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Improving Financial Service Innovation Strategies for Enhancing China's Banking Industry Competitive Advantage during the Fintech Revolution: A Hybrid MCDM Model

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Received: 16 February 2019; Accepted: 3 March 2019; Published: 7 March 2019

Abstract: The recent emergence and rapid growth of new financial services by financial technology (Fintech) companies have driven banking institutions towards operational innovation in order to gain sustainable competitive advantage. This study aims to conduct an in-depth investigation of the banking sector in response to the challenges brought by Fintech startups. Based on the service innovation theory, we propose a novel hybrid multiple criteria decision-making method (MCDM) to evaluate service innovation strategies for improving the sustainability of China's banking industry during the Fintech revolution. A six-dimensional model comprising 20 sub-criteria is constructed and both the decision making trial and evaluation laboratory (DEMATEL) technique and DEMATEL-based analytic network process (DANP) are used to explore interrelationships among the indices and their related weights. Finally, the modified VIšekriterijumsko KOmpromisno Rangiranje (VIKOR) method is employed to evaluate performance gaps in the four major types of commercial banks in China—state-owned, joint-stock, city commercial banks, and other credit cooperatives—in the field of service innovation. The improvement priorities, ranked from highest to lowest, are new business partners, new service concepts, organizational innovation, technological innovation, new customer interactions, and new revenue models. These results will provide strategies for the sustainable development of China's banking industry and the implementation of changes in response to the impact of the Fintech revolution.

Keywords: Fintech; service innovation strategy; China's banking industry; DEMATEL; DANP; modified VIKOR; hybrid MCDM model

1. Introduction

Recent advances in information technology (IT) have led to the rapid development of new and innovative financial services called financial technology (Fintech). Fintech is a portmanteau that combines "finance" and "technology" and involves the integration of finance and emerging technologies such as cloud computing, big data, and artificial intelligence (AI) [1]. This combination provides users with more innovative financial services including mobile payments, crowdfunding, peer to peer (P2P) lending, insurance, and wealth management [2–5]. Rapid development in IT and the subprime crisis in 2008 triggered a long-term global economic slowdown. In response, governments

across the world are actively encouraging a new financial paradigm [3] and these initiatives have resulted in the establishment of numerous Fintech companies (e.g., Kabbage, LendingClub, OnDeck, Apple Pay, Ant Financial, and JD Finance). They are usually non-financial institutions but provide innovative financial services [6]. In China, Internet-based companies such as Alibaba, Baidu, and Tencent have participated in Fintech development and gained much recognition as unicorn companies [7]. For example, Alipay provides mobile payment services to 520 million users, which is several times greater than the number of PayPal's global users. Alibaba's subsidiary Ant Financial offers loan services, and over the past five years, has issued a total loan amount of more than US $100 billion to small- and medium-sized enterprises (SMEs), which is five times the Lending Club's total loan amount. According to the 2015 annual report released by Klynved Peat Marwick Goerdeler (KPMG) [8], there are more than 2000 Fintech companies worldwide, and most of the top 100 global Fintech companies are from China and the United States. Following the rapid growth of these Fintech giants, China has become one of the largest Fintech markets in the world, with investments in the Fintech sector accounting for more than USD 8 billion in 2016 [9].

Fintech companies have recently started expanding their business scope beyond online business into mobile business, such as mobile payments and remittances, and from traditional banking services to innovative financial services. Citigroup estimated that Fintech's growth will lead to another 1.8 million job losses in Europe and the US in the next decade [5,10]. The increasing investments by Fintech companies in financial service innovation R&D have led to dramatic changes in the business environment and fierce competition among banks. Fintech companies provide new approaches concerning efficiency, customer experiences, and centricity, leading to innovation and transformation in the financial services industry. Although industry and academic observers believe that Fintech players are not capable of entirely reforming the system, many banks are looking for kinds of ways to better contribute to future development of the banking industry. Previous studies have indicated that service innovation play a significant role in the highly competitive banking industry [11,12]. Lusch and Nambisan [12] stated that the banking industry could achieve higher profits through innovation and that the performance of banks that invest in innovation is significantly better than the performance of those that do not. Therefore, this study focuses specifically on innovative banking services in response to the impact created by Fintech competitors. We pose the following research question: How to conduct banking service innovation during the Fintech revolution?

Since Fintech is a new phenomenon, banks' service innovative strategies to counter the market pressure by Fintech companies have not been quantitatively explored. Previous studies rarely used MCDM method to evaluate the service innovation strategies for the banking industry during the Fintech revolution. Tan et al. [13] explored the service innovation strategies in Malaysian banking industry towards sustainable competitive advantage through environmentally and socially practices. They propose the strategic planning of banking institutions by optimizing their resource allocation to ensure sustainable growth. Furthermore, other methods such as the structural equation model (SEM) in previous studies do not consider the interrelationship between criteria or a decision model that could simplify the evaluation process [11]. They do not include gap analysis. Important issues have not been considered, for example, how to enhance the competitive advantage of the banking industry following the risks of competition from the unorganized financial sector. Therefore, this study addresses the concept of service innovation theory (including new service concepts, new customer interaction, new business partners, new revenue models, organizational innovation, and technological innovation) [14] to develop a service innovation index system to evaluate and provide service innovation strategies for enhancing the competitive advantages of the banking industry in China during the Fintech revolution.

Developing a banking service innovation strategy is a multiple criteria decision-making problem [15,16]. MCDM is considered as a complex decision-making tool involving both qualitative and quantitative indicators [17–22]. In recent years, several MCDM techniques have been suggested as valuable ways for selecting the best strategy [16,18,19,21,22]. Several studies outside the banking field have used MCDM tools and applications for solve problems in areas such as national

museums business strategy [21,22], airline operational and financial performance [23], hospital service quality [24], and supplied selection [25].

This study leverages the following three MCDM methods, namely, DEMATEL (decision making trial and evaluation laboratory), DANP (DEMATEL-based analytic network process), and modified VIKOR (VIšekriterijumsko KOmpromisno Rangiranje) for constructing the financial service innovation strategies evaluation model. Based on the six perspectives of the service innovation research framework [14], DEMATEL is first used to explore the cause-effect relationships between the criteria/sub-criteria and to create an influential network relations map (INRM). Then, the DANP technique that finds the influential weights, and the modified VIKOR to find the performance gaps. The novel hybrid evaluation model can assess the competitive advantage of banking industry in China, as well as in improving and creating service innovation strategies that reduce the gasp in the criteria and sub-criteria, enhance their competitive advantage, and satisfy the needs of customers to encourage their return.

Our contribution to theory and practice is threefold. First, it extends service innovation theory to the context of Fintech. In fact, the financial sector has been relying on technology to bring new services to market for some time now. For example, the introduction of the automated teller machine (ATM) in the 1960s changed the way customers dealt with their financial assets [2]. However, the Fintech revolution goes beyond the effect of new technology (e.g., big data, cloud computing) on financial industry. It involves many innovation strategies for products, processes, services, business models, technology and the delivery system [13]. Therefore, based on service innovation theory, this study aims to provide a comprehensive view on how banks are making improvements to keep a competitive advantage. A model of six service innovation dimensions is employed to construct a service innovation index system for the banking industry. The model also identifies major service innovation strategies for the industry during the Fintech revolution. Secondly, this study also contributes to Fintech research. The majority of Fintech-based studies apply the business perspective provided by Fintech companies to investigate the willingness of individuals and companies to use new systems such as mobile payments [26], crowdfunding [27], and online lending [28]. However, few studies discuss coping strategies adopted in the banking industry. Moreover, most current studies are qualitative in nature [3,29]. This study adopts a hybrid multi-criteria decision model to empirically analyze the performance gaps in the banking industry during the Fintech revolution and identify the major strategies adopted to counter its impact. The findings serve as a decision-making reference for the banking industry concerning their response to changes generated by Fintech companies. Third, focus on Fintech has largely been from a Western perspective [7]; few studies have explored service innovation in Asian banks. Because of cultural and legislative differences, the findings of studies on Western countries may not be generalizable to Asia [6]. With the rapid development of Fintech in Asia, China has now become the largest Fintech market in the world. Therefore, this study offers a new perspective on the development of new service innovation strategies in China's banking industry during the Fintech revolution.

The remainder of this study is organized as follows. In Section 2, based on service innovation theory, a model is built to evaluate banking service innovation strategies. In Section 3, a hybrid MCDM research methods with DEMATEL, DANP, and modified VIKOR is introduced. In Section 4, an empirical study is performed, based on the hybrid financial service innovation strategies evaluation models. Finally, in Section 5, the conclusions are presented.

2. Evaluation Attributions Development for Banking Sector

Schumpeter [30] was the first to propose the concept of innovation in that innovation significantly impacts productivity and competitiveness. Innovation is a fundamental source for the ability of an enterprise, industry, or country to maintain competitiveness [31]. Panesar and Makeset [32] suggest that the focus of innovation has evolved over time, that is, from early industrial innovation to service innovation. With a rapidly growing service sector and its continually increasing economic contribution,

scholars began paying attention to the characteristics of services and service innovation research. Miles [33] classified service innovation into product, process, and delivery innovation on the basis of its characteristics. Djellal and Gallouj [34] classified service innovation into product, process, internal organizational, and external organizational innovation. The most noteworthy is the four-dimensional service innovation model introduced by Bilderbeek et al. [35] who employed a SEM approach to classify the content of service innovation into service concept, customer interface, delivery system, and technology innovation. Den Hertog et al. [14] extended the four-dimensional model by combining a service-dominant logic perspective [36,37] to propose a six-dimensional service innovation model including new service concept, new customer interaction, new business partners, new revenue models, organizational innovation, and technological innovation. This model has been widely recognized in academia [13] and therefore the six-dimensional service innovation model is used in this study.

Based on service innovation theory [14], a six-dimensional model comprising 20 sub-criteria is developed in this study to evaluate the service innovation strategies of banking industry in China during Fintech revolution. This conceptual model is discussed in the following sub-sections.

2.1. New Service Concpet

New service concept innovation refers to the proposal of a new method or idea to resolve problems [13,38]. Tidd and Hull [39] defined service innovation as the use of a novel service concept to deliver new value-added services to customers. Because Fintech is an emerging concept, public understanding of how to create business value using the Fintech approach is diverse [40]. Shim and Shin [7] highlighted that the focus of Fintech is the use of technology to drive financial innovation aimed at enhancing the efficiency of financial services and lowering transaction costs. Shi [41] supported the use of technology such as big data and cloud computing to better identify the risks associated with specific groups and conduct precise evaluations to reduce credit risks. Chen [6] argued that Fintech is no longer a traditional financial product but rather is integrated into daily lives and considers financial needs in the current scenario to provide satisfactory solutions for customers through a scenario application platform. For example, the Bank of China launched cross-border e-commerce service solutions as an exploration of "Hai Tao", which combines "scenario finance" with its strong cross-border business.

Therefore, the following evaluation criteria are applied for new service concepts: customer centricity, service efficiency enhancement, reduced credit risk, and the development of scenario finance.

2.2. New Coustomer Interaction

New customer interaction emphasizes a customer's role in value co-creation and that innovation is generated through interactions between service providers and recipients. This definition is further supported by Gallouj [42], who confirms that service innovation is rarely produced in a laboratory. Therefore, service providers must regularly interact with customers to identify their needs [14]. Foss et al. [43] stated that increasing the number of communication channels and platforms for customers is conducive to improving innovation capabilities by mobilizing customer knowledge acquired through communication. The Bank of Ningbo, for example, launched a series of social platform-based financial products, such as WeChat Bank and Weibo Bank, to enhance customer interaction and promote customer loyalty. Acar et al. [44] showed that customer-centric banks positively impact new customer relationships. Using innovation technologies, banks can provide customized services that are based on customer needs, including personalized loan schemes and interest rates as well as investment portfolios that suit their individual financial goals and risk types.

Therefore, the following evaluation criteria are applied for new customer interactions: increase customer communication channels, actively identify customer needs, and provide customized services.

2.3. New Business Partners

New business partners can be defined as an enterprise's use of partners' resources to provide innovative services. Brandenburger and Nalebuff [45] introduced the theory of co-opetition and emphasized that enterprises that follow the co-opetition approach must unify each other's core advantages when competing to open up new opportunities. Brentani [46] showed that the pursuit of strategic partners is highly correlated with banks' innovative success, while Tee and Gawer [47] emphasized that alliances between service providers that facilitate new service innovation systems and business partners are likely to produce a higher number of service innovations. For example, banks partner with businesses to install ATM machines in business locations, offer free parking to credit card customers, and set up other convenience services aimed at enhancing customers' perceived value. Another example, the Development Bank of Singapore (DBS) partnered with Funding Societies, Moolah Sense, and other P2P lending platforms. Under this partnership, the DBS refers these P2P lending platform partners to small-scale enterprise owners unable to secure loans from the bank owing to the lack of personal income proof. On the other hand, the lending platform partners refer the bank to small-scale enterprise owners who have completed two rounds of loans on their platform to help them secure larger loan amounts and other financial solutions, such as cash management, from the DBS. Wu [48] argued that commercial banks should further strengthen cooperation with their peers because it is conducive to achieving resource complementarity and competitiveness and enhancing profitability and innovation capability.

Therefore, the following evaluation criteria for new business partners are adopted: alliance with Fintech companies, alliance with offline merchants, and alliance with financial peers.

2.4. New Revenue Models

New revenue model innovation concerns organizational changes necessary to facilitate service innovation. This necessitates an appropriate approach to allocating interests, sharing costs, and making profits [14]. Many banks have built their own e-commerce platforms to provide customers with convenient capital integration channels. The China Construction Bank launched Good Financial Business on its online banking platform to provide individuals with microloans—such as rapid personal, small personal, and personal assistance loans—and credit card services, as well as auto, home mortgage, and cash loans [49]. Moreover, Dubois et al. [50] suggested ways for banks to operate their businesses more professionally; for example, increasing the level of professionalism offered through financial products to further promote customer trust.

Thus, we employ multi-faceted business strategies and professional business strategies as evaluation criteria for the construct of new revenue models.

2.5. Organizational Innovation

Organizational innovation refers to the degree of adoption of change in the organization. Organizational innovation is an enterprise's status once its internal organization has been adjusted to provide innovative services, enabling employees to appropriately execute new services. Organizational structure refers to the interrelationships constructed among various departments and at different levels. Rajan and Zingales [51] indicated that technology can change the availability of finance, and therefore, organizational structure and enterprise boundaries. Khafri and Budhwar [52] stated that organizational structure is a key factor that impacts systems and procedures as well as innovation adoption. Ponsignon et al. [53] argued that the professional knowledge and technical skills of service personnel impact how customers accept a service. The authors also stressed that employees can develop systematic thinking and acquire professional knowledge through training and learning, which will ensure the smooth development of new banking services [39,54]. Griffin [55] noted that a positive culture and atmosphere for new product development is crucial for the success of banking service innovation. That is, banks must create an innovation-based culture and atmosphere, improve product innovation

guarantee mechanisms, establish product management and innovation incentive mechanisms, and fully mobilize the enthusiasm of personnel.

Accordingly, organizational structure reform, employee training and learning, and organizational innovation culture are selected as evaluation criteria for the construct of organizational innovation.

2.6. Technnological Innovation

Technological innovation emphasizes an integration of finance and technology and the use of new technologies to improve the efficiency of financial services, lower costs, and control risks. The Standard and Chartered Bank of the United Kingdom started a Fintech innovation laboratory in Singapore to explore the incorporation of technologies such as big data, cloud computing, and blockchains into traditional financial services to provide customers with innovative and comprehensive business solutions. Acar et al. [44] argued that in addition to traditional marketing strategies, banks should employ digital tools to communicate with the public and more effectively educate them about new services. Moreover, Den Hertog et al. [14] proposed that organizations promoting new service concepts to customers should consult marketing experts to design specific marketing strategies. Sing'oei and Wang [56] showed that database marketing is an effective marketing tool for banks because it enhances marketing efficiency. Today, banks are competing for customers with both their peers and institutions outside of the banking sector. Since big data and advanced analytic capabilities have become fundamental in digital marketing, mastering the skills of digital media, content marketing, digital customer lifecycle management, and marketing operations has become a key factor in a bank's success.

Therefore, the development of big data analysis, smart investment management, blockchain applications, new payment methods, and digital marketing enhancement are used as evaluation criteria for technological innovation.

Based on a review of the literature, we develop criteria and sub-criteria for banking service innovation during the Fintech revolution. These crucial criteria and sub-criteria are then confirmed by expert interviews. A total of 11 experts were invited: six from middle and senior bank management, three university scholars from a financial faculty, and two heads of a finance regulatory department. Next, the interview information gathered is combined with the literature review to present the major strategies for the banking sector to implement service innovation during the Fintech revolution. Descriptions of the evaluation criteria and sub-criteria for banking service innovation are provided in Table 1.

However, how to assign weights to each criterion and the 20 sub-criteria for the implementation of banking service innovation remains unclear. To estimate these weights, we combined DEMETAL with DEMATEL-based analytical network process (DANP). A total of 35 questionnaires were issued, 31 of which were returned. Among these, 27 were considered to be valid. Using the research results, primary and secondary strategies were identified for service innovation implementation in the banking industry. Furthermore, the modified VIKOR method was implemented to evaluate performance gaps in the four types of banks in the context of service innovation implementation during the Fintech revolution to provide suggestions for improvement.

Table 1. Descriptions of the evaluation criteria and sub-criteria for banking service innovation.

Criteria	Sub-Criteria	Definition
New service concept (NS)	Customer-centric (NS_1)	Focus on customer needs to provide personalized and customized services.
	Service efficiency enhancement (NS_2)	Mobilize new technologies to expedite transaction speed and improve service efficiency.
	Reduced credit risk (NS_3)	Mobilize new technologies to collect consumer behavior data to lower credit risk.
	Development of scenario finance (NS_4)	Combine financial services with new commercial scenarios to develop new services.
New customer interaction (NC)	Increased communication channels with customers (NC_1)	Mobilize new technologies to launch more service channels such as mobile banking, WeChat banking, and Weibo banking.
	Active identification of customer needs (NC_2)	Mobilize new technologies to actively analyze the potential needs of target customers, undertake initiatives to care for consumer needs, and provide precise financial services.
	Provision of customized services (NC_3)	Provide personalized services as per customer needs such as private banking.
New business partners (NB)	Alliance with Fintech (NB_1)	Share data with Fintech and e-commerce companies to explore potential customers' financial needs to enhance customer satisfaction.
	Alliance with offline merchants (NB_2)	Partner with offline businesses to install ATM machines in business premises, provide free parking for credit card holders, and offer other convenient services.
	Alliance with financial peers (NB_3)	Form an alliance with domestic and overseas financial peers to develop service content and scope.
New revenue models (NR)	Multi-faceted business strategies (NR_1)	Operate cross-border banking businesses to develop diversified products or markets such as in-house e-commerce platforms and mobilize business data collected through e-commerce transactions to provide financing services that are convenient.
	Professional business strategies (NR_2)	Focus on specific groups to provide more professional products and services.
Organizational innovation (OI)	Organizational structure reform (OI_1)	Set up online financial centers and process reform departments to expedite financial innovation, promptly adapt to external changes, and improve decision-making efficiency.
	Employee training and learning (OI_2)	Train service personnel to enhance their professional knowledge and skills to ensure smooth implementation of new services.
	Organizational innovation culture (OI_3)	Establish incentive mechanisms to motivate employees to participate in innovation and develop an innovative organizational culture.
Technological innovation (TI)	Development of big data analysis (TI_1)	Utilize big data analytics to construct customer behavior patterns to explore new customer demands.
	Development of smart investment management (TI_2)	Employ new technologies to provide customers with effective investment portfolio recommendations (e.g., Capricorn Smart Investment by China Merchants Bank).
	Blockchain application (TI_3)	Apply blockchain technology to improve transaction security.
	New payment methods (TI_4)	Adopt Internet-of-Things and biometric identification technology to provide innovative payment methods using, for example, face recognition and voice control.
	Digital marketing enhancements (TI_5)	Use digital media, content marketing, and database marketing to enhance the publicity of new services and accelerate customer understanding of these services.

3. Research Design and Methodology

An empirical analysis of banking service innovation strategies is based on a hybrid MCDM model. A hybrid MCDM model is adopted to conduct banking service innovation strategies research because it is able to consider several criteria/sub-criteria, and the interactions between and among them, simultaneously. In this study, the hybrid MCDM model included five stages: first, we defined the research problem statement and constructed an evaluation framework for banking service innovation; second, measured the cause and effect relationships among and identify evaluation criteria and sub-criteria; third, constructed the influential network relationship map (INRM) and computed the influential weights of criteria/sub-criteria based on DEMATEL technique and DANP method; fourth, evaluated the performance gaps by using a modified VIKOR method when banking managers face several different banking types; and finally, discussed the final empirical results and determined the improvement in banking service innovation strategies map. The analytic process of the present study is shown in Figure 1.

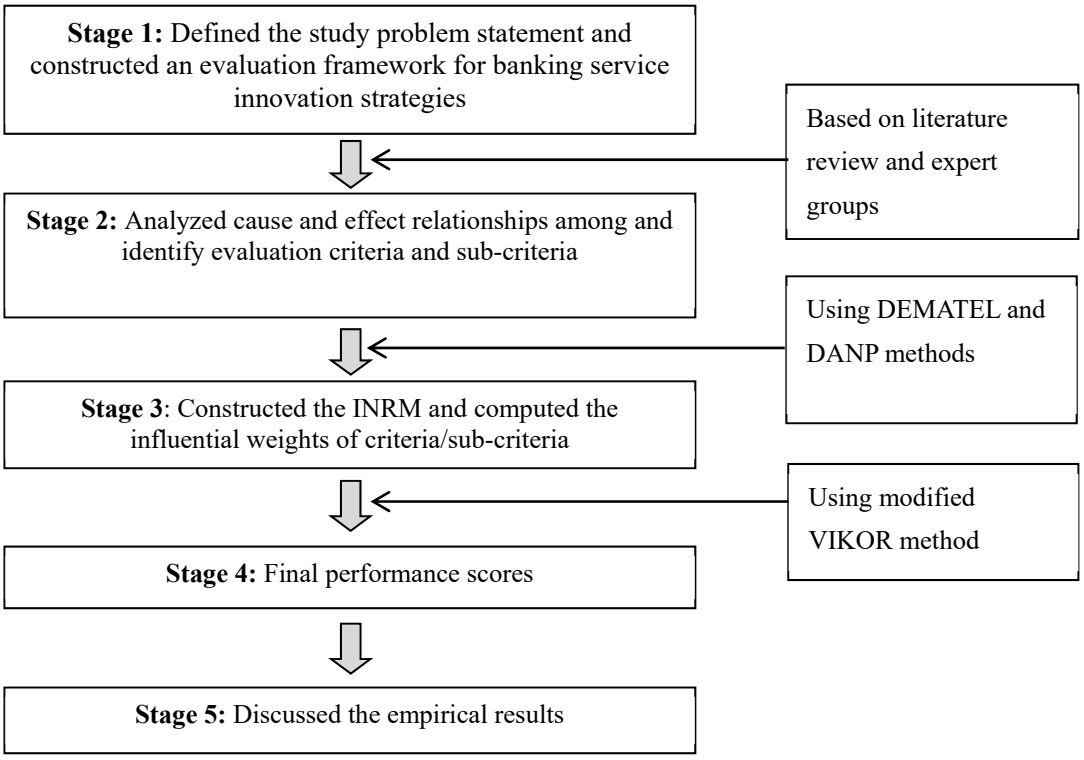

Figure 1. The analytic stages of the study.

3.1. Establishment of an Influential Network Relationship Map Based on the DEMATEL

DEMATEL is an analytical method for constructing the structure of the INRM [57]. The DEMATEL, originating from the Geneva Research Centre of the Battelle Memorial Institute, is especially pragmatic in visualizing the structure of complicated causal relationships [58,59]. DEMATEL is a comprehensive method for constructing and analyzing a structural model involving causal relationships between complex factors [60]. It can clearly distinguish the cause-effect relationship of indices when measuring a problem [61]. The DEMATEL technique has been widely adopted in various fields, such as intelligent medical terminals [62], national museums business strategy [21,22], and sustainable supply chain management [61]. The steps of this process are shown Appendix A.

In the following section, the decision-making trial and evaluation laboratory based on analytic network process (DANP) and its calculation steps are introduced to solve the problem of interdependence and feedback among each measurement criterion generated by the DEMATEL technique.

3.2. Obtain the Influential Weights by DANP

This study used the DEMATEL with the DANP to construct a hybrid evaluation model to conduct the interdependence and feedback among each criteria/sub-criteria. DEMATEL constructs an INRM, and the DANP obtains the influential weights using the basic concept of ANP [57,63]. The steps for computing the influential weights of a DANP based on a total-influential matrix are summarized in Appendix B [21,22,57].

3.3. Analysis of Banking Service Innovation Strategies and Evaluation of the Gaps by Using Modified VIKOR Method

In 1998, Opricovic proposed the VIKOR method for the multiple-criteria optimization of complex systems [64]. The basic concept of the VIKOR method is based on the compromise programming used in MCDM by comparing the measure of "closeness" to the "ideal" alternative [64–66]. VIKOR uses the class distance function based on the concept of the positive-ideal (or in this study adopt the aspiration level) solution and negative-ideal (or in this study adopt the worst level) solution and orders the results [67]. By the modified VIKOR method (Appendix C) for the normalized class distance function, it is preferable to be nearer the aspiration level and farther from the worst value for normalized class distance function. Opricovic and Tzeng [65] proposed the compromise ranking method (VIKOR) as a suitable technique for implementation within MCDM [66]. Modified VIKOR comprises the following steps: The first step is to check the best and worst values of the assessment criteria/sub-criteria. The second step is to calculate the mean group utility based on the sum of all individual-criterion regrets (i.e., average overall performance gaps, and those for each criteria, and for each sub-criteria; and strategies for reducing these gaps), and calculate the maximal regret for an individual-criterion for improvement priority, both overall and for each criteria. The third step is to obtain the comprehensive/integrating indicators and sort the results provided to the decision-maker to implement improvement strategies and reduce competitiveness gaps in both overall performance and individual criteria of performance.

4. Empirical Cases from the Banking Service Innovation Following Fintech Revolution

In this section, four empirical cases are reviewed. The four categories of empirical cases are state-owned commercial banks (Bank A), joint-equity commercial banks (Bank B), urban commercial banks (Bank C), and others (Bank D). First, the interrelationships among the interactional criteria and sub-criteria are demonstrated through the DEMATEL to build an influential network relationship map. Second, we computed the influential weights of each indicator by using the DANP method. Finally, we measure the overall performance gap by using the modified VIKOR. The data collected from experts are analyzed by using hybrid MCDM models, and the empirical results are presented in banking service innovation following Fintech revolution.

4.1. Collection of Data and Information from the DEMATEL Technique

Questionnaire data collected from 27 banking experts who are well versed in banking industry development and have practical experience of a particular banking service innovation. In order to reach consensus, the statistical significance confidence was 99.95%, and the gap error was 0.05%. The group of experts have several years of experience in the banking industry, service innovation development field, and Fintech. Their professional and practical experience can strongly support the personal interviews and questionnaire.

This study has constructed the network structure and analysed six criteria and twenty sub-criteria for evaluating the banking service innovation within a Fintech context. In the DEMATEL questionnaire completed by the 27 experts, the initial matrix $\boldsymbol{A}$ is obtained by pairwise comparison (Table A1), through which a normalized matrix $\boldsymbol{D}$ (Table A2) is derived and is available for calculating the total influence matrix $\boldsymbol{T}$ of the sub-criteria (Table A3). The analysis results show highly significant confidence, with a

high consistency ratio of 99.95%, and serve to derive a sum of influences given and received on the sub-criteria (Table 2); these influences are further illustrated in the INRM in Figure 2. Table 2 shows that new business partners (NB) have the highest positive value of 0.444 and thus a stronger influence on the other criteria (indicating that it is the most important criteria). New revenue models (NR) have the lowest negative value of −1.163 and are therefore the most vulnerable to influence. Therefore, the improvement priorities can be sequenced as new business partners (NB), new service concept (NS), organizational innovation (OI), technological innovation (TI), new customer interaction (NC), and new revenue models (NR). This effect is further illustrated in Figure 2.

The network of relationships can also be seen as influencing each criteria. Overall, customer-centric (NS_1), active identification of customer needs (NC_2), alliance with Fintech (NB_1), multi-faceted business strategies (NR_1), organizational structure reform (OI_1), and development of big data analysis (TI_1) can be identified as having a greater influence on the other sub-criteria in the individual criteria. For instance, in the new service concept (NS) criteria, customer-centric (NS_1) exert a direct effect on the remaining sub-criteria, including service efficiency enhancement (NS_2), reduced credit risk (NS_3), and the development of scenario finance (NS_4). This effect indicates that banking experts agree that the superior function of customer-centricity (NS_1), such as a focus on customer needs to provide personalized and customized services, is the most influential way to improve banking service excellence. In contrast, the service efficiency enhancement (NS_2) criterion is the most vulnerable to influence and should be improved last. Because the improved visual service will help to improve responsible problem-solving abilities and guarantee the service performing process, the banking service staff will be able to more readily attend to the needs of customers and become trustworthiness and credibility in their performance of the promised service. Therefore, the general improvement priority can be sequenced NS_1, NS_4, NS_3, and NS_2 for new service concepts (NS).

Table 2. Sum of influences given and received on the sub-criteria.

Criteria/Sub-Criteria	D_i	R_j	$D_i + R_j$	$D_i - R_j$
New service concept (NS)	10.850	10.445	21.295	0.405
(NS_1)	1.256	1.179	2.434	0.077
(NS_2)	1.143	1.197	2.340	−0.054
(NS_3)	0.953	0.964	1.917	−0.011
(NS_4)	1.079	1.090	2.169	−0.011
New customer interaction (NC)	10.526	10.689	21.215	−0.614
(NC_1)	0.837	0.827	1.664	0.010
(NC_2)	0.855	0.843	1.698	0.012
(NC_3)	0.848	0.870	1.718	−0.022
New business partners (NB)	10.166	9.722	19.888	0.444
(NB_1)	0.652	0.654	1.307	−0.002
(NB_2)	0.580	0.593	1.173	−0.014
(NB_3)	0.576	0.560	1.136	0.016
New revenue models (NR)	9.965	11.127	21.092	−1.163
(NR_1)	0.483	0.473	0.955	0.010
(NR_2)	0.477	0.487	0.964	−0.010
Organizational innovation (OI)	9.895	9.573	19.468	0.322
(OI_1)	0.613	0.564	1.178	0.049
(OI_2)	0.588	0.648	1.236	−0.060
(OI_3)	0.596	0.585	1.182	0.011
Technological innovation (TI)	10.326	10.171	20.497	0.156
(TI_1)	1.334	1.300	2.633	0.034
(TI_2)	1.174	1.167	2.341	0.007
(TI_3)	1.065	1.104	2.168	−0.039
(TI_4)	1.152	1.160	2.312	−0.008
(TI_5)	1.172	1.166	2.339	0.006

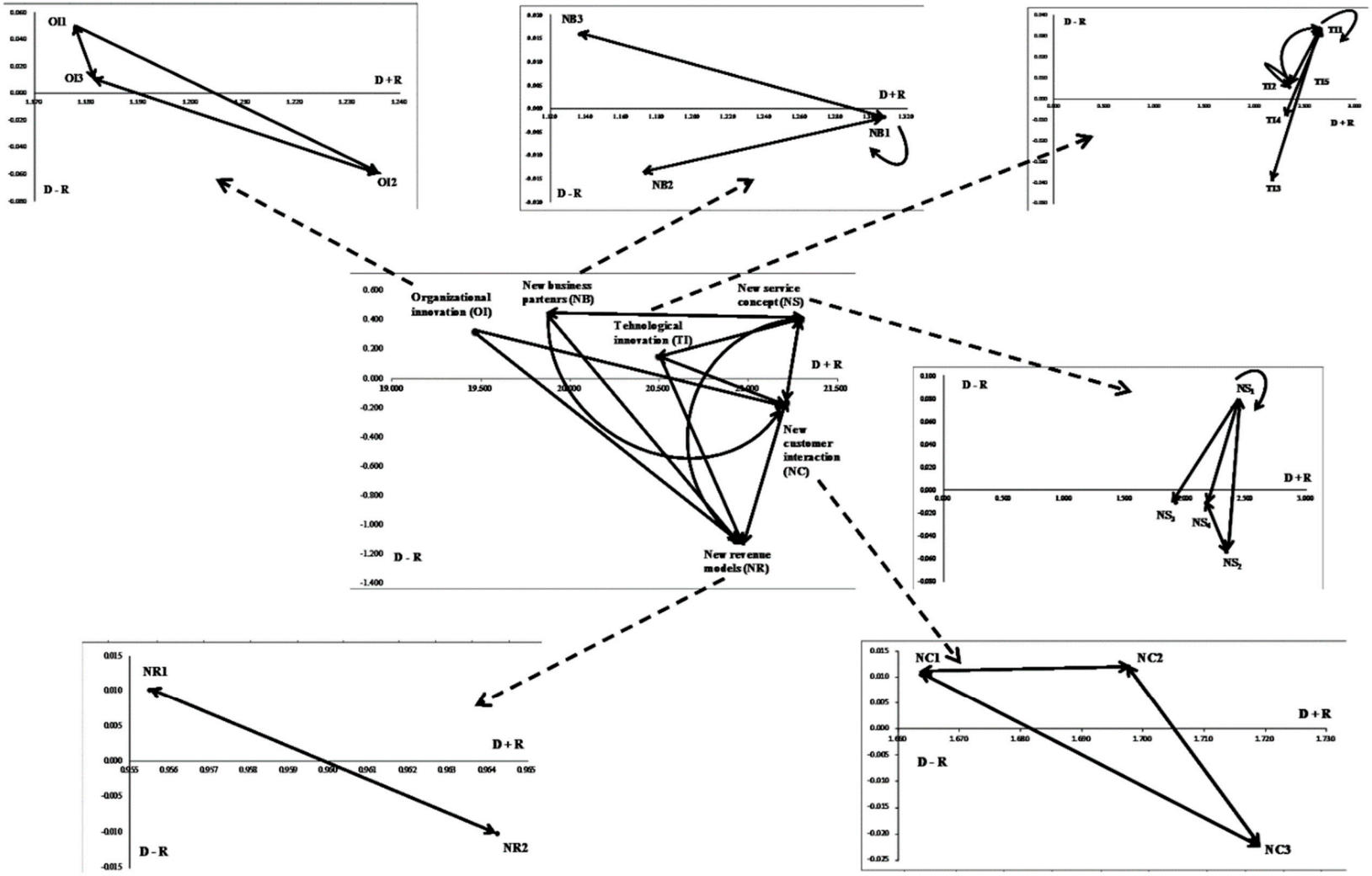

Figure 2. The INRM of each criteria and sub-criteria.

In addition to the summary above, banking managers can refer to the INRM network relationship map to prioritise the improvement of criteria/sub-criteria and creating improvement strategy for their banking following Fintech revolution.

4.2. Analyze Influential Weights Using the DANP Technique

Based on DEMATEL analysis results, we can confirm the influential relationships between the criteria/sub-criteria. The study can thus proceed to obtain the influential weights using the DANP technique. Based on pairwise comparisons of the unweighted supermatrix (Table A4) and weighted supermatrix (Table A5), the limiting power of the weighted supermatrix, $\lim_{\varphi\to\infty}(\mathbf{W}_c^*)^{\varphi}$, is obtained, and a steady-state condition, which shows the weights of each sub-criteria (Table A6) for further analysis by the modified VIKOR, is reached.

4.3. Evaluating the Strategies of Banking Service Innovation Using the Modified VIKOR

The performance questionnaire was the four banking types' important questionnaire, which was distributed to 29 experts who frequent perform banking services. The questionnaire used an eleven-point scale ranging from 0 (very unimportant) to 10 (very important). The reliability is 96.1% (Cronbach's Alpha analysis is used to the 29 questionnaires to evaluate the reliability) and the validity is 91.7% (KMO-test). It is hoped that the study can help banking managers to improve and develop their banking service innovation more effectively to satisfy their customers within a Fintech context. The modified VIKOR obtains the overall banking service performance, as shown in Table 3. The banking managers can identify the problem-solving points according to this integrated index with respect to either the overall criteria or an individual criteria, or with respect to the sub-criteria as a whole. The priority sequence for reaching the desired level can be determined by the weights of the performance values, from high to low, and the gap values, from high to low.

From Table 3, integration of the performance index scores of Bank A (state-owned commercial banks) in the DANP further demonstrates that the gap for the organizational innovation (OI) criteria is 0.238 and that for the alliance with financial peers (NB_3) sub-criteria is 272, constituting the largest gaps, which Bank A should improve as a priority. Integration of the performance index scores of Bank B (joint-equity commercial bank) in the DANP showed that the gap of the organizational innovation (OI) criteria is 0.217 and that of the alliance with financial peers (NB_3) sub-criteria is 0.210, constituting the largest gaps, which Bank B should improve as a priority. Integration of the performance index scores of Bank C (urban commercial banks) in the DANP showed that the gap of the organizational innovation (OI) criteria is 0.228 and that of the blockchain application (TI_3) sub-criteria is 0.297, constituting the largest gaps, which Bank C should improve as a priority. Integration of the performance index scores of Bank D (others) in the DANP showed that the gap of the organizational innovation (OI) criteria is 0.259 and that of the blockchain application (TI_3) sub-criteria is 0.407, constituting the largest gaps, which Bank D should improve as a priority. Thus, the priority for Bank A, B, C, and D is to enhance their service innovation and thus increase their efficiency of service for customers following the Fintech revolution.

Table 3. The gaps evaluation of the banking service innovation by modified VIKOR.

Criteria/Sub-Criteria	Original Weights	Overall Weights (by DANP)	Bank A		Bank B		Bank C		Bank D	
			Scores	Gap	Scores	Gap	Scores	Gap	Scores	Gap
New service concept (NS)	0.169		8.034	0.197	8.931	0.107	8.862	0.114	7.931	0.207
NS_1	0.267	0.045	8.414	0.159	9.069	0.093	8.724	0.128	8.345	0.166
NS_2	0.270	0.045	8.621	0.138	9.103	0.090	8.966	0.103	8.310	0.169
NS_3	0.218	0.037	8.379	0.162	8.897	0.110	8.483	0.152	8.034	0.197
NS_4	0.246	0.041	8.172	0.183	8.690	0.131	8.241	0.176	7.414	0.259
New customer interaction (NC)	0.173		8.000	0.200	8.724	0.128	8.103	0.190	7.759	0.224
NC_1	0.326	0.056	8.069	0.193	8.655	0.134	8.207	0.179	7.517	0.248
NC_2	0.332	0.057	8.000	0.200	8.966	0.103	8.586	0.141	7.552	0.245
NC_3	0.342	0.059	8.000	0.200	9.069	0.093	8.414	0.159	7.552	0.245
New business partners (NB)	0.158		7.655	0.234	8.552	0.145	8.241	0.176	7.517	0.248
NB_1	0.362	0.057	7.483	0.252	8.103	0.190	8.172	0.183	7.414	0.259
NB_2	0.328	0.052	7.379	0.262	8.172	0.183	8.034	0.197	7.207	0.279
NB_3	0.310	0.049	7.276	0.272	7.897	0.210	7.690	0.231	7.034	0.297
New revenue models (NR)	0.180		7.724	0.228	8.310	0.169	8.379	0.162	7.690	0.231
NR_1	0.493	0.089	8.034	0.197	8.483	0.152	7.931	0.207	6.931	0.307
NR_2	0.507	0.091	8.000	0.200	8.586	0.141	7.897	0.210	7.379	0.262
Organizational innovation (OI)	0.155		7.621	0.238	7.828	0.217	7.724	0.228	7.414	0.259
OI_1	0.316	0.050	8.069	0.193	8.000	0.200	7.690	0.231	7.138	0.286
OI_2	0.358	0.055	8.207	0.179	8.414	0.159	8.379	0.162	7.828	0.217
OI_3	0.326	0.050	7.931	0.207	7.966	0.203	8.000	0.200	7.310	0.269
Technological innovation (TI)	0.165		8.345	0.166	8.759	0.124	8.276	0.172	7.724	0.228
TI_1	0.221	0.036	8.759	0.124	8.690	0.131	8.034	0.197	7.000	0.300
TI_2	0.198	0.032	7.690	0.231	8.379	0.162	7.172	0.283	6.069	0.393
TI_3	0.187	0.031	8.103	0.190	7.966	0.203	7.034	0.297	5.931	0.407
TI_4	0.197	0.033	8.241	0.176	8.621	0.138	7.552	0.245	6.586	0.341
TI_5	0.198	0.032	7.862	0.214	8.621	0.138	8.103	0.190	6.793	0.321

4.4. Discussions and Managerial Implications

In terms of theoretical and managerial implications, the DEMATEL analysis results can provide some insight that may allow banking managers to improve service innovation based on the indicators that most significantly influence the service innovation of other indicators. For the empirical results, the criteria/sub-criteria of influence are calculated and illustrated using an INRM (Figure 2). In Figure 2 (according to the degree of influence), the improvement priorities are sequenced as new business partners, new service concept, organizational innovation, technological innovation, new customer interaction, and new revenue models. The banking emphasis that new business partners must be assigned the highest priority. Efforts in this direction will produce network effects on Fintech revolution and influence banking service innovation.

After analysing the criteria, the study discusses the sub-criteria considered in each criteria. According to the results, we create an INRM of the sub-criteria in Figure 2. Hence, for the influence relationships between twenty sub-criteria, NB_3 was the most influential sub-criteria in the new business partners and should be improved first, followed by NB_1 and NB_2 (see Figure 2 for more details on the causal relationship between new service concept, new customer interaction, new business partners, new revenue models, organizational innovation, and technological innovation). Each of the evaluation criteria/sub-criteria creates the necessary services for improving service innovation in banking. Therefore, banking mangers should evaluate all of the criteria/sub-criteria for enhancing banking service innovation in accordance with Figure 2. This service innovation evaluation model following Fintech context can be used for most banking.

In Table 3, from the six major criteria, new revenue models (NR), featuring the largest gap value of 0.180, should be the first priority for improvement if banking mangers wish to achieve the desired level (creating service innovation for all customers). For long-term banking service improvement, banking managers should manage internal service motivation efficiently, as mentioned above. In four banking comparison results, the organizational innovation (OI), featuring the largest gap value (0.238, 0.217, 0.228, 0.289) with banking of A (state-owned commercial banks), B (joint-equity commercial banks), C (urban commercial banks), and D (others), should be first priority for improvement if banking managers wish to enhance the service innovation. According to the same rule, the priority improvement banking service innovation following Fintech context can be sequenced in the sub-criteria for each banking. Given these empirical findings, our analysis results, as holistically formulated in Table 4, fulfil the purpose of the study. Banking managers can easily prioritize the improvement service innovation strategies from these schemes according to the priorities of influence powers or gap values.

Previous study has focused on environmentally and socially practices context to explore banking industry sustainable competitive advantage with service innovation, whereas the current study confirms that banking industry are useful and that satisfying customers' needs and giving perfect financial service are very important to banking's success. This study indicates that the service innovation strategies of the four selected banking is rather unsatisfactory in this regard. Their managers must therefore bridge existing gaps in understanding the customers' needs to improve the banking service innovation strategies for enhancing China's banking industry competitive advantage. In summary, the study develops and creates a hybrid service innovation evaluation model for banking industry. This is a good reference for the four different types of banking mangers to form service innovation competitive strategies.

Table 4. Strategic planning for improving banking service innovation following Fintech revolution.

Formula	Strategies (Sequence of Improvement Priorities)
F1: influential network of criteria	(NB), (NS), (OI), (TI), (NC), (NR)
F2: influential network of sub-criteria	**(NB):** (NB_3), (NB_1), (NB_2) **(NS):** (NS_1), (NS_3), (NS_4), (NS_2) **(OI):** (OI_1), (OI_3), (OI_2) **(TI):** (TI_1), (TI_5), (TI_2), (TI_4), (TI_5) **(NC):** (NC_2), (NC_1), (NC_3) **(NR):** (NR_1), (NR_2)
F3: Bank A (state-owned commercial banks) (by gap value, from high to low)	**(NB):** (NB_3), (NB_2), (NB_1) **(NS):** (NS_4), (NS_3), (NS_1), (NS_2) **(OI):** (OI_3), (OI_1), (OI_2) **(TI):** (TI_2), (TI_5), (TI_3), (TI_4), (T_1) **(NC):** (NC_2), (NC_3), (NC_1) **(NR):** (NR_2), (NR_1)
F4: Bank B (joint-equity commercial banks) (by gap value, from high to low)	**(NB):** (NB_3), (NB_1), (NB_2) **(NS):** (NS_4), (NS_3), (NS_1), (NS_2) **(OI):** (OI_3), (OI_1), (OI_2) **(TI):** (TI_3), (TI_2), (TI_4), (TI_5), (T_1) **(NC):** (NC_2), (NC_3), (NC_1) **(NR):** (NR_2), (NR_1)
F5: Bank C (urban commercial banks) (by gap value, from high to low)	**(NB):** (NB_3), (NB_2), (NB_1) **(NS):** (NS_4), (NS_3), (NS_1), (NS_2) **(OI):** (OI_1), (OI_3), (OI_2) **(TI):** (TI_3), (TI_2), (TI_4), (TI_1), (T_5) **(NC):** (NC_1), (NC_3), (NC_2) **(NR):** (NR_2), (NR_1)
F6: Bank D (others) (by gap value, from high to low)	**(NB):** (NB_3), (NB_2), (NB_1) **(NS):** (NS_4), (NS_3), (NS_2), (NS_1) **(OI):** (OI_1), (OI_3), (OI_2) **(TI):** (TI_3), (TI_2), (TI_4), (TI_5), (T_1) **(NC):** (NC_1), (NC_2), (NC_3) **(NR):** (NR_1), (NR_2)

5. Conclusions and Remarks

To create service innovation in banks and encourage banking to revisit it's intentions are important missions that, if properly implemented, could result in significant benefits for the banking industry. To help the industry identify the key service innovation indicators and to achieve service innovation following the Fintech revolution, a hybrid service innovation evaluation model was proposed. To explore the causal relationships among the six criteria of service innovation in Fintech as well as their key sub-criteria, a hybrid MCDM model combining DEMATEL, DANP, and a modified VIKOR method was adopted. Among the various evaluations of banking service innovation in this study, the evaluations provided by the experts and banking managers produced useful results. The sequence of innovation improvement priorities were as follows: new business partners, new service concepts, organizational innovation, technological innovation, new customer interaction, and new revenue models. The implications of these results for improvement strategies are provided in Tables 3 and 4.

The main contributions of this study are fourfold: first, an evaluation of improving banking service innovation is an MCDM problem with dependence and interaction indicators. A literature review and expert interviews were used to create twenty sub-criteria and six criteria for use in evaluating service innovation in banking following the Fintech revolution. Second, three MCDM approaches (including DEMATEL, DANP, and modified VIKOR) were combined to create a hybrid service innovation evaluation model that prioritizes the weighting of criteria and sub-criteria and finds the gaps in banking service innovation. The proposed hybrid method not only handles the causal

relationships within a set of criteria and sub-criteria but also produces more valuable information with which to construct an INRM for banking managers to make decisions. Third, the findings indicate that the analysis results are valid. Analyzing the evaluation results provides guidance for banking managers when identifying key sub-criteria to facilitate weighting or gap evaluations and when finding the best direction for improving banking's service innovation following the Fintech revolution. Finally, a questionnaire was conducted using banking experts (n = 27) from different positions in the banking field. Using a process of comparison analysis, we analyzed the drivers of banking service innovation and concluded that while some banking service innovation factors exist, service innovation from different aspects of banking can also be satisfied by following the Fintech revolution. In addition, the results of the above analyses were used to examine the current strengths and weaknesses of different types of banks through performance questionnaires (n = 29) to provide a reference for banks' sustainable development of improvement strategies.

However, there are some limitations within this study. First, the evaluation indicators were selected from a literature review on banking service innovation. Other methods, such as qualitative analysis and longitudinal studies, could have been used to identify other possible indicators. We found that, currently, the most unsatisfactory performance for these four types of banks in China is in organizational innovation, which may be related to the development process and organizational culture of the banking industry. In the future, the reasons for this weakness can be explored through case studies and literature reviews. Second, future research can adopt different MCDM approaches to estimate the relative weights of the evaluation criteria on service innovation evaluation in banking. Finally, we hope that this study will contribute to enhancing the improvement of sustainable strategies for service innovation in banking following the Fintech revolution. The results of the analysis should help banking managers decide how to more effectively implement their banking service innovation strategies. As such, this study provides a good reference model for banking service innovation and sustainable development following the Fintech revolution.

Author Contributions: Q.Z. designed the research framework, wrote the paper, and participated in revision work; P.-H.T. analyzed the data, wrote the paper, and participated in revision work; J.-L.W. Investigation, revised the grammar of this paper and participated in the revision session.

Funding: This research was sponsored by K.C. Wong Magna Fund in Ningbo University, the Social Science Research Funds from Ningbo under Grant No. 2017A10026, and the Fundamental Research Funds from College of Science & Technology, Ningbo University (No. YK180011).

Acknowledgments: We wish to thank anonymous referees and the editors for their valuable comments and suggestions which helped in improving the quality of this paper.

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

Appendix A DEMATEL Method

The five steps for the DEMATEL are: first, define criteria and determine relationship; second, set up direct-relation matrix; third, calculate the normalized direct-relationship matrix; fourth, calculate the total-relationship (direct/indirect) matrix, and finial, draw and analyze the INRM.

Step 1: Define criteria and determine relationships.

The relationships among the elements of the systems, determined following a literature review, brainstorming, inducting, and defining, were judged by the professional subjectively via the design of the questionnaire, which compared criteria from each pair of elements represented by numbers ranging from 0 to 4.

Step 2: Calculate the original average matrix.

In this study, experts with practical experience and extensive scholarship were consulted during mutual direct influence evaluations of each evaluation criterion/sub-criterion. The scales ranged from 0 to 4 where "0" means "no influence" and "4" means "extremely strong influence". "1", "2", and "3" mean "low influence", "medium influence" and "high influence", respectively. After we obtain these

groups of direct matrices from the sample of experts, we can generate an average matrix **A** in which each element is the mean of the corresponding elements in the experts' direct matrices.

Step 3: Calculate the direct influence matrix.

We processed the original influence matrix **A** by using (A1) and (A2) and obtained the direct influence matrix **D**.

$$\mathbf{D} = s \times \mathbf{A}, s > 0 \tag{A1}$$

where:

$$s = \min_{i,j}\left[\frac{1}{\max\limits_{1\le i\le n}\sum\limits_{j=1}^{n} a_{ij}}, \frac{1}{\max\limits_{1\le j\le n}\sum\limits_{i=1}^{n} a_{ij}}\right], i, j = 1, 2, \cdots, n \tag{A2}$$

and $\lim\limits_{m\to\infty}\mathbf{D}^m = [0]_{n\times n}$, where: $\mathbf{D} = \left[d_{ij}\right]_{n\times n}$, when $0 < \sum\limits_{j=1}^{n} d_{ij} \le 1$ or $0 < \sum\limits_{i=1}^{n} d_{ij} \le 1$, and at least one $\sum\limits_{j=1}^{n} d_{ij}$ or $\sum\limits_{i=1}^{n} d_{ij}$ equal one, but not all. Therefore, we can guarantee $\lim\limits_{m\to\infty}\mathbf{D}^m = [0]_{n\times n}$.

Step 4: Calculate the total-relationship (direct/indirect) matrix.

Using T to represent a total-relationship matrix, I the unit matrix, D the total-relationship matrix, and $\mathbf{D} = \left[d_{ij}\right]_{n\times n}$, $\lim\limits_{k\to\infty}\left(\mathbf{D}^2 + \cdots + \mathbf{D}^k\right)$ the indirect matrix, when $0 \le d_{ij} < 1$, then $\lim\limits_{k\to\infty}\mathbf{D}\left(\mathbf{I} + \mathbf{D}^2 + \cdots + \mathbf{D}^{k-1}\right)$ and $\mathbf{T} = \mathbf{D}(\mathbf{I} - \mathbf{D})^{-1}$, $\mathbf{T} = \left[t_{ij}\right]$, $i, j \in \{1, 2, \cdots, n\}$.

Step 5: Draw the influential network relationship map (INRM) and result analysis.

The total amount of each row is represented by D_i, and the total amount of each column is represented by R_j considering.

$$D_i = \sum_{j=1}^{n} t_{ij}, i = 1, 2, \ldots, n, \tag{A3}$$

$$R_j = \sum_{i=1}^{n} t_{ij}, j = 1, 2, \ldots, n. \tag{A4}$$

The INRM uses $\left(D_i + R_j, D_i - R_j\right)$ as ordered pairs. The horizontal axis $\left(D_i + R_j\right)$ represents the degrees of influence of the relationships among the elements; however, the vertical axis $\left(D_i - R_j\right)$ represents the degrees of influence of the relationships between one element and other elements. Therefore, the sophisticated causality of the elements can be observed as a simple and explicit structure in the INRM. The structure can be used by decision makers and managers to aid in strategy.

Appendix B DANP Method

The DANP method is summarized as follows:

Step 1. Finding the normalized total-influential matrix $\mathbf{T}_D^{nor}$.

The total-influential matrix $\mathbf{T}_D$ is normalized by dividing it by the following equations:

$$t_D^i = \sum_{j=1}^{m} t_D^{ij}$$

$$\mathbf{T}_D = \begin{bmatrix} t_D^{11} & \cdots & t_D^{1j} & \cdots & t_D^{1m} \\ \vdots & & \vdots & & \vdots \\ t_D^{i1} & & t_D^{ij} & & t_D^{im} \\ \vdots & & \vdots & & \vdots \\ t_D^{m1} & \cdots & t_D^{mj} & \cdots & t_D^{mm} \end{bmatrix} \begin{matrix} \\ \\ \rightarrow \sum\limits_{j=1}^{m} t_D^{1j} = t_D^1 \\ \rightarrow \sum\limits_{j=1}^{m} t_D^{ij} = t_D^i \\ \rightarrow \sum\limits_{j=1}^{m} t_D^{mj} = t_D^m \end{matrix} \tag{A5}$$

Thus, the total-influential matrix can be normalized and presented as $\mathbf{T}_D^{nor}$. Then, the sum of each row can be defined as $t_D^i = \sum_{j=1}^{m} t_D^{ij}$, where $i = 1, \cdots, m$, and $\mathbf{T}_D$ can be normalized by the sum of the rows by dividing the elements in each row by the sum of the row, as in (A5). Therefore, a total-influential matrix $\mathbf{T}_D$ can be normalized and represented as $\mathbf{T}_D^{nor}$. Thus, $\mathbf{T}_D^{nor} = \left[\frac{t_D^{ij}}{t_D^i}\right]_{m \times m}$, as in (A6). Then, each row of the normalized $\mathbf{T}_D^{nor}$ can be summed to equal one, so that $\sum_{j=1}^{m} t_D^{nor_{ij}} = 1$.

$$\mathbf{T}_D^{nor} = \begin{bmatrix} t_D^{11}/t_D^1 & \cdots & t_D^{1j}/t_D^1 & \cdots & t_D^{1m}/t_D^1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_D^{i1}/t_D^i & \cdots & t_D^{ij}/t_D^i & \cdots & t_D^{im}/t_D^i \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_D^{m1}/t_D^m & \cdots & t_D^{mj}/t_D^m & \cdots & t_D^{mm}/t_D^m \end{bmatrix} = \begin{bmatrix} t_D^{nor_{11}} & \cdots & t_D^{nor_{1j}} & \cdots & t_D^{nor_{1m}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_D^{nor_{i1}} & \cdots & t_D^{nor_{ij}} & \cdots & t_D^{nor_{im}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_D^{nor_{m1}} & \cdots & t_D^{nor_{mj}} & \cdots & t_D^{nor_{mm}} \end{bmatrix} \quad \text{(A6)}$$

Step 2. Finding the normalized matrix $\mathbf{T}_c^{nor}$ by dimensions and clusters.

Normalizing $\mathbf{T}_c$ with the total degrees of effect and influence of the dimensions and clusters obtains $\mathbf{T}_c^{nor}$, as shown in (A7).

$$\mathbf{T}_c^{nor} = \begin{array}{c} \\ \\ c_{11} \\ c_{12} \\ \vdots \\ c_{1n_1} \\ \vdots \\ D_1 \quad c_{i1} \\ c_{i2} \\ D_i \quad \vdots \\ \vdots \\ D_m \quad c_{in_i} \\ \vdots \\ c_{m1} \\ c_{m2} \\ \vdots \\ c_{mn_m} \end{array} \begin{array}{c} \begin{array}{ccccc} D_1 & & \cdots & & D_j \end{array} \quad \cdots \quad \begin{array}{c} D_m \\ c_{m1} \cdots c_{mn_m} \end{array} \\ \begin{array}{ccc} c_{11} \cdots c_{1n_1} & & c_{j1} \cdots c_{jn_j} \end{array} \\ \begin{bmatrix} \mathbf{T}_c^{nor_{11}} & \cdots \mathbf{T}_c^{nor_{1j}} & \cdots \mathbf{T}_c^{nor_{1m}} \\ \vdots & \vdots & \vdots \\ \mathbf{T}_c^{nor_{i1}} & \cdots \mathbf{T}_c^{nor_{ij}} & \cdots \mathbf{T}_c^{nor_{im}} \\ \vdots & \vdots & \vdots \\ \mathbf{T}_c^{nor_{m1}} & \cdots \mathbf{T}_c^{nor_{mj}} & \cdots \mathbf{T}_c^{nor_{mm}} \end{bmatrix} \end{array} \quad \text{(A7)}$$

Step 3. Constructing an unweighted super-matrix $\mathbf{W}_c$.

Then, the total-influential matrix can be normalized into a supermatrix according to the interdependence between the relationships of the dimensions and clusters to obtain an unweighted super-matrix, $\mathbf{W}_c$, as shown in (A8).

$$\mathbf{W}_c = (\mathbf{T}_c^{nor})' = \begin{array}{c} \\ \\ \\ D_1 \\ \\ D_i \\ \\ D_m \\ \\ \\ \end{array} \begin{array}{c} \begin{array}{ccccc} & D_1 & \cdots & D_j & \cdots & D_m \\ & c_{11}\ldots c_{1n_1} & & c_{m1}\ldots c_{mn_m} & & c_{j1}\ldots c_{jn_j} \end{array} \\ \begin{bmatrix} \mathbf{W}_c^{11} & \cdots \mathbf{W}_c^{i1} & \cdots \mathbf{W}_c^{m1} \\ \vdots & \vdots & \vdots \\ \mathbf{W}_c^{1j} & \cdots \mathbf{W}_c^{ij} & \cdots \mathbf{W}_c^{mj} \\ \vdots & \vdots & \vdots \\ \mathbf{W}_c^{1m} & \cdots \mathbf{W}_c^{im} & \cdots \mathbf{W}_c^{mm} \end{bmatrix} \end{array} \begin{array}{l} c_{11} \\ \vdots \\ c_{1n_1} \\ \vdots \\ c_{i1} \\ \vdots \\ c_{in_i} \\ \vdots \\ c_{m1} \\ \vdots \\ c_{mn_m} \end{array} \tag{A8}$$

The unweighted supermatrix $\mathbf{W}_c$ is the matrix transposed from $\mathbf{T}_c^{nor}$, which is the basic concept from the ANP by Saaty (1996) and differs from the traditional ANP. If a blank or 0 is shown in the matrix, the dimensions and criteria are independent.

Step 4. Finding the influential weights of the DANP.

The total-influential matrix $\mathbf{T}_c$ must be normalized by dividing the dimension and cluster ((A7)). Thus, $\mathbf{T}_c$ is normalized by summarizing the row by dimensions and clusters to obtain $\mathbf{T}_c^{nor}$. An unweighted supermatrix $\mathbf{W}_c$ can be obtained by transposing $\mathbf{T}_c^{nor}$, i.e., $\mathbf{W}_c = (\mathbf{T}_c^{nor})'$. Using (A9), a weighted supermatrix $\mathbf{W}_c^*$, which improves the traditional ANP by using equal weights to make it appropriate for the real world, can be obtained by the product of $\mathbf{T}_c^{nor}$ and $\mathbf{W}_c$, i.e., $\mathbf{W}_c^* = \mathbf{T}_D^{nor}\mathbf{W}_c$ ((A9)). This demonstrates that the influential level values are the basis of normalization to determine a weighted supermatrix.

$$\mathbf{W}_c^* = \mathbf{T}_D^{nor}\mathbf{W}_c = \begin{bmatrix} t_D^{nor_{11}} \times \mathbf{W}_c^{11} & \cdots & t_D^{nor_{1i}} \times \mathbf{W}_c^{i1} & \cdots & t_D^{nor_{m1}} \times \mathbf{W}_c^{m1} \\ \vdots & & \cdots & & \vdots \\ t_D^{nor_{1j}} \times \mathbf{W}_c^{1j} & \cdots & t_D^{nor_{ij}} \times \mathbf{W}_c^{ij} & \cdots & t_D^{nor_{mj}} \times \mathbf{W}_c^{mj} \\ \vdots & & \vdots & & \vdots \\ t_D^{nor_{1m}} \times \mathbf{W}_c^{1m} & \cdots & t_D^{nor_{im}} \times \mathbf{W}_c^{im} & \cdots & t_D^{nor_{mm}} \times \mathbf{W}_c^{mm} \end{bmatrix} \tag{A9}$$

Step 5. Obtaining the influential weights.

The weighted supermatrix is limited by raising it to a sufficiently large power φ until it converges and becomes a long-term stable supermatrix to obtain a global priority vector, which defines the influential weights $\mathbf{w} = (w_1, \cdots, w_j, \cdots, w_n)$ from $\lim_{\varphi\to\infty}(\mathbf{W}_c^*)^{\varphi}$ for the criteria.

Appendix C Modified VIKOR Method

The modified VIKOR analysis procedure is summarized as follows.

Step 1. Determine the positive-ideal solution (PIS) and negative-ideal solution (NIS).

Determine the best value f_j^* and the worst value f_j^- of assessment criteria for the quality factors. Here f_j^* represents the positive-ideal point, which means that the expert scores this as the best value (aspired levels) in each criterion; by contrast, f_j^- represents the negative-ideal point, which indicates that the expert assigns this the worst values in criterion. (A10) and (A11) are used to obtain the results.

$$\begin{gathered} f_j^* = \max_k f_{kj}\,, j = 1, 2, \cdots, n \text{ (traditional approach)} \\ \text{or setting the aspired levels, vector } f^* = \left(f_1^*, f_2^*, \cdots, f_n^*\right), \end{gathered} \tag{A10}$$

$$\begin{gathered} f_j^- = \min_k f_{kj}, , j = 1, 2, \cdots, n \text{ (traditional approach)} \\ \text{or setting the worst levels, vector } f^- = \left(f_1^-, f_2^-, \cdots, f_n^-\right), \end{gathered} \tag{A11}$$

where f_j^* is a positive-ideal point, representing the best values (aspiration level), and f_j^- is a negative-ideal point, representing the worst values in each criterion. We set the aspired level $f_j^* = 10$ and the worst value as $f_j^- = 0$ (from very unimportant or very bad $\leftarrow 0, 1, 2, \cdots, 9, 10 \rightarrow$ very important or very good), in contrast to the traditional approach, which sets $f_j^* = \max_k f_{kj}$ and $f_j^- = \min_k f_{kj}$. This allows us to avoid "choosing the best among inferior options/alternatives (i.e., avoid picking the best apple from among a barrel of rotten apples)".

Step 2. Calculate the mean group utility S_k for the gap and maximal gap Q_k for prioritizing improvement.

The development of the modified VIKOR method begins with the following form of the L_P metric:

$$L_k^p = \left\{ \sum_{j=1}^{n} \left[w_j \left(\left| f_j^* - f_{kj} \right| \right) / \left(\left| f_j^* - f_j^- \right| \right) \right]^p \right\}^{\frac{1}{p}}, \tag{A12}$$

where $1 \leq p \leq \infty$; $k = 1, 2, \cdots, m$ and influential weight w_j is derived from the DANP. $L_k^{p=1}(asS_k)$ and $L_k^{p=\infty}(asQ_k)$ are used by modified VIKOR to formulate the ranking and gap measure.

$$S_k = L_k^{p=1} = \sum_{j=1}^{n} \left[w_j \left| f_j^* - f_{kj} \right| / \left| f_j^* - f_j^- \right| \right], \tag{A13}$$

$$Q_k = L_k^{p=\infty} = \max_j \left\{ \left| f_j^* - f_{kj} \right| / \left| f_j^* - f_j^- \right| | j = 1, 2, \ldots, n \right\}. \tag{A14}$$

We define $r_{kj} = \left| f_j^* - f_{kj} \right| / \left| f_j^* - f_j^- \right|$ as the gap ratio of alternative k for criterion j. The compromise solution $\min_k L_k^p$ shows the synthesized/aggregated gap ratio that will also be minimized using (A14), and $L_k^{p=\infty}$ indicates which alternative will be the improvement priority, that is, which one has the maximum gap ratio of the criteria in each dimension or criterion. Here represents the influential weights of the criteria obtained from DANP; represents the ratios of distance to the aspired/worst value. For calculating the means of group utility and maximal regret, these gap values can be computed using (A15) and (A16).

$$S_k = \sum_{j=1}^{n} w_j r_{kj} = \sum_{j=1}^{n} w_j \left| f_j^* - f_{kj} \right| / \left| f_j^* - f_j^- \right|, \tag{A15}$$

$$Q_k = \max_j \left\{ r_{kj} | j = 1, 2, \cdots, n \right\}. \tag{A16}$$

Step 3. Obtain the comprehensive indicator R_k.

To obtain the comprehensive indicator R_k and the sorting results. The values can be computed by (A17).

$$R_k = v(S_k - S^*) / \left(S^- - S^*\right) + (1 - v)(Q_k - Q^*) / \left(Q^- - Q^*\right). \tag{A17}$$

Those values are derived from $S^* = \min_k S_k$ or by setting $S^* = 0$ (the aspired level), $S^- = \max_k S_k$ or setting $S^- = 1$ (the worst situation); $Q^* = \min_k Q_k$ or setting $Q^* = 0$ (the aspired level), and $Q^- = \max_k Q_k$ or setting $Q^- = 1$ (the worst situation). Therefore, when $S^* = 0$ and $S^- = 1$, and $Q^* = 0$ and $Q^- = 1$, we can re-write (A17) as $R_k = vS_k + (1 - v)Q_k$. If $v = 1$ indicates only consideration of the average gap weight, then $v = 0$ represents only consideration of the maximum gap for improvement priority. Generally speaking, we can set $v = 0.5$, but this can be adjusted depending on expert opinion.

Appendix D

Table A1. The initial influence matrix ***A*** of sub-criteria.

	NS_1	**NS_2**	**NS_3**	**NS_4**	**NC_1**	**NC_2**	**NC_3**	**NB_1**	**NB_2**	**NB_3**	**NR_1**	**NR_2**	**OI_1**	**OI_2**	**OI_3**	**TI_1**	**TI_2**	**TI_3**	**TI_4**	**TI_5**
NS_1	0.000	3.407	2.037	2.889	3.370	3.333	3.444	2.481	2.481	2.222	2.556	2.815	2.556	2.778	2.407	3.111	2.741	2.667	2.852	2.926
NS_2	3.000	0.000	1.852	2.407	2.963	2.926	2.852	2.370	1.963	2.333	2.222	2.778	2.370	2.704	2.333	2.852	2.889	2.481	2.667	2.407
NS_3	2.000	2.148	0.000	2.111	1.963	2.148	1.815	2.407	1.593	2.000	1.778	2.259	2.148	2.556	1.963	2.815	2.000	2.593	1.852	1.926
NS_4	2.778	2.556	1.926	0.000	2.667	2.667	2.519	2.593	2.741	2.148	2.481	2.222	2.111	2.148	2.074	2.778	2.037	2.000	2.481	2.259
NC_1	3.333	3.148	2.111	2.556	0.000	2.963	2.926	2.481	2.444	2.111	2.667	2.074	2.111	2.222	2.000	2.593	2.148	2.074	2.296	2.185
NC_2	3.333	3.259	2.519	2.630	2.704	0.000	3.111	2.667	2.407	1.926	2.259	2.370	2.000	2.296	2.037	2.667	2.519	2.074	2.481	2.481
NC_3	3.370	3.074	2.185	2.630	2.778	2.667	0.000	2.519	2.370	2.296	2.111	2.667	2.111	2.333	2.296	3.037	2.630	2.074	2.259	2.333
NB_1	2.333	2.630	2.407	2.852	2.519	2.444	2.889	0.000	1.556	1.444	2.630	2.333	2.148	2.037	2.037	2.852	2.481	2.370	2.593	2.444
NB_2	2.444	2.259	1.852	2.926	2.667	2.037	2.407	1.630	0.000	1.407	2.519	2.148	1.704	1.926	1.667	2.148	1.593	1.704	2.296	1.852
NB_3	2.333	2.519	2.296	2.630	2.259	1.963	2.296	1.407	1.444	0.000	2.222	2.074	1.630	1.926	1.667	2.296	2.074	2.037	2.111	2.111
NR_1	2.519	2.148	2.296	2.741	2.741	2.704	2.667	2.630	2.667	2.370	0.000	1.963	2.444	2.407	2.333	2.667	2.222	2.259	2.407	2.444
NR_2	2.741	3.185	2.519	2.185	2.296	2.593	2.704	2.593	2.370	2.111	1.926	0.000	2.370	2.667	2.111	2.407	2.630	2.148	2.259	2.148
OI_1	2.222	2.593	1.963	2.000	1.889	1.852	2.148	2.074	1.852	1.778	2.148	2.148	0.000	2.556	2.519	2.111	1.889	1.889	1.741	1.926
OI_2	2.630	2.963	2.667	2.222	2.000	2.296	2.370	1.444	1.556	1.778	1.889	2.370	1.741	0.000	2.222	1.778	1.667	1.444	1.667	1.852
OI_3	2.519	2.481	2.222	2.074	1.778	1.963	2.111	1.889	1.741	1.741	2.259	2.037	2.000	2.556	0.000	1.852	1.741	1.815	1.926	1.889
TI_1	2.889	2.852	3.148	2.815	2.481	3.333	3.111	2.667	2.185	1.963	2.778	2.926	2.148	2.185	2.074	0.000	2.667	2.222	2.333	2.778
TI_2	2.741	2.704	2.259	2.481	2.407	2.704	2.963	2.630	1.704	1.815	2.370	2.741	1.852	2.185	1.926	2.481	0.000	1.778	1.667	2.259
TI_3	2.481	2.370	2.556	2.333	2.074	2.185	2.074	2.333	1.630	1.889	2.074	2.259	1.741	1.963	1.815	1.963	1.778	0.000	2.185	1.778
TI_4	3.037	3.074	1.815	2.481	2.556	2.296	2.296	2.741	2.630	2.000	2.407	2.296	1.593	1.926	1.704	2.074	1.852	2.222	0.000	1.889
TI_5	2.667	2.704	1.741	2.407	2.741	2.593	2.444	2.444	2.000	1.815	2.333	2.407	1.852	2.222	1.815	2.741	2.296	1.889	1.963	0.000

Appendix E

Table A2. The normalized matrix ***D*** of sub-criteria.

	NS_1	**NS_2**	**NS_3**	**NS_4**	**NC_1**	**NC_2**	**NC_3**	**NB_1**	**NB_2**	**NB_3**	**NR_1**	**NR_2**	**OI_1**	**OI_2**	**OI_3**	**TI_1**	**TI_2**	**TI_3**	**TI_4**	**TI_5**
NS_1	0.000	0.064	0.038	0.054	0.064	0.063	0.065	0.047	0.047	0.042	0.048	0.053	0.048	0.052	0.045	0.059	0.052	0.050	0.054	0.055
NS_2	0.057	0.000	0.035	0.045	0.056	0.055	0.054	0.045	0.037	0.044	0.042	0.052	0.045	0.051	0.044	0.054	0.054	0.047	0.050	0.045
NS_3	0.038	0.040	0.000	0.040	0.037	0.040	0.034	0.045	0.030	0.038	0.033	0.043	0.040	0.048	0.037	0.053	0.038	0.049	0.035	0.036
NS_4	0.052	0.048	0.036	0.000	0.050	0.050	0.047	0.049	0.052	0.040	0.047	0.042	0.040	0.040	0.039	0.052	0.038	0.038	0.047	0.043
NC_1	0.063	0.059	0.040	0.048	0.000	0.056	0.055	0.047	0.046	0.040	0.050	0.039	0.040	0.042	0.038	0.049	0.040	0.039	0.043	0.041
NC_2	0.063	0.061	0.047	0.050	0.051	0.000	0.059	0.050	0.045	0.036	0.043	0.045	0.038	0.043	0.038	0.050	0.047	0.039	0.047	0.047
NC_3	0.064	0.058	0.041	0.050	0.052	0.050	0.000	0.047	0.045	0.043	0.040	0.050	0.040	0.044	0.043	0.057	0.050	0.039	0.043	0.044
NB_1	0.044	0.050	0.045	0.054	0.047	0.046	0.054	0.000	0.029	0.027	0.050	0.044	0.040	0.038	0.038	0.054	0.047	0.045	0.049	0.046
NB_2	0.046	0.043	0.035	0.055	0.050	0.038	0.045	0.031	0.000	0.027	0.047	0.040	0.032	0.036	0.031	0.040	0.030	0.032	0.043	0.035
NB_3	0.044	0.047	0.043	0.050	0.043	0.037	0.043	0.027	0.027	0.000	0.042	0.039	0.031	0.036	0.031	0.043	0.039	0.038	0.040	0.040
NR_1	0.047	0.040	0.043	0.052	0.052	0.051	0.050	0.050	0.050	0.045	0.000	0.037	0.046	0.045	0.044	0.050	0.042	0.043	0.045	0.046
NR_2	0.052	0.060	0.047	0.041	0.043	0.049	0.051	0.049	0.045	0.040	0.036	0.000	0.045	0.050	0.040	0.045	0.050	0.040	0.043	0.040
OI_1	0.042	0.049	0.037	0.038	0.036	0.035	0.040	0.039	0.035	0.033	0.040	0.040	0.000	0.048	0.047	0.040	0.036	0.036	0.033	0.036
OI_2	0.050	0.056	0.050	0.042	0.038	0.043	0.045	0.027	0.029	0.033	0.036	0.045	0.033	0.000	0.042	0.033	0.031	0.027	0.031	0.035
OI_3	0.047	0.047	0.042	0.039	0.033	0.037	0.040	0.036	0.033	0.033	0.043	0.038	0.038	0.048	0.000	0.035	0.033	0.034	0.036	0.036
TI_1	0.054	0.054	0.059	0.053	0.047	0.063	0.059	0.050	0.041	0.037	0.052	0.055	0.040	0.041	0.039	0.000	0.050	0.042	0.044	0.052
TI_2	0.052	0.051	0.043	0.047	0.045	0.051	0.056	0.050	0.032	0.034	0.045	0.052	0.035	0.041	0.036	0.047	0.000	0.033	0.031	0.043
TI_3	0.047	0.045	0.048	0.044	0.039	0.041	0.039	0.044	0.031	0.036	0.039	0.043	0.033	0.037	0.034	0.037	0.033	0.000	0.041	0.033
TI_4	0.057	0.058	0.034	0.047	0.048	0.043	0.043	0.052	0.050	0.038	0.045	0.043	0.030	0.036	0.032	0.039	0.035	0.042	0.000	0.036
TI_5	0.050	0.051	0.033	0.045	0.052	0.049	0.046	0.046	0.038	0.034	0.044	0.045	0.035	0.042	0.034	0.052	0.043	0.036	0.037	0.000

Appendix F

Table A3. The total influence matrix of criterion T_c.

	NS_1	NS_2	NS_3	NS_4	NC_1	NC_2	NC_3	NB_1	NB_2	NB_3	NR_1	NR_2	OI_1	OI_2	OI_3	TI_1	TI_2	TI_3	TI_4	TI_5
NS_1	0.295	0.358	0.280	0.323	0.330	0.334	0.344	0.299	0.273	0.256	0.296	0.309	0.270	0.300	0.269	0.327	0.292	0.277	0.294	0.295
NS_2	0.323	0.273	0.256	0.291	0.300	0.304	0.310	0.275	0.244	0.239	0.269	0.286	0.247	0.278	0.248	0.300	0.274	0.255	0.270	0.265
NS_3	0.259	0.265	0.185	0.244	0.240	0.248	0.248	0.236	0.202	0.200	0.222	0.237	0.209	0.236	0.207	0.257	0.220	0.221	0.218	0.219
NS_4	0.302	0.301	0.243	0.233	0.279	0.284	0.288	0.264	0.245	0.223	0.259	0.262	0.230	0.254	0.231	0.283	0.245	0.233	0.253	0.249
NC_1	0.319	0.319	0.253	0.286	0.239	0.296	0.302	0.269	0.246	0.229	0.269	0.266	0.236	0.262	0.235	0.287	0.254	0.241	0.256	0.254
NC_2	0.326	0.328	0.265	0.293	0.293	0.250	0.312	0.278	0.250	0.230	0.268	0.277	0.239	0.269	0.241	0.295	0.266	0.246	0.265	0.264
NC_3	0.326	0.325	0.260	0.293	0.294	0.297	0.256	0.275	0.249	0.236	0.265	0.282	0.241	0.269	0.246	0.301	0.267	0.246	0.261	0.262
NB_1	0.294	0.302	0.251	0.283	0.276	0.279	0.293	0.218	0.224	0.211	0.261	0.263	0.230	0.251	0.230	0.284	0.252	0.239	0.254	0.251
NB_2	0.265	0.264	0.216	0.256	0.250	0.243	0.255	0.220	0.172	0.188	0.233	0.232	0.199	0.223	0.199	0.243	0.211	0.203	0.224	0.215
NB_3	0.263	0.268	0.224	0.250	0.243	0.242	0.253	0.216	0.198	0.162	0.228	0.231	0.198	0.223	0.199	0.245	0.220	0.209	0.220	0.220
NR_1	0.304	0.301	0.255	0.288	0.286	0.290	0.296	0.270	0.248	0.232	0.220	0.263	0.241	0.263	0.240	0.287	0.253	0.243	0.257	0.257
NR_2	0.305	0.315	0.256	0.275	0.276	0.285	0.294	0.267	0.241	0.225	0.252	0.225	0.237	0.266	0.234	0.280	0.258	0.238	0.252	0.249
OI_1	0.259	0.268	0.217	0.238	0.235	0.239	0.249	0.226	0.204	0.193	0.225	0.231	0.167	0.233	0.214	0.241	0.215	0.205	0.213	0.216
OI_2	0.264	0.272	0.227	0.239	0.235	0.244	0.251	0.213	0.197	0.191	0.218	0.233	0.197	0.185	0.206	0.233	0.209	0.196	0.209	0.212
OI_3	0.261	0.263	0.218	0.236	0.230	0.237	0.245	0.220	0.199	0.190	0.224	0.226	0.201	0.230	0.166	0.233	0.210	0.202	0.213	0.212
TI_1	0.327	0.330	0.284	0.304	0.298	0.317	0.320	0.286	0.254	0.238	0.284	0.294	0.249	0.275	0.249	0.255	0.276	0.256	0.270	0.277
TI_2	0.294	0.297	0.243	0.270	0.268	0.278	0.289	0.259	0.221	0.213	0.251	0.264	0.220	0.248	0.223	0.272	0.203	0.224	0.233	0.243
TI_3	0.266	0.266	0.229	0.246	0.240	0.246	0.250	0.233	0.201	0.196	0.226	0.235	0.200	0.224	0.202	0.240	0.215	0.173	0.222	0.215
TI_4	0.295	0.298	0.231	0.267	0.267	0.267	0.273	0.257	0.234	0.212	0.248	0.253	0.212	0.240	0.215	0.260	0.232	0.228	0.199	0.233
TI_5	0.290	0.293	0.232	0.266	0.271	0.273	0.277	0.253	0.224	0.210	0.248	0.256	0.218	0.246	0.218	0.273	0.241	0.223	0.236	0.199

Note: $\frac{1}{n^2}\sum_{i=1}^{p}\sum_{j=1}^{p}\frac{\left|t_{ij}^{p}-t_{ij}^{p-1}\right|}{t_{ij}^{p}} \times 100\% = 0.048\% < 5\%$, i.e., significant confidence is 99.95% > 95%, where p = 27 is the number of experts and t_{ij}^{p} and t_{ij}^{p-1} in n sub-criteria denote the average influence of i criterion on j by p samples and $p-1$ samples respectively. n denotes the number of sub-criteria, here n = 20 and matrix $n \times n$.

Appendix G

Table A4. The unweighted supermatrix.

	NS_1	**NS_2**	**NS_3**	**NS_4**	**NC_1**	**NC_2**	**NC_3**	**NB_1**	**NB_2**	**NB_3**	**NR_1**	**NR_2**	**OI_1**	**OI_2**	**OI_3**	**TI_1**	**TI_2**	**TI_3**	**TI_4**	**TI_5**
NS_1	0.235	0.282	0.272	0.280	0.271	0.269	0.271	0.260	0.265	0.261	0.265	0.265	0.264	0.263	0.267	0.263	0.266	0.264	0.270	0.268
NS_2	0.285	0.239	0.278	0.279	0.271	0.271	0.270	0.267	0.264	0.267	0.262	0.274	0.273	0.272	0.269	0.265	0.269	0.265	0.273	0.271
NS_3	0.223	0.224	0.194	0.225	0.215	0.219	0.216	0.222	0.216	0.222	0.222	0.223	0.221	0.226	0.223	0.228	0.220	0.227	0.212	0.214
NS_4	0.257	0.255	0.256	0.216	0.243	0.242	0.243	0.250	0.256	0.249	0.251	0.239	0.242	0.239	0.241	0.244	0.245	0.244	0.244	0.246
NC_1	0.327	0.328	0.327	0.328	0.285	0.343	0.347	0.325	0.334	0.329	0.328	0.323	0.325	0.322	0.323	0.318	0.321	0.326	0.331	0.330
NC_2	0.332	0.333	0.337	0.333	0.354	0.292	0.351	0.329	0.325	0.328	0.332	0.334	0.330	0.334	0.333	0.339	0.333	0.334	0.331	0.333
NC_3	0.341	0.339	0.337	0.338	0.361	0.365	0.302	0.346	0.341	0.343	0.339	0.344	0.345	0.344	0.344	0.343	0.346	0.339	0.338	0.337
NB_1	0.361	0.363	0.370	0.361	0.362	0.366	0.362	0.333	0.380	0.376	0.360	0.364	0.364	0.355	0.362	0.368	0.374	0.369	0.365	0.368
NB_2	0.330	0.322	0.317	0.334	0.331	0.330	0.328	0.343	0.296	0.343	0.331	0.328	0.327	0.327	0.327	0.326	0.319	0.319	0.333	0.326
NB_3	0.309	0.315	0.313	0.305	0.308	0.304	0.311	0.323	0.324	0.281	0.309	0.307	0.310	0.318	0.312	0.306	0.307	0.311	0.302	0.306
NR_1	0.490	0.485	0.484	0.498	0.503	0.491	0.485	0.498	0.501	0.496	0.456	0.529	0.493	0.484	0.498	0.491	0.487	0.490	0.496	0.492
NR_2	0.510	0.515	0.516	0.502	0.497	0.509	0.515	0.502	0.499	0.504	0.544	0.471	0.507	0.516	0.502	0.509	0.513	0.510	0.504	0.508
OI_1	0.322	0.320	0.320	0.322	0.322	0.319	0.319	0.324	0.320	0.319	0.323	0.322	0.272	0.335	0.337	0.322	0.319	0.319	0.318	0.319
OI_2	0.358	0.359	0.362	0.355	0.357	0.359	0.356	0.353	0.359	0.360	0.354	0.360	0.380	0.314	0.386	0.356	0.359	0.358	0.359	0.361
OI_3	0.320	0.321	0.317	0.323	0.321	0.322	0.325	0.323	0.321	0.322	0.323	0.318	0.348	0.351	0.278	0.322	0.322	0.323	0.323	0.320
TI_1	0.220	0.220	0.226	0.224	0.222	0.221	0.225	0.221	0.221	0.220	0.221	0.219	0.221	0.220	0.218	0.191	0.231	0.226	0.226	0.233
TI_2	0.197	0.201	0.194	0.194	0.196	0.199	0.200	0.197	0.193	0.197	0.195	0.202	0.198	0.198	0.196	0.207	0.173	0.202	0.202	0.206
TI_3	0.187	0.187	0.195	0.185	0.186	0.184	0.184	0.187	0.185	0.188	0.187	0.187	0.189	0.185	0.188	0.192	0.191	0.162	0.198	0.190
TI_4	0.198	0.198	0.192	0.200	0.199	0.198	0.195	0.199	0.204	0.198	0.198	0.197	0.195	0.198	0.199	0.202	0.199	0.209	0.173	0.201
TI_5	0.198	0.194	0.193	0.197	0.197	0.198	0.196	0.196	0.196	0.197	0.198	0.195	0.198	0.200	0.198	0.208	0.207	0.201	0.202	0.170

Appendix H

Table A5. The weighted supermatrix.

	NS_1	**NS_2**	**NS_3**	**NS_4**	**NC_1**	**NC_2**	**NC_3**	**NB_1**	**NB_2**	**NB_3**	**NR_1**	**NR_2**	**OI_1**	**OI_2**	**OI_3**	**TI_1**	**TI_2**	**TI_3**	**TI_4**	**TI_5**
NS_1	0.037	0.044	0.043	0.044	0.047	0.047	0.047	0.044	0.045	0.045	0.045	0.045	0.046	0.046	0.046	0.045	0.046	0.045	0.046	0.046
NS_2	0.045	0.037	0.044	0.044	0.047	0.047	0.047	0.046	0.045	0.046	0.045	0.047	0.047	0.047	0.046	0.045	0.046	0.045	0.047	0.047
NS_3	0.035	0.035	0.030	0.035	0.037	0.038	0.037	0.038	0.037	0.038	0.038	0.038	0.038	0.039	0.039	0.039	0.038	0.039	0.036	0.037
NS_4	0.040	0.040	0.040	0.034	0.042	0.042	0.042	0.043	0.044	0.042	0.043	0.041	0.042	0.041	0.042	0.042	0.042	0.042	0.042	0.042
NC_1	0.058	0.058	0.058	0.058	0.046	0.055	0.056	0.057	0.049	0.061	0.058	0.057	0.057	0.056	0.057	0.056	0.056	0.057	0.058	0.058
NC_2	0.059	0.059	0.060	0.059	0.057	0.047	0.056	0.058	0.052	0.055	0.058	0.059	0.058	0.059	0.058	0.060	0.058	0.059	0.058	0.058
NC_3	0.060	0.060	0.060	0.060	0.058	0.058	0.048	0.061	0.054	0.062	0.060	0.060	0.060	0.060	0.060	0.060	0.061	0.060	0.059	0.059
NB_1	0.058	0.058	0.059	0.057	0.058	0.058	0.058	0.049	0.055	0.055	0.058	0.058	0.058	0.057	0.058	0.059	0.060	0.059	0.059	0.059
NB_2	0.053	0.051	0.051	0.053	0.053	0.053	0.052	0.050	0.043	0.050	0.053	0.053	0.052	0.052	0.052	0.052	0.051	0.051	0.053	0.052
NB_3	0.049	0.050	0.050	0.049	0.049	0.048	0.049	0.047	0.047	0.041	0.050	0.049	0.049	0.051	0.050	0.049	0.049	0.050	0.048	0.049
NR_1	0.089	0.088	0.088	0.091	0.092	0.090	0.088	0.092	0.092	0.091	0.076	0.088	0.090	0.088	0.091	0.090	0.089	0.090	0.091	0.090
NR_2	0.093	0.094	0.094	0.092	0.091	0.093	0.094	0.092	0.092	0.093	0.091	0.079	0.092	0.094	0.092	0.093	0.094	0.093	0.092	0.093
OI_1	0.051	0.050	0.050	0.051	0.051	0.050	0.050	0.051	0.050	0.050	0.051	0.051	0.039	0.048	0.048	0.050	0.050	0.050	0.050	0.050
OI_2	0.056	0.057	0.057	0.056	0.056	0.056	0.056	0.056	0.056	0.057	0.056	0.057	0.054	0.045	0.055	0.056	0.056	0.056	0.056	0.056
OI_3	0.050	0.051	0.050	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.050	0.050	0.050	0.040	0.050	0.050	0.051	0.050	0.050
TI_1	0.037	0.037	0.038	0.037	0.037	0.037	0.038	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.036	0.029	0.035	0.034	0.034	0.035
TI_2	0.033	0.034	0.032	0.032	0.033	0.033	0.034	0.033	0.032	0.033	0.033	0.034	0.033	0.033	0.033	0.032	0.026	0.031	0.031	0.031
TI_3	0.031	0.031	0.032	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.029	0.029	0.025	0.030	0.029
TI_4	0.033	0.033	0.032	0.033	0.033	0.033	0.033	0.033	0.034	0.033	0.033	0.033	0.032	0.033	0.033	0.031	0.030	0.032	0.026	0.031
TI_5	0.033	0.032	0.032	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.032	0.032	0.031	0.031	0.026

Appendix I

Table A6. The stable supermatrix of DANP.

	NS_1	**NS_2**	**NS_3**	**NS_4**	**NC_1**	**NC_2**	**NC_3**	**NB_1**	**NB_2**	**NB_3**	**NR_1**	**NR_2**	**OI_1**	**OI_2**	**OI_3**	**TI_1**	**TI_2**	**TI_3**	**TI_4**	**TI_5**
NS_1	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.044	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
NS_2	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.046	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
NS_3	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.036	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
NS_4	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.042	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
NC_1	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.055	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056
NC_2	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.056	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
NC_3	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.058	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
NB_1	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.056	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
NB_2	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.051	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
NB_3	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.048	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049
NR_1	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.087	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089
NR_2	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.089	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
OI_1	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.049	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
OI_2	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.054	0.056	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
OI_3	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.049	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
TI_1	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
TI_2	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.033	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
TI_3	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.030	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031
TI_4	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.032	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
TI_5	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032

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