
	Bachelor's degree	81	65.85%
	Master's degree	18	14.63%
	Doctoral degree	4	3.25%
Relation	Platform party	33	283%
	Customer	14	11.38%
	Supplier	1	0.81%
	Partner	5	4.07%
	Government agency worker	7	5.69%
	Investor	2	1.63%
	Other	61	49.59%
Occupation	Technical/R&D personnel	22	17.89%
	Manager	15	12.20%
	Production personnel	1	0.81%
	Salesperson	6	4.88%
	Marketing/public relations practitioner	2	1.63%
	Customer service staff member	0	0%
	Administrative/support staff member	10	8.13%
	Human resources	2	1.63%
	Financial auditor or accountant	3	2.44%
	Clerk	17	13.82%
	Student	45	359%

"Platform party" was the most common identity selected in relation to the knitting industry Internet platform of Yingyun Tech, accounting for 28.3%. This was followed by customers and governmental agency workers, making up 11.38% and 5.69% of the sample, and thus standing as relatively common identities. Meanwhile, suppliers, partners, and investors were represented in low proportions, at 0.81%, 4.07%, and 1.63%, respectively. Beyond those, many respondents chose "others" (49.59%) to describe their relations with the knitting industry Internet platform of Yingyun Tech.

In terms of occupations, most respondents selected the "student" option, with a proportion of 35.9%. Meanwhile, the other occupations were relatively dispersed in terms of the number, without any significant trend. Among all the options, the number of customer service staff members was the lowest (0).

In summary, "platform party" was most commonly selected as the identity of a respondent in relation to the knitting industry Internet platform of Yingyun Tech, indicating that the target group was covered comprehensively, though there was also a sizeable proportion of people who selected the "others" option. In addition, respondents with diverse occupations were sampled, which supported us to gain a comprehensive understanding of the empowering mechanism in terms of its capacity to facilitate the digital transformation of industrial clusters.

4.2. Reliability and Validity Tests

The items in our scales were mainly self-developed according to the analysis results and based on grounded theory, so reliability and validity tests were deemed important. It is worth noting that the measured items in this research only included reflective indicators, which are external manifestations of the connotations of constructs, and deleting a certain indicator does not influence the core connotation reflected by the construct. In this research, "FD", "TB", and "VCC" (representing the empowering mechanism of the platform) and the "effects" of platform empowerment were all reflective constructs [37].

4.2.1. Cronbach's Reliability Analysis

The software SPSS (version 26.0) was used to conduct reliability tests on the sample data. Researchers generally measure the stability of results by testing Cronbach's α coefficient, which reflects the internal consistency. When Cronbach's α coefficient is greater than 0.7, the research data are regarded as reliable, while they are deemed to have good reliability and internal consistency if the coefficient exceeds 0.9.

The above table shows that the reliability coefficient was 0.978, which was greater than 0.9, meaning that the research data were highly reliable. Furthermore, it can be seen from the column titled "α coefficient after deleting the corresponding item" that the reliability coefficient did not increase obviously after deleting an arbitrary item. Additionally, the CITC values of the analyzed items all exceeded 0.4, which was indicative of good correlations between the analyzed items and high reliability. In summary, the reliability coefficient of the research data was higher than 0.9, which comprehensively indicated that the data were reliable and could be used for further analysis (Table 3).

Table 3. Cronbach's reliability analysis.

Item	Corrected Item Total Correlation (CITC)	α Coefficient after Deleting the Corresponding Item	Cronbach's α Coefficient
FD1	0.855	0.976	0.978
FD2	0.850	0.976	
FD3	0.832	0.977	
FD4	0.857	0.976	
FD5	0.847	0.976	
FD6	0.817	0.977	
TB1	0.855	0.976	
TB2	0.818	0.977	
TB3	0.813	0.977	
TB4	0.816	0.977	
TB5	0.839	0.976	
TB6	0.806	0.977	
VCC1	0.822	0.977	
VCC2	0.819	0.977	
VCC3	0.858	0.976	
VCC4	0.850	0.976	
VCC5	0.833	0.976	
E	0.853	0.976	
The standardized Cronbach α coefficient: 0.978.			

4.2.2. KMO Validity Analysis

Validity tests are used to judge whether the items are reasonable and meaningful. In this case, the data analysis method of factor analysis was used as our validity test. Factors including the Kaiser–Meyer–Olkin (KMO) value, communality, percentage of explained variance, and factor loading were used to perform a comprehensive analysis, to verify the validity of the data. The KMO value is used to judge the appropriateness of information extraction; communality is adopted to eliminate unreasonable items; the percentage of explained variance is used to describe the information extraction level; and factor loading is utilized to measure the correspondence of factors (dimensions) to items. It can be seen from Table 4 that the communality for all items was higher than 0.4, suggesting that information for the items could be extracted. Additionally, the KMO value was 0.947, which is larger than 0.6, meaning that information could be extracted from the data. Moreover, the percentage of explained variance of a single factor was 73.115%, and the cumulative percentage of explained variance of the rotated factors was 73.115% (>50%), which implied that information could be extracted from the items. Finally, the correspondence of the factors (dimensions) to the items was determined and combined with the factor loading, to verify whether it met our expectations. If it meets expectations, this means that the data have validity; otherwise, the information extraction needs to be adjusted. The options are regarded as having correspondence to factors as long as the absolute value of the factor loading exceeds 0.4 (Table 4).

Table 4. Validity analysis results.

Item	Factor Loading	Communality (Common Factor Variance)
	Factor 1	
FD1	0.875	0.765
FD2	0.869	0.756
FD3	0.851	0.724
FD4	0.873	0.762
FD5	0.867	0.752
FD6	0.840	0.705
TB1	0.871	0.759
TB2	0.839	0.704
TB3	0.834	0.695
TB4	0.837	0.700
TB5	0.859	0.738
TB6	0.826	0.683
VCC1	0.842	0.709
VCC2	0.839	0.704
VCC3	0.874	0.764
VCC4	0.868	0.753
VCC5	0.853	0.727
E	0.872	0.760
Characteristic root (before rotation)	13.161	-
Percentage of explained variance % (before rotation)	73.115%	-
Cumulative percentage of explained variance % (before rotation)	73.115%	-
Characteristic root (after rotation)	13.161	-
Percentage of explained variance % (after rotation)	73.115%	-
Cumulative percentage of explained variance % (after rotation)	73.115%	-

KMO and Bartlett tests were used to verify the validity. Table 4 shows that the KMO value was 0.947, which is larger than 0.8, indicating that the research data were suitable for extracting information (evidencing good validity, albeit indirectly) (Table 5).

Table 5. KMO and Bartlett tests.

Item		Factor Loading
KMO value		0.947
Bartlett sphericity tests	Approximate chi-squared	2030.034
	d*f*	153
	p value	0.000

5. QCA

In recent years, the QCA method has been applied in the research on smart cities and industrial platforms, which has demonstrated its effectiveness in exploring urban development models under the combined effects of technology, policies, and socio-economic factors [38]. Furthermore, this method overcomes the limitations of traditional quantitative research methods in order to deal with complex causal relationships. Through QCA, researchers can identify the key configuration of conditions that drives the successful construction of smart cities and, thanks to its emphasis on equivalent heterogeneity, the patterns of how industrial platforms promote their development, thus providing a strong basis for urban planning and policy making [39]. Accordingly, QCA was chosen as the methodological basis for this study, with confidence that it would effectively address the key topic at hand, namely the complex combination of conditions and causal paths in the construction of smart cities and industrial platforms.

5.1. Data Calibration

Before calibrating the data, we needed to calculate the values of each conditional variable and outcome variable. In this case, since we were using reflective variables, the mean values of the measurement indices could be used to directly represent the indices.

Then, for the fsQCA, the collected data need to be calibrated. Calibration refers to assigning a certain membership to the condition of each case. The subset relations of necessity and sufficiency cannot be analyzed before calibrating the original case data so they are fit for set membership. Ragin put forward a direct calibration method that can be used to directly calibrate the initial values, establishing them as members of fuzzy sets. The method defines three important anchors: separate thresholds of complete non-membership (membership = 0.05), intersection (membership = 0.5), and complete membership (membership = 0.95). The set membership after calibration is in the range of 0 to 1. In this case, the research data were mainly questionnaire data with a large sample size, and each item was measured using a five-point Likert scale. Previously, researchers have found that data for some items have held a positively skewed distribution, and when using three values (5, 3, and 1) as the anchors, the negative cases in the samples have not been sufficient to obtain a reduced solution. Considering this, the anchors for the three conditional variables and the outcome variable were separately set to 95%, 50%, and 5% quantiles. The specific calibration anchors are listed in Table 6. This system should avoid all cases falling into the membership of 0.5 under a certain condition (and then being ruled out of the analysis range as they cannot be classified). Nonetheless, owing to the membership of 0.5, a certain number of cases are still lost, which may influence the analysis. To solve this problem, researchers have proposed the following method: if the membership is 0.5, the case is replaced with a figure either increased or decreased by 0.001. Accordingly, in this research, 0.499 was uniformly assigned to the cases with membership of 0.5 after calibration (Table 6).

Table 6. Calibration anchors of conditional variables and outcome variable.

Variables		Anchors		
		Complete Membership	**Intersection**	**Complete Non-Membership**
Conditional variables	FD	5	4	3
	TB	5	4	3
	VCC	5	4	3
Outcome variable	E	5	4	3

5.2. Analysis of Necessary Conditions

Before carrying out fuzzy-set configuration analysis, an analysis of the necessary conditions is required, that is, to determine which antecedents are necessary conditions resulting in consumers' high or low satisfaction with the collaborative services of the empowering platform. In essence, this reflects the capacity of single antecedents in explaining the outcome variable. Judging whether a certain antecedent is a necessary condition of the outcome follows this rule: when the consistency score of the antecedent exceeds 0.9, it can be interpreted that the outcome variable is more than 90% subject to the antecedent from the perspective of sets. Here, it needs to be further stated that if the necessary condition is absent, the outcome will never arise, and the presence of the necessary condition also does not mean that the outcome is bound to arise. Instead, researchers need to judge whether the necessary condition will combine with the remaining conditions to incur a composite effect that influences the outcome in a configuration form.

The software fsQCA ANSYS 3.0 was used for data processing and analysis. We selected the "Necessary Conditions" option in the software so that various antecedents and the non-set consistency and coverage were calculated. Since QCA adopts asymmetric causalities, conditions that led to high and low satisfaction were calculated separately. Table 7 lists the results.

Table 7. Detection of the necessary conditions for high effects.

Conditional Variables	**Outcome Variable High Effect (E)**	
	Consistency	**Coverage**
PD	0.876536	0.914508
~PD	0.528462	0.679193
TB	0.853382	0.914185
~TB	0.516405	0.643044
VCC	0.903826	0.905527
~VCC	0.481011	0.651397

As shown in Tables 7 and 8, only one antecedent conditional variable had a consistency exceeding 0.9 in influencing the high effect, indicating that it served as the necessary condition. Meanwhile, the consistency of the other antecedent conditional variables' influences on the high and low satisfaction was not higher than 0.9, so they were not necessary conditions. The specific detection results for the necessary conditions for the low effect showed that the consistencies of ~PD, ~TB, and ~VCC all exceeded 0.8, which indicated that, although the three conditional variables were not necessary conditions for the low effect, they showed strong explanatory power (Table 8). Therefore, these antecedents were incorporated into the fsQCA in the next step, to explore the configurations that led to high and low effects.

Table 8. Detection of necessary conditions for low effects.

Conditional Variables	**Outcome Variable Low Effect (E)**	
	Consistency	**Coverage**
PD	0.661108	0.508035
~PD	0.888748	0.84132
TB	0.610811	0.481949
~TB	0.89124	0.817426
VCC	0.650508	0.480034
~VCC	0.871976	0.869758

5.3. Analysis of Sufficient Conditions

5.3.1. Truth Table Construction

The truth table is used to study the sufficiency of conditional variables, which serves to explore configurations that can lead to certain outcomes. A truth table is a fuzzy-set membership matrix compiled after the assignment of the conditional variables and outcome variable. After running the truth table algorithm in fsQCA software (version 3.0), the truth table results present all valid conditional configurations, the number of cases matching with the configuration results, and some reference indices, such as the consistency and PRI consistency. To obtain the final truth table, it is crucial to set the frequency threshold of cases, original consistency threshold, and PRI consistency threshold. When multiple samples and cases are involved in the research, the frequency threshold of cases can be appropriately improved; here, it was set to two (cases below the threshold are considered logical remainders). As such, more than 75% of the cases were retained, which is a principle generally followed by the academic community. Meanwhile, the original consistency threshold and the PRI consistency were set to 0.8 and 0.7, respectively. A value of 1 was assigned to the outcome variable of cases meeting the above condition, and 0 was assigned to the outcome of the remaining cases. In this way, the truth table was constructed. The table indicated that diverse combinations of causes could lead to the high or low effect of the platform, that is, the antecedents and outcomes had complex causalities, with the outcome not simply caused by a single condition.

5.3.2. Standardization Analysis

After constructing the truth table, three types of solutions for the outcome variable could be obtained through standardization analysis, namely, the complex solution, simple solution, and intermediate solution. Therein, the complex solution is that which does not contain any logical remainder, while the simple solution with logical remainders lacks theoretical or practical knowledge to support its rationality. Meanwhile, the intermediate solution is generally deemed reasonable and moderately complex. This is because the intermediate solution only incorporates logical remainders based on theoretical or practical knowledge into the outcome, and it does not eliminate the necessary condition. Therefore, it is the preferred solution in the reports of QCA research. Moreover, it is necessary to determine the core and edge conditions that cause a certain outcome, which is achieved by combining the simple and intermediate solutions. Therein, conditions in the simple solution are called core conditions of the configuration, implying strong causalities with the outcome of concern, while the remaining conditions that appear in the intermediate solution but not the simple solution are considered edge conditions, which have weak causalities with the outcome and only play an auxiliary role. The configuration results finally leading to the high and low effects in our research, as determined via standardization analysis, are listed in Tables 9 and 10.

Table 9. Configuration results causing high effects.

Conditional Variables	Configuration 1	Configuration 2	Configuration 3	Configuration 4
PD	●	●	●	
TB	●	●		●
VCC	●		●	●
Consistency	0.905527	0.949912	0.953221	0.939818
Original coverage	0.903826	0.826811	0.854144	0.835607
Unique coverage	0.0877311	0.0107158	0.0380487	0.0195115
Consistency of solution	0.895589			
Coverage of solution	0.914542			

Note: "●" represents the presence of conditional variables.

Table 10. Configuration results causing low effects.

Conditional Variable	Configuration 1	Configuration 2	Configuration 3
PD	⊗		⊗
TB	⊗	⊗	
VCC	⊗	⊗	⊗
Consistency	0.798256	0.887042	0.890856
Original coverage	0.798256	0.835863	0.817635
Unique coverage	0.798256	0.0376078	0.019379
Consistency of solution	0.880543		
Coverage of solution	0.855242		

Note: "⊗" indicates the absence of conditional variables.

5.4. Configuration Analysis and Results' Interpretation

5.4.1. Configuration Results' Analysis for High Platform Effects

Through fuzzy-set standardization analysis, four configurations that caused high platform effects were finally determined (Table 9). The consistencies of the four configurations were 0.905527, 0.949912, 0.953221, and 0.939818, indicating that they were all sufficient conditions leading to a highly satisfactory effect. Meanwhile, the consistency of the solution was 0.895589, which indicated that the four configurations covered the majority of original cases and generated a highly satisfactory outcome on the whole. The original coverages of each configuration were 0.903826, 0.826811, 0.854144, and 0.835607, respectively. According to their order, the explanatory power of each configuration for the high platform effects could be determined. Configuration 1 was the most important, that is, the first path to the high platform effects, which made the majority contribution. On the whole, the coverage of the model solutions was 0.914542 (the threshold of this is not strictly stipulated but is generally no lower than 0.1), indicating that the four configurations explained the majority of the high platform effects.

5.4.2. Configuration Results' Analysis for Low Platform Effects

Considering the asymmetrical causalities of QCA, the presence and absence of a certain outcome must be discussed and explained separately using different conditional combinations (causes). Therefore, to comprehensively explore the action mechanism of the empowering platform, configurations that led to low platform effects were estimated (Table 10). Through fuzzy-set standardization analysis, three configurations that caused low platform effects were finally determined, of which the consistencies were 0.798256, 0.887042, and 0.890856, respectively. This indicated that the three configurations all offered sufficient conditions for low platform effects. Meanwhile, the consistency of the solution was 0.880543, suggesting that the three configurations covered the majority of original cases and were sufficient to cause the outcome of low platform effects. Moreover, the original coverages of each configuration were 0.798256, 0.835863, and 0.817635, and according to their order, the explanatory power of each configuration for the low platform effect was ascertained. In this way, configuration 2 was determined to be the most important, that is to say, most of the low platform effects arose from this second path. Generally, the coverage of the model solutions was 0.855242, indicating that the three configurations explained the majority of the causes for low satisfaction.

5.5. Robustness Tests

Following the suggestion of Ragin, 0.75 was used as the acceptable lowest threshold of original consistency; when the original consistency was 0.8, we considered that the configuration showed good explanatory power for the outcome, and if the original consistency was 0.85, the configuration was understood to exhibit better explanatory power. Accordingly, in the above analysis of sufficient conditions, the consistency threshold was set to 0.8, and

1 was assigned to the outcome variable of cases meeting the standard. To further verify the robustness of the final research results, the original consistency threshold in the data processing was then set to 0.85, followed by reassignment of the outcome variable. Finally, a standardization analysis was performed on the conditional combinations influencing the outcome variable. The results showed that the final simple and intermediate solutions did not change after improving the threshold of original consistency, indicating that the configuration results we obtained were highly robust.

6. Discussion

In the present research, we further analyzed and verified the construction mechanism and path of the establishment of an industrial platform. Using fsQCA, we determined that this occurs in three stages: functional development, trust building, and value co-creation.

6.1. Platform Establishment Stage: Functional Development

Functional development (FD) is the initial stage of establishing an industrial brain, whereby industrial platforms are introduced and adapted to the needs of users and partner enterprises. Through such development, targeting the pain points of enterprises' production and operations, these platforms may begin to improve operating efficiency and raise enterprises' revenues. For instance, after identifying bottleneck problems that impede users' experience, analysis of the relevant data may allow for the formation of a value proposition targeted at enterprise users (the demand side), which may involve VCC actions such as refining the platform architecture and adding new connections with users. This stimulates a process of optimizing the quality of platform services and improving the user experience. Such a process may play out in three stages, as is discussed in Sections 6.1.1–6.1.3

6.1.1. Demand Analysis of Enterprises in Clusters

To improve the operations of an industrial platform during the development of enterprises in clusters, first, users' demands and difficulties may be determined. In its initial stage of development, a platform cannot offer one-to-one services tailored to different enterprises, which may be small-scale, dispersed, and disordered and uneven in their distribution. It may also encounter difficulty in providing comprehensive services, and the common demands of the industry have to be extracted in order to facilitate the appropriate expansion of the offering. In view of these limitations, performing a market survey can be a useful first step toward identifying the current problems in the development of the enterprises in the cluster. For example, in the initial stage of its activities, the results of such a survey inspired Yingyun Tech to launch a supply chain service platform. With the players in the knitting industry as the focus, this allowed all entities along the supply chain (manufacturers, suppliers, distributors, and retailers) to establish close cooperation and relationships, with benefits for all involved. The core business rewards of using this platform were that these entities could reduce their operating costs and risks, improve their combined strength and competitiveness, and enjoy success and see win–win results throughout the business circle. To make this work, the company utilized its existing business infrastructure in order to provide related supporting facilities, including those for all kinds of equipment, parts, yarns, and technical services for the knitting industry. In sum, in this stage of applying the platform model, integrating supply chains in the industry helped medium- and small-sized knitting enterprises to cut their operating costs and enhance their competitiveness.

6.1.2. Identification of Capacity Bottlenecks of Enterprises

To improve the targeted empowerment that an industrial platform can produce, an in-depth industry survey and demand analysis of enterprises may be carried out to identify capacity bottlenecks for the enterprises in the cluster. Then, vertical (specialized) development of the industrial platform may be pursued, with the goals of improving the operating efficiency of the enterprises in the cluster and further binding together various interested parties. For instance, on the premise of improving the technical services for production equipment in the knitting industry, which were identified as having bottlenecked, Yingyun Tech applied its technological advantages to build a networked digital service platform for weaving machines. The platform now helps enterprises to manage their production equipment in all states. Its specific functions include connecting machines, planning and managing production, monitoring the operating states of all machines, checking the working efficiency of all machines in real time, managing production pauses and waste, organizing labor, improving product quality, directly transferring fashion-style files, and saving and using production data.

6.1.3. Formation of a Data-Based Value Proposition and Streamlining the Platform Architecture

In this next stage, the operator of the industrial platform and its users innovate jointly to hone the value proposition of the platform. At first, the service development direction of the platform is determined. Based on the previous user survey and associated feedback, to go further to integrate enterprises into the cluster and establish relevant service organizations, efforts may be made to set value goals that align with those of multiple parties. This may support the platform's data acquisition and analysis to facilitate risk reduction and improve enterprises' operating efficiency. Furthermore, if a risk arises, the platform can engineer a negotiation with large-scale enterprises to reach a solution, such as, for instance, forging a corresponding benefit-sharing mechanism. In this way, the values of multiple parties may become compatible. Finally, the architectural complexity of the platform should also be considered when clarifying user demands. In response to those, the platform architecture should be optimized and streamlined, thus reducing its complexity, improving users' experience, and inspiring a relationship-based cross-boundary network effect through use of the platform.

6.2. Platform Growth Stage: Trust Building

Jin et al. found that growing a platform that empowers industrial clusters hinges on a co-evolution of FD and trust-building (TB) behaviors. This involves three stages: unifying the value cognition of the platform, accumulating its data resources, and extracting the data value of the platform. At first, the platform is established by unifying a related value cognition. Here, institutional trust building is facilitated to attract angel users who will join the joint innovation and collate feedback on the positives and negatives of the FD actions underway, including identifying the pain points for platform users, and, in this way, a data-based value proposition is formed. Then, through FD behaviors such as acquiring and accumulating platform data, the stage of rolling out the data resources of the platform is propelled, including the provision of digital tools that facilitate relationship trust building. This promotes joint innovation of the platform and its users and strengthens their database. Finally, the data value of the platform is realized with FD behaviors such as data-driven efficiency improvement and data-driven business innovation, which inspire computing trust building. User data can rapidly scale up in the process, which assists the continuous upgrading of the platform functions.

In this stage, the VCC behaviors of the industrial platform operators and user enterprises are characterized by bridging behaviors, that is, linking with existing users and developing new users and business within the commercial relationship sets of the existing users. New business and the volume of business can be increased continuously in tandem with appropriate value measurement, value distribution, and value communication activities. Through iterative improvements, the industrial Internet platform is upgraded from a preliminary version to an intermediate one, while all the while sustaining interactions with user enterprises that have joined therewith. Furthermore, it attracts new industry-related enterprises and links upstream and downstream enterprises to the platform, thus creating more bonds and interactions. As time goes on, with the constant introduction of new business, the bond density and the linkage intensity are both enhanced. This strengthens the trust between various users and constantly increases the number and scale of enterprises joining the platform.

6.2.1. Institutional Trust Building

Unifying the value cognition of the platform is not a unilateral act completed by its operators. Instead, this calls for joint innovation involving both the platform's operators and its users, which requires that the platform be trusted by its users. On the one hand, exploration of the optimal direction to take with the platform for its FD can guide the emphasis of TB. For instance, the formulation of new operating specifications may rapidly enhance users' trust in the platform, that is, promoting institutional trust building (where institutional trust refers to the perceived legitimacy of the overall political, legal, or economic framework, as well as informal factors [40,41]). On the other hand, institutional trust can attract angel users to participate in the joint innovation, and obtaining feedback from users can allow the data-based value proposition of the platform to be adapted to meet user demands. This mainly plays out in three ways: (1) Analyzing demand and studying users in the early stage, along with the policy orientation of local government, can allow enterprises' pain points to be directly targeted, which attracts enterprises in the cluster to join the platform and form joint-venture companies. (2) Through a value-driving mechanism, the platform operators may cooperate with the government in regard to public services; the platform relieves enterprises' financial stress and thus removes their barriers to purchasing raw materials via empowerment based on digital techniques and a counter approach to the inadequate marketization with traditional platforms; and government cooperation and institutional design inspire users to recognize the legality of the platform. (3) The platform operators obtain users' feedback, explore their views, and modify the value proposition of the platform accordingly, accompanied by adjustments to its services and business; in this way, institutional trust building promotes the matching of value propositions of the platform and users, and mutual benefits are realized through related business linkages.

6.2.2. Relationship Trust Building

Relationship trust building takes place when the platform operators enhance its interactions with users, so that the identity of the platform can be better recognized by the users, thus improving their level of trust. One effect of this is the accumulation of data resources for the platform and the sourcing of more in-depth data; achieving this requires users to join the platform and be willing to share their real-time dynamic data, which calls for a high level of trust. If this is achieved, then based on the acquired data, the platform operators go on to provide an improved visual tool for users and have greater success in interactions with them. In turn, continuous interactions between the platform and its users can improve the relationships and trust therein [42].

6.2.3. Computing Trust Building

Computing trust building refers to how the empowering platform for the industrial cluster earns the trust of its users based on its professional ability and performance. Again, enlarging the data scale is an important outcome of this effort, which requires that the platform gains the trust of many users (and do so rapidly). If it succeeds, then when equipped with large-scale data, the platform may achieve more accurate data analysis, which allows for the optimization of both its functions and services (e.g., helping enterprises to optimize their production). In turn, such successes may enable the platform to attract an even larger number of potential users to participate, as it wins their trust in the underlying computing.

6.3. Platform Expansion Stage: VCC

The focus of platform-based enterprises in the era of the digital economy is shifting from the R&D department to the interactions with customers, namely, VCC [43]. In addition, the business logic is also changing to become service- and customer-led [44,45]. The "value" in the theory of VCC refers, in particular, to the value of terminal consumers. In this regard, the ideal state of VCC is to meet the personalized demands of all consumers. This requires taking apart the B2C model of the traditional industrial age and reconstructing that based on Internet platforms, which necessitates a revolution in supply chain management.

6.3.1. VCC Mode Based on "Bonds"

In a market-oriented economy, many entities are involved in business. In a simplified market, there are four discrete entities (not considering the government and competitors): the manufacturer, supplier, retailer, and customer. They are initially related in a general way by transactions through the supply chain. This is the primary form of VCC of Internet platforms, corresponding to their initial stage. Then, the VCC activities undertaken in the platform value creation process are adaptive, that is, working to appeal to trading partners' desire for improved operating efficiency. One VCC mode based on "bonds" is built on the trust forged through previous trades. It binds various interested parties using Internet technology, thus establishing the (preliminary) Internet platform.

6.3.2. VCC Mode Based on "Linkages"

"Linkages" are another mode of VCC, which work through the interactions of the Internet platform, its existing users, and new users, fueled by the design and incorporation of value-added services. When new users join, this can increase the level of digitization of both existing and new users, and the digitization of new users can bring new business to the Internet platform. Even if this only constitutes migrating old business to new users, in the process, it can serve to increase the volume of old business. According to these ideas, a business-driven VCC mode based on linkages can be constructed, as shown in Figure 1.

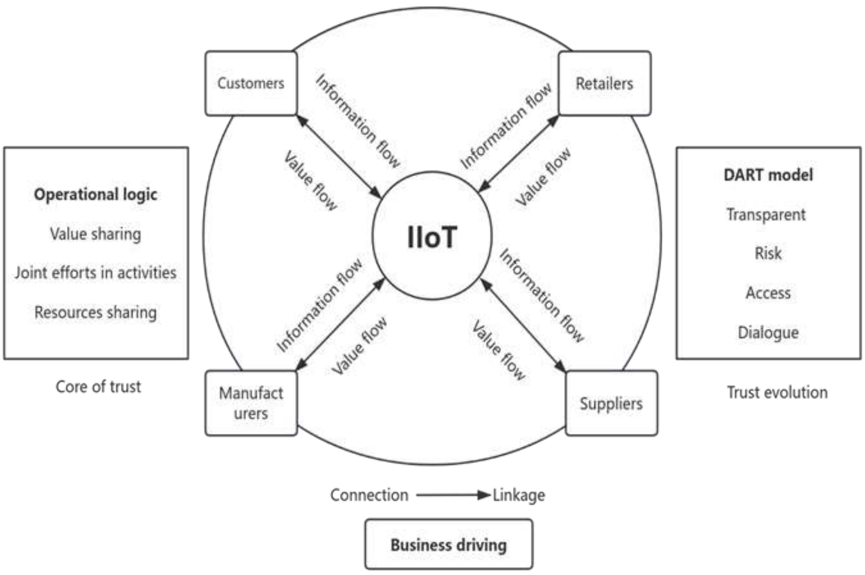

Figure 1. Business-driven VCC mode based on linkages [32]. (Data source: Ma Yongkai, Li Shiming, Pan Jingming, The value co-creation mode of the industrial Internet. Journal of Management World, 2020, 8, 211–221).

6.3.3. VCC Mode Based on the United Ecosystem

Through the mechanisms just described, the level of digitization of enterprises joining the platform gradually rises. This leads the platform to accumulate greater strength and, as a result of this, its value creation capacity increases abruptly. Improvements in the volume and type of business that participating enterprises receive tend to be felt slowly at first, but then rapidly. Meanwhile, the value shared by enterprises joining the platform also grows, which impels certain enterprises to accelerate their digitization of their own volition and participate in more VCC on the platform. At the macro level, as more enterprises join, more business is undertaken, and then more data are generated, and so more VCC opportunities are created, meaning the platform becomes increasingly attractive. This attracts other digital service platforms (possibly consumer or industrial Internet platforms) to participate actively in, and intelligently cooperate with, the platform in order to co-create derivative business. Meanwhile, at the micro level, the VCC on the industrial Internet platform gradually improves as the participating enterprises gain greater self-organizing and self-circulating abilities. Through cyclic evolution, the platform gradually becomes a "united ecosystem" with co-created and shared value. The appearance of self-organizing VCC activities on the Internet platform marks its entry into its advanced stage. Nonetheless, operators are always needed for the platform, such as to provide consultancy services and develop new users' bond-/linkage-based VCC, either in their own transaction relationship set or in those of other users on the platform. Therefore, even when a united ecosystem is achieved, consideration must be given to the platform's digital modules for bond-/linkage-based VCC. VCC's evolution to this third stage is displayed in Figure 2.

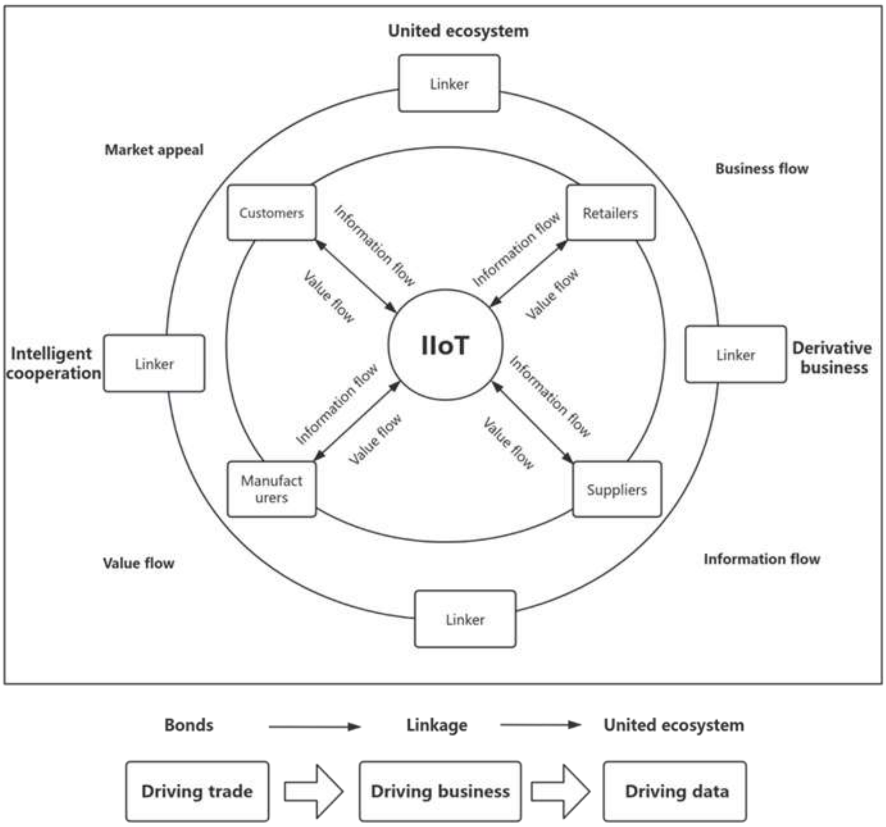

Figure 2. Evolution of VCC based on bonds, interactions, and a united ecosystem [32]. (Data source: Ma Yongkai, Li Shiming, Pan Jingming, The value co-creation mode of the industrial Internet. Journal of Management World, 2020, 8, 211–221).

7. Conclusions

This study aimed to explore the mechanism of construction and the path of implementation of the industrial brain in the development of smart cities. To do so, we studied the typical case of the Yiwu knitting industry platform in China, conducting an analysis of relevant research results. As such, we adopted the qualitative comparative analysis (QCA) methods. Our complete research steps were a literature review, research design, data collection and analysis, qualitative comparative analysis, and discussion. These permitted us to draw the following research conclusions on the construction mechanism and implementation path of the industrial brain in the development of smart cities:

(1) The industrial brain in a smart city is platform-based, and the establishment of online platforms can be divided into three stages: construction, growth, and expansion;
(2) The construction mechanism and implementation path of the industrial brain in a smart city are successively reflected in function development, trust construction, and value co-creation;
(3) Function development is the primary stage of the construction of the industrial brain, which involves enterprise demand analysis, enterprise capability bottleneck identification, industrial brain data value formation, and platform architecture simplification;
(4) Trust construction is the core mechanism of building the industrial brain, which operates in institutional, relationship, and computing terms;
(5) Finally, during the business paradigm revolution, value co-creation through the industrial brain can be established via bonds, linkages, and a united ecosystem.

The main theoretical contribution of this study is to propose a normative analytical framework for revealing the construction mechanism and implementation path of industrial platforms in the development of smart cities. Furthermore, in terms of practical contributions, this paper provides policy guidance for urban planners and decision makers on how to promote the transformation and upgrading of the urban manufacturing industry through industrial platforms, to realize the coordinated development of smart city construction and the economy and society, thus achieving sustainable development.

In reflecting on our work, we wish to note that the Yiwu knitting industry platform has provided fertile grounds for us to gain an in-depth understanding of the role of industrial platforms in smart cities, but our focus on a single case limits the generalizability of the research results. In addition, we mainly relied on questionnaires and secondary data, though biases and limitations may have been introduced through these modes of data collection.

To address these limitations, future research could comparatively analyze multiple cases, to enhance the generalizability and reliability of the findings. Additionally, we recommend that future research further explore the mechanisms of industrial platforms in different types of industries and urban contexts, as well as their long-term impacts on urban economic and social development. Furthermore, it may be beneficial to employ more diverse data collection methods, such as in-depth interviews and participant observation, to gain richer and deeper insights.

In summary, this study provides a new theoretical framework and empirical evidence for the construction mechanism and implementation path of industrial platforms in smart cities. Despite certain limitations, our findings have important theoretical and practical value for guiding the coordinated development of smart city construction and the economy and society. They also provide valuable references and insights that will inform future research in this field.

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

Funding: This research was funded by the National Social Sciences Foundation of China (grant No. 20BGL294), and the Key Projects of Soft Sciences Research in Zhejiang Province (grant No. 2023C25005).

Data Availability Statement: Data will be made available on request.

Conflicts of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Zhou, X.; Li, L. Can smart city construction become a new driving force for economic growth. *Econ. Longit. Latit.* **2020**, *V37*, 10–17.
2. Zheng, P.; Chen, W.; Wang, P.; Shen, D.; Chen, S.; Wang, X.; Zhang, Q.; Yang, L. Big data for social transportation. *IEEE Trans. Intell. Transp. Syst.* **2018**, *17*, 620–630. [CrossRef]
3. Zhou, K.; Liu, T.; Zhou, L. Industry 4.0: Towards future industrial opportunities and challenges. In Proceedings of the 2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), Zhangjiajie, China, 15–17 August 2015; pp. 2147–2152.
4. Ke, Q.; Ma, W.; Zhou, F.; Chen, X.; Shi, W.; Le, H.; Ding, X. Zhejiang Province "fishery industry brain"—Exploration and Practice on the construction of fishery industry public intelligent digital platform. *Fish. Sci. Technol. Inf.* **2023**, *50*, 397–402. [CrossRef]
5. Xu, Q. Deeply focus on scene innovation and promote the construction of industrial brain—Take the construction of digital scene of "ten thousand mu and hundreds of billions" new industrial platform as an example. *Informatiz. Constr.* **2021**, *12*, 31–33.
6. Batty, M.; Axhausen, K.W.; Giannotti, F.; Pozdnoukhov, A.; Bazzani, A.; Wachowicz, M.; Ouzounis, G.; Portugali, Y. Smart cities of the future. *Eur. Phys. J. Spec. Top.* **2012**, *214*, 481–518. [CrossRef]
7. Hollands, R.G. Will the real smart city please stand up? *City* **2008**, *12*, 303–320. [CrossRef]
8. Caragliu, A.; Del Bo, C.; Nijkamp, P. Smart cities in Europe. *J. Urban Technol.* **2011**, *18*, 65–82. [CrossRef]
9. Zhang, X. "Technology brain" set off a storm of innovation and transformation Zhejiang Modern Textile Research Institute provides a technology research and development platform for Shaoxing textile industry cluster. *Zhejiang Today* **2011**, *7*, 24–25.
10. Neirotti, P.; De Marco, A.; Cagliano, A.C.; Mangano, G.; Scorrano, F. Current trends in Smart City initiatives: Some stylised facts. *Cities* **2014**, *38*, 25–36. [CrossRef]
11. Chen, S.; Zhang, C.; Wang, J. Intelligent and Connected Systems for Smart Cities. *IET Smart Cities* **2020**, *2*, 1–4.
12. Gawer, A.; Cusumano, M.A. Industry Platforms and Ecosystem Innovation. *J. Prod. Innov. Manag.* **2014**, *31*, 417–433. [CrossRef]
13. Kagermann, H.; Wahlster, W.; Helbig, J. *Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0. Final Report of the Industrie 4.0 Working Group*; Acatech: Munich, Germany, 2013.
14. McIntyre, D.P.; Srinivasan, A. Networks, Platforms, and Strategy: Emerging Views and Next Steps. *Strateg. Manag. J.* **2017**, *38*, 141–160. [CrossRef]
15. Xing, D.; Zhao, Q.; Gao, H. Research on pricing strategy of logistics information platform based on bilateral market theory. *Bus. Econ. Manag.* **2018**, *5*, 31–40.
16. Xin, R.; Chen, W.; Hou, Z. Platform-Based Management. *Chin. Foreign Manag.* **2019**, *11*, 133.
17. Chen, D.; Wang, L.; Chen, A. Digitalization and Strategic Management Theory: A Review of Challenges and Prospects. *Manag. World* **2020**, *36*, 220–236+20. [CrossRef]
18. Zheng, X.; Lu, L. Research on Regional Innovation Platform from the Perspective of Industrial Cluster Transformation and Upgrading. *Sci. Sci. Manag. S. T.* **2011**, *32*, 65–70, 106.
19. Chen, S.; Xiang, L.; Yu, R. Entrepreneurial Ecosystem of Maker Spaces: Characteristics, Structure, Mechanism, and Strategies—A Case Study of Hangzhou Dream Town. *Bus. Econ. Manag.* **2015**, *11*, 35–43. [CrossRef]
20. Wu, Y. Industrial Cluster Upgrading Based on the Entrepreneurial Strategy of Leading Enterprises in Commercial Platform Type: A Case Study of Haining Leather Cluster. *Sci. Res. Manag.* **2016**, *37*, 54–61. [CrossRef]
21. Wang, J.; Cai, N.; Sheng, Y. Cross-Border Entrepreneurship of Leading Enterprises, Dual-Platform Architecture, and Upgrading of Industrial Cluster Ecology: A Case Study of the "Environmental Hospital" Model in Yixing, Jiangsu Province. *China Ind. Econ.* **2018**, *2*, 157–175. [CrossRef]
22. Yu, W.; Wu, S. Internet Platform Economy and Industry Productivity Transformation: An Empirical Study Based on the Third Economic Census Data. *Financ. Sci.* **2019**, *8*, 55–68.
23. Jin, Y.; Shi, R.; Wu, B.; Wang, J. Where does the enabling platform of industrial clusters come from: From the perspective of function development and trust building. *Manag. World* **2023**, *39*, 127–145. [CrossRef]
24. Zhou, W.; He, Q. The impact of entrepreneurship Incubation Platform empowerment on resource allocation optimization—A case study from the perspective of mechanism design. *Res. Dev. Manag.* **2021**, *33*, 162–174. [CrossRef]
25. Luo, Z.; Li, X.; Song, X.; Li, Y. The evolution of enterprise organizational structure from "empowerment" to "empowerment"—A case study of handu Yishe. *China Ind. Econ.* **2017**, *9*, 174–192.
26. Hao, J.; Yin, M. Sharing economy: Empowerment, value co creation and business model innovation—A case study based on zhubajie.com. *Bus. Res.* **2018**, *60*, 31–40. [CrossRef]
27. Yang, D.; Wang, J. Research on the mechanism of platform enabled enterprise digital transformation. *Contemp. Financ. Econ.* **2022**, *9*, 75–86. [CrossRef]
28. Wang, F.; Zheng, T.; Wang, S. Enterprise customer identity differentiation and the formation of business ecosystem—A multi case study based on Haier Group's innovation and entrepreneurship. *J. Manag.* **2019**, *16*, 633–643.
29. Ragin, C.C. *The Comparative Method: Moving Beyond Qualitative and Quantitative Strategies*; University of California Press: Berkeley, CA, USA, 1987.
30. Rihoux, B.; Ragin, C.C. *Configurational Comparative Methods: Qualitative Comparative Analysis (QCA) and Related Techniques*; SAGE Publications, Inc.: Thousand Oaks, CA, USA, 2009.
31. Ragin, C.C. *Fuzzy-Set Social Science*; University of Chicago Press: Chicago, IL, USA, 2000.
32. Ma, Y. Value co creation model of industrial Internet. *Manag. World* **2020**, *36*, 211–221.

33. Du, H.; Wang, J.; Li, Q. Value co creation mechanism of industrial Internet platform—A case study based on Hongtu intelligent logistics. *Bus. Econ. Manag.* **2021**, *3*, 5–18. [CrossRef]
34. Chen, W.; Chen, J.; Li, Y. Industrial Internet platform: Connotation, evolution and empowerment. *Econ. Manag.* **2022**, *44*, 189–208. [CrossRef]
35. Pavlou, P.A. Consumer acceptance of electronic commerce: Integrating trust and risk with the technology acceptance model. *Int. J. Electron. Commer.* **2003**, *7*, 101–134.
36. Prahalad, C.K.; Ramaswamy, V. Co-creation experiences: The next practice in value creation. *J. Interact. Mark.* **2004**, *18*, 5–14. [CrossRef]
37. Nunnally, J. *Psychometric Theory*, 2nd ed.; McGraw-Hill: New York, NY, USA, 1978.
38. Schneider, C.Q.; Wagemann, C. *Set-Theoretic Methods for the Social Sciences: A Guide to Qualitative Comparative Analysis*; Cambridge University Press: Cambridge, UK, 2012.
39. Pombo-Juárez, L.; Thøgersen, J.; Gracia, A.; Solís, E. The configurational effects of the determinants of energy-efficient household behavior: A comparative study for five EU countries. *Energy Res. Soc. Sci.* **2017**, *28*, 1–13.
40. Suchman, M.C. Managing Legitimacy: Strategic and Institutional Approaches. *Acad. Manag. Rev.* **1995**, *20*, 571–610. [CrossRef]
41. Welter, F. All You Need Is Trust? A Critical Review of the Trust and Entrepreneurship Literature. *Int. Small Bus. J.* **2012**, *30*, 193–212. [CrossRef]
42. Rousseau, D.M.; Sitkin, S.B.; Burt, R.S.; Camerer, C. Introduction to Special Topic Forum: Not So Different After All: A Cross-Discipline View of Trust. *Acad. Manag. Rev.* **1998**, *23*, 393–404. [CrossRef]
43. Prahalad, C.K.; Ramaswamy, V. Coopting Customer Competence. *Harv. Bus. Rev.* **2000**, *78*, 79–88.
44. Vargo, S.L.; Lusch, R.F. Evolving to a New Dominant Logic for Marketing. *J. Mark.* **2004**, *68*, 1–17. [CrossRef]
45. Prahalad, C.K.; Ramaswamy, V. Co-creating Unique Value with Customers. *Strategy Leadersh.* **2004**, *32*, 4–9. [CrossRef]