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The Impact of Social Networks on the Operating Efficiency of Chinese Technology Business Incubators

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Received: 4 March 2020; Accepted: 27 March 2020; Published: 30 March 2020

Abstract: Based on data reflecting 1202 technology business incubators (TBIs) in China from 2016 to 2018, this study measures the operating efficiency of TBIs in China through their use of the data envelopment analysis(DEA) and analyzes the impact of network tie strength, network size, and network centrality on the operating efficiency of TBIs through Tobit, while discussing differences among specific regions. The results demonstrate that the operating efficiency of TBIs in China is increasing. The average operating efficiency of TBIs in the eastern region has increased annually, reaching its highest levels in China in 2018. Moreover, the average operating efficiency of TBIs in the northeastern and western regions is low. Network size and network centrality have a significant positive impact on the overall operating efficiency of the TBI, and network tie strength has an inverted U-shape form of impact. The established time, size, nature, and reputation of TBIs have a significant positive impact on the operating efficiency of the TBI. In the western China, geographical location has a positive correlation with the operating efficiency of the TBI. However, in the northeastern region, the nature of the TBI has a negative correlation with the operating efficiency of the TBI. This is the first use of full sample data to study the operation efficiency of Chinese TBIs from the perspective of social networks.

Keywords: technology business incubators; incubating efficiency; social networks

1. Introduction

Since the establishment of the “Batavia Industrial Center” by American businessman Joseph Mancuso in 1959, technology business incubators (TBIs) have evolved and developed with the rise of novel and advanced technological industries in the world. TBIs provide a wealth of resources and services to support the successful development of newly established or small enterprises. Similarly, as a policy tool for the government to support the development of newly established scientific and technological enterprises, they provide funds and services for venture enterprises while encouraging and stimulating the birth of innovation and entrepreneurship, which has been widely promoted and developed globally. In China, the first TBI, the Wuhan Donghu New Technology Entrepreneurship Center, was established in 1987. After over 30 years of development, business incubation services in China have gradually diversified and specialized, and some TBIs have formed a relatively complete entrepreneurial ecosystem.

Attracting the right resources to new businesses is one of the biggest challenges facing entrepreneurs [1]. Freeman [2] put forward an early definition of stakeholders as “all of those groups and individuals that can affect, or are affected by, the accomplishment of organizational purpose.”

His view is that value co-creation transcends formal organizational boundaries, and a firm is perceived to be embedded in a network of relationships where value is jointly created and shared in interactions with customers and other stakeholders [3]. When starting a new business, social networking serves as a vital asset for entrepreneurs to find a place in such a competitive market. Essentially, when creating enterprises, social networks aid enterprises to acquire resources (physical resources, information, emotional support, capital, and business contacts) that can transform the business's vision and plans into reality [4,5]. Social networks can help TBIs establish ties (what connects A to B, e.g. A is friend with B = A is tied to B [6]) with other actors (social entities linked together according to a relationship [6]), so that other actors within the network may provide TBIs with resources such as technology, innovative ideas, and information. This may be done to connect and integrate different actors' ideas and entrepreneurial resources, stimulate TBIs to challenge existing knowledge and generate new ideas, and encourage TBIs to generate creativity and innovative solutions to help TBIs solve current issues and promote technological innovation. Therefore, social networks play an important role in the development of a TBI.

Although many researchers have studied the operating performance of TBIs, few studies on the impact of social network in relation to the operating efficiency of TBIs exist. However, this perspective on social networks is crucial because the core mission of an TBI is to provide internal and external connections for incubated enterprises; social networks help enterprises to identify new entrepreneurial opportunities and build effective relationships with their partners (STAM, 2014) [7]. Thus, in this paper, the authors seek to address these important, yet under-researched, questions in a non-Western context. The specific research questions are

- What is the operating performance of TBIs based on data from throughout China?
- What is the impact of social networks on the operation efficiency of TBIs?
- Are there any regional differences in the impact of social networks on the operational efficiency of TBIs?

In order to address these questions, this study draws on social network theory. First, this paper determines the operating efficiency of TBIs according to the data envelopment analysis (DEA) method, in which the panel Tobit method is used to measure social network factors influencing the operating efficiency of TBIs. Moreover, this study proposes social network factors that play an important role in the operating efficiency of TBIs. Next, the impact of social networks on the operating performance of TBIs are specifically analyzed by region. Finally, suggestions for the development of China's TBIs are given based on the actual situation of TBIs in China, followed by the conclusions reached by this paper.

This paper's innovation is reflected in the following aspects. First, this article introduces social network theory into research on the operating performance of TBIs, uses a mid-scale perspective instead of a micro perspective focusing on the research of the TBI itself, which further strengthens the theoretical background in TBI performance research. Second, this paper uses TBI data from 2016 to 2018 on a national level, which was published by the Chinese authoritative organization, the Torch High Technology Industry Development Center, Ministry of Science & Technology. The data is authoritative, and the sample size is 1202. A comprehensive and large amount of data is conducive in improving the results' accuracy. Furthermore, the issue of inter-regional differences is discussed, and the comparison depicts the prominent problems that exist throughout the different regions of China.

2. Literature Review and Hypotheses Development

2.1. TBI and Its Operating Efficiency

TBIs provide a supportive environment for newly established technology enterprises at their early stages [8]. This "supportive environment" may be summarized in two aspects: operating environment and services. Specifically, a TBI can determine the enterprises to be incubated by reviewing projects of the entrepreneurial team and providing training for venues in work and

infrastructure, government services, management experience and entrepreneurial specifications, as well as investment and finance docking. Current studies on TBIs mainly focus on two aspects.

The first aspect regards research on TBI services and business models. Enterprise incubation is a dynamic process in enterprise development. Based on qualities embodying high-tech enterprises, an enterprise's life cycle may generally be divided into three stages: project approval for incubation (seed stage); mid-term development research (growth stage); and mature graduation at the end (mature stage) [9]. TBIs can be divided into comprehensive TBIs and professional TBIs [10]. Comprehensive TBIs provide incubation services for venture enterprises in multiple industries simultaneously, and professional TBIs are focus on one or some complementary fields [11]. Professional TBIs are the deconstruction and optimization of integrated servers. A TBI must realize the interests of itself as well as of its stakeholders during internal business incubation [12]. A TBI forms a network with incubated enterprises, colleges and universities, research institutions, governments, other organizations, enterprises, and stakeholders. A TBI network includes both internal and external networks. An internal network refers to the network between TBIs and incubating enterprises, while an external network refers to the network between TBIs and government agencies and scientific research organizations [13]. The core capabilities of the TBI include integration and networking. Integration is the ability to introduce and absorb external network resources in a dynamic environment, while networking is the ability to coordinate and use external network resources [14]. An important role of an TBI is to assist incubated enterprises in identifying suitable resources on the network and strengthen collaboration and cooperation among members of the network [15]. The problem concerning resource allocation in China's TBIs is relatively prominent, and existing resource input–output combinations require improvement in order to effectively control redundancy and waste in resource inputs [16]. Business models with regard to TBIs have been widely debated recently. Typical TBI business models may be roughly divided into four models: property, integrated service, professional service, and venture investment models. With respect to value proposition and customer location, they may be divided into the simple, value chain trap, single and capital models [17]. Specifically, the business model is composed of five parts: strategic choice, value input, value realization, value transmission, and value protection [18]. In terms of the evolution of a TBI's business model, there are four types of innovative activities: organizational reform, value chain improvement, network location improvement, and institutional entrepreneurship, which promote the evolution of a TBI from a single business model to a compound business model, achieving the balance between social and economic benefits [19].

Second, research on the operating efficiency of TBIs and its influential factors serve as another aspect. Xiyu [20] was the first to evaluate the performance of Chinese TBIs and selected five dimensions: hard and soft environments, financing, management, talent gathering, and market development ability. The five dimensions were further divided into 18 secondary indicators, and the performance of the TBIs was studied using AHP and fuzzy evaluation. Liu Ping [21] studied the relationship between network behavior and incubation efficiency of TBIs according to data on 192 TBIs in China. Accordingly, he proposed that TBI networking may organically integrate various network resources and significantly improve incubation efficiency. Zhang Lijian et al. [22] established a weight determining model regarding the efficiency evaluation index system for TBIs using an analytic hierarchy. Lin et al. [14] divided the TBI resources into government policy resources, infrastructure resources and external support resources. The core capabilities of the TBI included comprehensive service and network core capabilities. They believed that the three TBI resources affect the incubating efficiency through the core capabilities. Xu Lingjuan et al. [23] concluded that five influence factors have the greatest impact on incubating efficiency based on a survey of 32 TBIs located in Nanjing, Shanghai, and Hangzhou, which represented the external environment of the TBI, the operating capability of the TBI, the developmental capability of the TBI, and the innovative ability of the TBI and the incubated enterprises. Yin Hong [24] studied the relationship between developmental factors, incubating capacity and incubating efficiency of the TBI, constructed a model of influential factors on TBI efficiency, and conducted fitting research on the model using research data. The results showed that only via incubating capacity may TBI developmental factors influence

the incubating efficiency. Zdemir and Sehitolu evaluated the performance of TBIs from the perspectives of innovation, information service, and financial support [25]. Cheng Yu believed that investments and finance are important factors affecting incubating enterprises. In the future, policies should shift from basic support to investment and financial services, entrepreneurship guidance, and other aspects [26].

2.2. Social Networks and TBIs

Granovetter (1973) [27] defined networks as systems composed of knots or ties, and the connections between them are represented by social subjects (individuals, groups, organizations) connected by some type of relationship in the social sciences. Jarillo (1988) [28] pointed out the “location function” of social networks, that is, entrepreneurs integrate social resources and business opportunities in accordance with the enterprise’s entrepreneurship within competitive market environments via social networks. Emirbayer and Goodwin (1994) [29] described the social network as the connection and combination of a “Group of Actors,” and different network members and complex relationships constitute a set of entrepreneurial social networks. Gulati, Nohria, and Zaheer (2000) [30] highlighted the “openness” of social networks, concentrating on establishing horizontal and vertical connections between venture enterprises and external organizations. Accordingly, contributions may be made to the development of venture enterprises in terms of resource acquisition, information exchange, and technological innovation. Adler and Kwon (2002) [31] put forward that the set formed by various “relations” is the social network. This may be observed from the definitions asserted by many scholars in that the characteristics of a social network are the focus of the network’s structure composed of “nodes.” Here, it emphasizes the importance of “relations” within the network structure, the restriction of “social behavior” on network operations, and that a social network refers to a network tie formed via formal and informal interactions among individuals. Johannesson (1998) [5] and Li (2008) [32] divided social networks into personal and business networks. A personal network is a relationship centered on entrepreneurs, while business or organizational networks involve various business activities and tasks. The social network involved in this study belongs to that of a business network.

As a form of academic theory with methodological traits, social networks have gradually been a subject of interdisciplinary research. The statistical methods and conceptual models found in social network theory have been widely used in empirical research in management and have been characterized by the combination of specialized, standardized and institutionalized qualitative and quantitative research.

The TBI plays an important role in fostering the growth of small and medium-sized technology-based enterprises. However, it is difficult to provide systematic support for TBIs solely by the strength of TBIs themselves. Therefore, during an TBI’s development, it establishes close connections with the government, colleges and universities, research institutions, venture capital institutions, legal and financial institutions, and interacts with these institutions to provide multi-level, solid support to incubated enterprises, forming an internally and externally associated social network that is centered on the TBI. The social network provides an integrated platform of external relationship networks for incubated enterprises, reduces the search costs of venture enterprises, makes up for the lack of resources and capabilities of individual enterprises, expands the social networks of incubated enterprises, and improves the success rate of venture enterprises. Networking in regard to TBIs has become a trend. Hansen [33] demonstrated that incubator network density has a positive effect on the growth and performance of incubated enterprises. Moreover, Soetanto et al. [34] showed that social networks centered on TBIs help incubated enterprises obtain more business opportunities and plays a significant role in improving the success rate of venture enterprises.

According to previous literature, most of the current research on TBIs has been of a qualitative nature, with only 15% of these studies devoted to the assessment of incubator performance (Mian et al., 2016). [35] Research on social networks pertaining to TBIs is still in its infancy. most research focus on analyzing the TBIs themselves while ignoring perspectives in networking. Moreover, most of the data used in the literature that analyzes the networking of TBIs are local survey data. The use of

national-level survey data is helpful to form a more objective and detailed analysis on the impact of social networks on the operating performance of TBIs as well as the analysis of its inter-regional differences.

Based on qualitative interviews, Sulafa (2017) [36] takes structural embeddedness (network density), relationship embeddedness (network tie strength), and significance of key stakeholders (network centrality) as appropriate measures of social network. This study refers to his methods, but due to data limitations in this article, it is impossible to measure network density. Therefore, network size is used to explain network structural embeddedness. This investigation adopts network size, network centrality, and network tie strength to measure the social network of TBIs.

2.2.1. Network Size and Operating Efficiency of the TBI

Generally speaking, network size is the number of individuals contained in the network (Thorgren et al, 2009) [37]. In a broad sense, network size refers to the number of partners, such as enterprises, universities, research institutions, intermediaries, and government departments, in an innovative network (Hemphala and Magnusson, 2012 [38]; Xie et al., 2014 [39]). Previous studies have shown that network size has a positive impact on knowledge transfer (Baum et al., 2000 [40], Lechner and Leyronas, 2007 [41]). Bhagavatula et al. (2010) [42] found empirical evidence positing that industrial network size positively influences the number of entrepreneurial opportunities, which was recognized by a sample of Indian startups. A large network size means that an individual has a large number of organizations with which to interact. These interactions may provide the individual with two substantial benefits: the opportunity to obtain a plethora of external information, knowledge, ideas, and other resources; and the participant and its contacts may share resources and reduce transaction costs (Ahuja, 2000 [43]; Hansen et al, 2005 [44]). Therefore, network size can provide richer and more diverse resources for the TBI as well as more opportunities for collaboration. The expansion of network size can provide the TBI itself as well as entrepreneurs with access to resources they do not possess, which is conducive to resource exchange and sharing and helps expand their rational boundaries to obtain new entrepreneurial opportunities. Furthermore, it reduces risks and promotes feasible operation of the TBI, improving the operating efficiency of the TBI. According to the above statements, this paper proposes the following hypothesis:

Hypothesis 1: *The social network size has a significant positive impact on the operating efficiency of the TBI.*

2.2.2. Network Centrality and Operating Efficiency of the TBI

The second network characteristic that is of interest in this study is “actor prominence,” or importance, in the network. Actors are said to be prominent if their ties afford them high visibility among other actors within the network. One of the more commonly used measures of prominence is “degree centrality,” which relates to the number of ties an actor has with other actors and is a simple count of the number of the actor’s network relationships. An actor with a high degree of centrality can communicate directly with many other actors, acting as an important conduit for information, enjoying high visibility and prominence [6].

Network centrality refers to the status of the network individuals within the network. The status of the network individuals at the center of the network is conducive in monitoring the information flow, boasting the advantage of having numerous contacts that are willing and able to provide important opportunities and resources. Higher centrality usually means a higher position in the status hierarchy and is an important source of power (Mehra et al, 2006) [45]. As a result, individuals in this advantageous position are more likely to benefit from the network. Important resources and tacit knowledge inside the network are often limited to dissemination among core members. The closer the individual is to the center, the more information and power it is able to control. Moreover, to a certain extent, that individual may make it work to his or her favor, helping identify opportunities and tolerate risks. If it is possible to grasp key information within the network, the individual will subjectively improve his or her self-confidence, especially in decision making. Similarly, the closer the individual is to the center, the more directly and rapidly he or she connects

with other network members and obtains sensitive information and feedback, which is beneficial in improving the degree of risk tolerance, refining the operating efficiency of the individual (the TBI). Based on the above statements, this paper also postulates the following hypothesis:

Hypothesis 2: *Network centrality has a significant positive impact on the operating efficiency of an TBI.*

2.2.3. Network Tie Strength and Operating Efficiency of the TBI

The most widely regarded definitions of tie strength are that of Granovetter [27], who stated, “The strength of a tie is a (probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confiding) and the reciprocal services which characterize the tie.” Social network tie strength is a quantifiable attribute representing the connection between two nodes, which can be divided into strong and weak ties (Rivanda, 2019) [46]. The stronger the social network, the closer the connection, the more opportunities for information and knowledge sharing, and the deeper the communication between social network members and entrepreneurs. There are strong and weak ties in social network research, which signifies that a strong tie is a type of emotionally close or frequently interacted connection, requiring organizational members to spend more time and energy to maintain. A weak tie, however, refers to a loose tie without organizational members spending too much time and energy to maintain [47].

Manjarrés-Henríquez et al. pointed out that heterogeneous resources are an important prerequisite to improve its own performance [48]. Since the biggest advantage of weak ties is that the frequency of communication between organizations is not high, the familiarity between the two parties is also low. The existence of weak ties means that the frequency of interaction between organizations is less, which may easily lead to large differences between resources owned by organizations (Granovetter, 1973) [27]. Therefore, maintaining weak ties between organizations helps improve the performance of innovative organizations to a certain extent. However, one should focus on its “advantageous” side regarding its impact on performance as well as its “disadvantageous” side. Current research shows that weak ties reduce the efficiency of cross-organizational transfer of information, knowledge, and other resources, which is not conducive in improving performance [49]. Therefore, weak ties may also serve as an obstacle for enterprises in smoothly obtaining innovative resources from the industrial circle. In early stages, the continuous strengthening of ties between the TBI and other individuals within the network is beneficial to the continuous improvement of its innovative performance, however, forming a tie requires resources and effort. When the tie strength established between the TBI and other individuals within the network exceeds a certain threshold, and the original weak tie becomes a strong tie, the TBI must spend an increasing amount of energy and resources to maintain the strong tie with others in the network, which may be an obstacle in improving the operating efficiency of the TBI [50]. In addition, the TBI as well as other individuals in the network (such as universities, research institutions, governments, etc.) always stem from different institutional systems, and large differences exist in value orientation, behavior, and culture between parties [51]. Establishing strong ties with others may easily enable the TBI to engage in too many activities unrelated to its own venture in order to meet the teaching requirements of the school, which will have a “crowding-out effect” on the TBI’s innovation and entrepreneurship activities, ultimately impairing the operating efficiency of the TBI.

Hypothesis 3: *The social network tie strength has an inverted U-shape effect on the operating efficiency of the TBI.*

3. Measurement of the Incubating Efficiency of TBIs

3.1. Data Sources

The data used in this study are derived from the annual national TBI survey conducted by the Torch High Technology Industry Development Center, Ministry of Science & Technology. This research takes the data of TBIs in China from 2016 to 2018 as a sample set and selects TBIs that have existed for three consecutive years based on the principles of universality, representativeness and

continuity to ensure the validity of the data. Total TBI samples from 30 provinces and municipalities in China were selected, excluding Tibet, where the number of TBIs that have existed for three consecutive years was less than 2. Finally, the final number of TBI samples utilizes in this research was 1202.

3.2. Theoretical Model

Data envelopment analysis (DEA) is a systemic analysis tool used to deal with complex systems with multiple inputs and outputs. The DEA method is more widely used to measure efficiency. Previous studies measured innovation efficiency using various DEA methods, however, all viewed the enterprise innovative process as a black box, where the innovation process is a “single stage” process of converting input to output [52]. In view of the fact that multiple input and output units are usually involved when evaluating the operating efficiency of an TBI, and that the DEA method obtains the optimal weight from the actual data of the input and output of the decision-making unit that eliminates researchers’ subjective factors, this study is uniquely advantageous in researching TBIs with multiple inputs and outputs. Therefore, this study utilizes the DEA method when evaluating the operating efficiency of an TBI.

3.3. Index Selection

According to the basic index classification rules of DEA, this paper divides indexes into two categories—input and output indexes. The input indexes are measured according to the material input, human input, financial input and comprehensive input of the TBI, and the output index is measured according to the three aspects of innovation output, economic output and social benefits. There was a total of 3606 observed values from 2016 to 2018.

The index used for material input is the total area of the TBI. The total area of the TBI measures the infrastructure of the TBI. Human input uses two indexes of the number of employees in the management’s organization and the number of entrepreneurial mentors, which reflect the human input of the management department and the training department, respectively. The employees of the management organization are responsible for the daily management and operation of the TBI and provide incubation services for entrepreneurs. Entrepreneurial mentors are successful entrepreneurs or excellent experts, which play an important role in promoting cognitive learning, skill learning and emotional learning of entrepreneurs, so as to affect the adaptability of entrepreneurs [53], accelerate the cultivation of technology-based SMEs and entrepreneurs, and expand the social impact of technical barriers to trade. Financial input uses two indexes—operating cost of the TBI and the amount of financial support, where the operating cost of the TBI reflects the capital investment of the TBI itself, and the amount of financial support reflects the financial support of the government department for the TBI. Science and technology entrepreneurship is considered different from general entrepreneurship. It is a practical activity that externalizes innovative ideas into effective organizational behaviors while providing products or services using high-tech strategies or innovative business models. It has characteristics of high growth, high income and high risk. Moreover, it is different from ordinary entrepreneurship as most of these entrepreneurs are full of entrepreneurial aspirations and possess a certain degree of technical expertise, however, they often lack social experience and enterprise management ability. Targeted entrepreneurship education and training are very necessary for entrepreneurs or potential technology entrepreneurs. In the past, through empirical research and a summary of the successful factors in the operation of business incubators, it was recognized that incubation training is a key factor affecting the performance of incubators [54,55]. Therefore, this study supplements entrepreneurship education and training as input indicators. Entrepreneurship education and training integrates three aspects—human, material, and financial input. These aspects reflect the TBI’s education and training for employees of the incubated enterprises, important among incubation services, which is classified as a comprehensive input index.

In terms of output indexes, Zahra and Covin (1995) believed that the efficiency of enterprises should include two aspects: growth and profitability. In this study, the growth index is defined as

innovation output, and profit index is defined as economic output. Innovation output is measured by the number of valid intellectual properties of the TBI. In terms of economic output, corporate income is a commonly used indicator (for example, Li Qingbo et al., 2018 [56]; Tone and Tsutsui, 2009 [57]). On the one hand, enterprise income can show the competitiveness of products, reflect the level of technological innovation, and also show the economic benefits of enterprises. Therefore, we choose the total revenue of TBIs as one of the indicators of economic output. The amount of venture capital obtained in the current year refers to the total amount of angel investment or venture capital obtained by all incubated enterprises in the TBI in the current statistical cycle. Venture capital plays an important role in the development and growth of enterprises, supporting the R&D of enterprises. Under adequate conditions, the cooperation of venture capital and TBIs is suitable for creating a bridge over the equity and knowledge gap, which means that such co-operations can also have significant economic development effects. TBIs operating on such bases can support small and medium-sized enterprises not only by offering financial and professional help. Whether to obtain venture capital and the amount of venture capital is the embodiment of the strength of the TBI [58]. Therefore, we choose the amount of venture capital obtained in the current year as another economic output indicator. Li Yanping [59] asserted that the social benefits of incubators is an important component in brand development, highlighting the social values of incubators. This investigation measures the social effect of the TBI according to the number of recent college graduates absorbed by the TBI. Social benefits are relative to economic benefits. Generally, the evaluation index of economic benefits can be measured by currency, while the evaluation index of social benefits is a more non-value form. Social benefits are mainly reflected in the aspects related to people and the country, such as increasing employment, improving human living standards, promoting the development of certain industries, etc.[60]Innovative start-ups are often considered to be a key source of job creation.[61,62]Absorbing new college graduates reflects the number of jobs that the TBI can provide for recent college graduates and helps the society solve the problem of employment. Therefore, we choose the number of recent college graduates absorbed as the index to measure the social benefits of TBI. The descriptive statistics on input–output variables are shown in Table 1.

Table 1. Descriptive statistics on input–output variables.

First-Level Index	Second-Level Index	Third-Level Index	Unit	Observed Value	Mean Value	Standard Deviation	Maximum Value	Minimum Value
Input Index	Material Input	Total Area of the TBI	Square Meter	3606	37206.607	47979.873	550000.000	520.000
		Number of Employees of the Management organization	Person	3606	17.561	22.677	1081.000	2.000
	Human Input	Number of Entrepreneurial Mentors	Person	3606	13.251	18.206	500.000	0.000
		Operating Costs of the TBI	Thousand Yuan	3606	8404.765	27704.123	1329004.000	0.000
	Financial Input	Amount of Financial Support	Thousand Yuan	3606	2282.561	7212.631	120100.000	0.000
		Entrepreneurship Education and Training of the Year	Times	3606	24.912	83.966	3109.000	0.000
Output Index	Innovation Output	Amount of Valid Intellectual Property	Pcs	3606	143.288	304.865	7745.000	0.000
		Total Revenue of the TBI	Thousand Yuan	3606	12065.114	61687.887	2160312.000	0.000
	Economic Output	Venture Capital Obtained in the Current Year	Thousand Yuan	3606	21259.544	82774.921	2000000.000	0.000
		Number of Recent College Graduates Absorbed	Person	3606	97.259	143.202	2227.000	0.000

Data source: The Torch High Technology Industry Development Center, Ministry of Science & Technology.

Based on the above evaluation index system, this article used MATLAB 2017b (MathWorks, Natick, MA, USA) to measure the operating efficiency of 1202 TBIs in China from 2016 to 2018, as shown in Table 2.

Table 2. Results of the operating efficiency of TBIs in China from 2016 to 2018.

Variable Name	Observed Value	Mean Value	Standard Deviation	Maximum Value	Minimum Value
Efficiency of TBIs in China in 2016	1202	0.281	0.282	1.000	0.000
Efficiency of TBIs in China in 2017	1202	0.303	0.266	1.000	0.000
Efficiency of TBIs in China in 2018	1202	0.317	0.266	1.000	0.000

In terms of overall efficiency, the average operating efficiency of TBIs in China from 2016 to 2018 was 0.281, 0.303, and 0.317, respectively, indicating that the overall efficiency of TBIs in China was not high and has immense potential to improve and developmental prospects. It is gratifying that the average operating efficiency of TBIs in China has increased annually, demonstrating adequate developmental momentum.

In terms of extreme values, TBIs with an operating efficiency of 1 and TBIs with an operating efficiency of 0 were present, indicating that there may be a large number of inefficient TBIs in China. Here, it is difficult to convert various incubation inputs into efficient outputs, reflecting the polarization of TBIs in China. Moreover, further analysis shows that the distribution of innovation and entrepreneurship resources of TBIs in China was uneven.

Next, according to the method of classification published by the National Statistics Bureau, the 30 provinces and municipalities in China included in the statistics were divided into four regions—eastern, central, western, and northwestern—and the operating efficiency of the TBIs was further summarized and counted according to these four regions, as depicted in Table 3.

Table 3. Descriptive statistics of the operating efficiency of TBIs in China from 2016 to 2018 by region.

Region	Province	Number of TBIs	Mean Value of Operating Efficiency in 2016	Mean Value of Operating Efficiency in 2017	Mean Value of Operating Efficiency in 2018
Eastern Region	Beijing	57	0.339	0.419	0.467
	Tianjin	50	0.284	0.340	0.316
	Hebei	27	0.272	0.272	0.272
	Shanghai	115	0.230	0.286	0.341
	Jiangsu	165	0.338	0.329	0.348
	Zhejiang	75	0.236	0.261	0.298
	Fujian	38	0.411	0.408	0.391
	Shandong	93	0.242	0.250	0.291
	Guangdong	112	0.247	0.344	0.349
	Hainan	2	0.227	0.235	0.444
	Mean Value	73.4	0.283	0.314	0.352
Central Region	Shanxi	10	0.281	0.274	0.277
	Anhui	50	0.360	0.365	0.286
	Jiangxi	10	0.411	0.352	0.327
	Henan	68	0.435	0.409	0.370
	Hubei	30	0.251	0.279	0.253
	Hunan	16	0.258	0.323	0.351
	Mean Value	30.667	0.333	0.334	0.311
Western Region	Inner Mongolia	21	0.169	0.182	0.172
	Guangxi	20	0.134	0.218	0.186
	Chongqing	14	0.216	0.206	0.212
	Sichuan	53	0.227	0.252	0.281
	Guizhou	4	0.578	0.516	0.528
	Yunnan	10	0.122	0.185	0.256
	Shaanxi	20	0.259	0.269	0.291
	Gansu	13	0.215	0.278	0.362
	Qinghai	3	0.088	0.126	0.137
	Ningxia	6	0.235	0.309	0.176
	Xinjiang	9	0.160	0.152	0.181
	Mean Value	15.727	0.218	0.245	0.253
Northeastern Region	Liaoning	33	0.252	0.276	0.294
	Jilin	20	0.275	0.327	0.271
	Heilongjiang	58	0.255	0.204	0.210
	Mean Value	37	0.261	0.269	0.258

Note: Xinjiang contains Xinjiang production and construction corps.

From the above table, we may observe the following:

- (1) Among the four regions in China, in 2016, the average operating efficiency of TBIs in the central region was the highest, while the average operating efficiency of TBIs in the northeastern region was the lowest. In 2017, the average operating efficiency of TBIs in the central region was still the highest, while the average operating efficiency of TBIs in the western region was the lowest among the four regions instead of the northeastern region. In 2018, the average operating efficiency of TBIs in the eastern region was the highest among the four regions in China,

reflecting the continuous economic advantages of the eastern region, which provides strong support for the development of TBIs.

- (2) The average number of TBIs per province in the eastern region was found to be the largest, and the province with the most TBIs was Jiangsu, with 165 TBIs, which were the only TBIs in Jiangsu in operation continuously from 2016 to 2018. In 2018, the average operating efficiency of TBIs in Beijing was the highest, however, not many TBIs existed continuously in Beijing from 2016 to 2018, reflecting the fierce competition among TBIs in Beijing. Furthermore, it demonstrates that TBIs that naturally survive this level of fierce competition have higher operating efficiency.

Table 4. Statistics of the operating efficiency growth rate of TBIs in China (by province).

Top 10 in Operating Efficiency Growth Rate of TBIs		Last 10 in Operating Efficiency Growth Rate of TBIs	
Yunnan	1.098	Shanxi	−0.014
Hainan	0.956	Jilin	−0.015
Gansu	0.684	Chongqing	−0.019
Qinghai	0.557	Fujian	−0.049
Shanghai	0.483	Guizhou	−0.087
Guangdong	0.413	Henan	−0.149
Guangxi	0.388	Heilongjiang	−0.176
Beijing	0.378	Jiangxi	−0.204
Hunan	0.360	Anhui	−0.206
Zhejiang	0.263	Ningxia	−0.251

Table 4 lists the top ten provinces and the last ten provinces with the operating efficiency growth rate of TBIs (from 2016 to 2018), and shows that:

- (1) Yunnan, Gansu, Qinghai, and Guangxi are the four western provinces with backward GDP in the top 10 operating efficiency growth rates of TBIs, showing that various preferential policies of the Chinese and local governments within the incubation industry have attained excellent results. These preferential policies include tax preferences, financial subsidies, talent introduction, rent reduction, etc.
- (2) Jilin and Heilongjiang are the two northeastern provinces in the last 10 operating efficiency growth rates of TBIs, which may have been due to backward financial markets and insufficient resources for innovation and entrepreneurship in the northeastern region.

It can be seen from the above two tables that the operating efficiency of TBIs in the eastern region has increased annually with the support of a favorable local economic environment. The operating efficiency of TBIs in the central region was adequate in 2016 but has declined every year following that, and four of the six central provinces are among the last 10 among operating efficiency growth rates of TBIs. The operating efficiency of TBIs in cities of the western region demonstrates rapid growth with the support of relevant policies, however, due to a poor economic environment, the operating efficiency of TBIs remains low. The operating efficiency of TBIs in the northeastern region is only slightly higher than that in the western region, and the operating efficiency growth rate of TBIs is lower than that of the western region. Financial market improvements in the northeastern region should be accelerated, and the development of the TBI industry should be supported.

4. Empirical Analysis and Results

4.1. Research Method

This paper uses the Tobit regression model to study the relationship between the social network and operating efficiency of the TBI. Tobit regression model differs from the discrete and continuous variable models, where the dependent variable is a bounded variable. The range of the operating

efficiency of the TBI is [0,1], hence, selecting the panel Tobit regression model for measurement confers better accuracy. The standard Tobit model was established as

$$y_i^* = \beta_0 + \sum_{j=1}^k \beta_j x_{ij} + \varepsilon_i$$

$$y_i = y_i^*, \text{ if } y_i^* \in (0, 1]$$

$$y_i = 0, \text{ if } y_i^* \in (-\infty, 0]$$

$$y_i = 1, \text{ if } y_i^* \in (1, +\infty)$$

where y_i refers to the operating efficiency of TBIs in China based on the DEA model mentioned above, and y_i^* is the potential variable that satisfies the hypothesis: when $y_i^* > 1$, $y_i^* = 1$; when $y_i^* \leq 0$, $y_i^* = 0$; and when $0 < y_i^* \leq 1$, $y_i = y_i^*$. x_{ij} represents the influential factors that affect the operating efficiency of the TBI, and β_i is the coefficient to be estimated. The statistical procedures in this part were performed in Stata 15.1 SE version (StataCorp, College Station, TX, USA).

4.2. Variable Declaration

4.2.1. Explanatory Variables

Previous studies often used the number of actors directly related to enterprises to measure network size [44]. However, in this study, due to limitations in data, it was impossible to count the number of actors associated with each TBI. Therefore, this study chooses the logarithmic value of the number of intermediaries contracted by the TBI in measuring network size as the intermediaries help the TBI establish more connections with other actors. Moreover, the more intermediaries contracted by the TBI, the more opportunities to get in touch with other actors in the network, thus expanding the network size.

Additionally, network centrality measures may be used to identify the most active, popular, or influential users within a network [63]. National-level TBIs are TBIs at the national level identified by the Torch High Technology Industry Development Center, Ministry of Science & Technology. When applying for identification as national-level TBIs, the TBIs themselves, incubated enterprises and graduated enterprises must adhere to strict requirements. Accordingly, identified national-level TBIs possess excellent management and entrepreneurial incubation abilities, having high authority within their respective networks, and they are more active and popular than non-state-level TBIs in the network. Therefore, the index of whether it is a national-level TBI is selected to measure network centrality. This study sets the national-level TBI as the treatment group (NATIONAL=1).

According to Granovetter's definition of network tie strength, the measurable dimensions of network tie strength include time, emotional strength, intimacy and reciprocal service. Though tie strength was seen as a multidimensional concept by Granovetter, he assumed that the different dimensions are highly correlated, and he operationalized tie strength as a single dimension based on the frequency of interaction. Since then, most researchers considered tie strength as a single dimension, operationalizing it as either the frequency of interaction [64,65] or the closeness of the relationship [66,67] between two individuals. Even when researchers captured both frequency and emotional closeness in data, they tended to aggregate these two dimensions into a single variable, defaulting to a unidimensional view of tie strength [68]. For example, Pallotti measured network tie strength according to the intensity of the flow of patients transferred between hospitals since the number of patients transferred served as a reliable proxy for the intensity of collaboration [69]. Van der Gaag and Webber (2008) [70] computed tie strength as the simple sum of the frequency of communication, favor exchanges, and value of emotional investment within the relationship. According to an TBI's specifics, the enterprise and social organizations are main actors that the TBI contacts within the network. The enterprise and social organizations must invest in the TBI to gain

understanding and trust. The larger the investment, the higher the frequency of cooperation and intimacy between the enterprise, social organizations and TBI. Therefore, this study utilizes the logarithmic value of investments in enterprises and social organizations to measure network tie strength.

4.2.2. Control Variables

Established Time

The age of the TBI is an important factor that affects the operating efficiency of the TBI. Studies have shown that the efficiency performance of newly established TBIs typically outperforms old TBIs (Johan et al, 2011) [71]. Therefore, this study considers the impact of the TBI's age into account. Moreover, it uses the number of days since establishing the technology business TBI for measurement and takes the logarithm for processing.

TBI Size

The TBI's size is measured by the number of incubated enterprises, and the logarithm is taken for processing.

The Nature of the TBI

The nature of the TBI refers to whether the TBI is a state-owned enterprise or institution. A state-owned enterprise or institution means that the TBI may acquire additional policy support from governmental sectors while benefiting from having more resources, which is conducive to the formation of good operating efficiency of an TBI. This study sets the TBI as a state-owned enterprise as the treatment group (CHAR=1).

Geographical Location

The geographical location refers to whether the TBI is located in a high-tech zone. If the TBI is in a high-tech zone, the TBI may benefit from preferential policies within such high-tech zones. A large number of technology innovative enterprises exist, and public technology platforms and intermediaries gather within high-tech zones, which is beneficial to the incubation TBI's expansion of its network, affecting the operating efficiency of the TBI. This study sets the TBI in a high-tech zone as the treatment group (HTZONE=1).

The Reputation of the TBI

Hsu [72] proposed that reputation is an important intangible asset that can provide economic utility when there is information asymmetry between market participants. Klein [73] proposed that reputation stimulates and promotes cooperative interaction and knowledge sharing among members of an innovative network and supervises and restrains their cooperative behavior by reducing transaction costs, such as negotiation costs and agency costs, speeding up the cooperation process and helping improve the operating performance of the enterprise. This study measures the reputation of the TBI by using the logarithmic value of obtained rewards above the provincial level in the year.

Table 5 reports the variable types and specific indexes.

Table 5. Variable types and specific indexes.

Variable Type	Factor	Index	Symbol
Explained variable	Operating efficiency of the TBI	Operating efficiency of the TBI measured by DEA method	DEA method
Explained variable	Network centrality	Whether it is a national-level TBI	NATIONAL
	Network size	Logarithmic value of number of intermediaries contracted by the TBI	LnINER
	Network tie strength	Logarithmic value of enterprises and social TBIs investment	LnINVEST
Control variable	Established time	Logarithmic value of the number of days since TBI establishment	LnTIME
	TBI size	Logarithmic value of number of incubated enterprises	LnNUM
	The nature of the TBI	Whether it is a state-owned enterprise or institution	CHAR
	Geographical location	Whether it is located in a national high-tech zone	HTZONE
	The reputation of the TBI	Logarithmic value of obtained rewards above the provincial level of the year	LnREWARD

4.3. Model Regression Results and Tests

The impact of network size, network tie strength, and network centrality on the operating efficiency of the TBI is explored in Model 1 of Table 6, and the quadratic term of network tie strength is supplemented in Model 2 to further explore whether network tie strength has an inverted U-shape effect on the operating efficiency of the TBI. Models 3 and 4 represent the stability test. This paper uses the logarithmic value of the number of graduated enterprises in the year to replace the operating efficiency of the TBI. In the current research on TBIs, the number of successful graduates of TBIs is an index commonly used by scholars to measure TBI performance [74,75]. The results demonstrate that all Wald statistics have passed the significance test, and the model is valid as a whole. The LR statistics are also observed to have passed the significance test, indicating that individual random effects exist, and these individual effects play a notable role in the operating efficiency of the TBI. Therefore, the panel Tobit model of random effects should be employed.

First, Model 1 shows that the network size and network centrality are positively significant at significance levels of 1% and 5%, respectively, confirming Hypotheses 1 and 2 while indicating that the TBI can significantly increase its own operating performance by expanding the network size and improving the network centrality.

Second, the results observed in Model 1 demonstrate that network tie strength is positively significant at the significance level of 5%. In Model 2, the quadratic term of network tie strength is found to be negatively significant at the significance level of 5%, indicating that with the increase in network tie strength, the positive impact on the operating efficiency of the TBI is gradually weakened and will eventually inhibit the growth and development of the TBI, conferring a negative impact on the operating efficiency of the TBI. Accordingly, Hypothesis 3 stands.

Third, the established time, size of the TBI, nature of the TBI and reputation of the TBI are positively associated with the operating efficiency of the TBI with a significance level of 1%, indicating that the increase in the established time of the TBI as well as the expansion of the TBI's size helps improve the operating efficiency of the TBI. In addition, TBIs in the form of state-owned enterprises and institutions have better operating efficiency than TBIs of other natures, such as private enterprises.

Finally, the stability test results in Models 3 and 4 show that the network size, network centrality and network tie strength are all similar to the original model, where network tie strength is positively significant and the quadratic term of network tie strength is negatively significant, again confirming

hypothesis 3. Network centrality shows a higher level of significance than the original model. Differences from the original model include the nature of the TBI being no longer significant because TBIs in the form of state-owned enterprises and institutions have higher requirements for the graduation of incubated enterprises. Hence, there is no advantage in terms of the number of graduated enterprises compared to TBIs of other natures. The geographic location is significant at a significance level of 10%.

Table 6. Model regression and test results.

Explained Variable	Operating efficiency of the TBI		Logarithmic value of the number of graduated enterprises in the year	
	Model 1	Model 2	Model 3	Model 4
Network Tie Strength	0.001307** (1.99)	0.0073553* (1.60)	0.0014758* (1.66)	0.0022206** (1.84)
Quadratic Term of the Network Tie Strength		−0.0005833** (−1.93)		−0.0003553* (−1.74)
Network Size	0.0365047*** (6.00)	0.0367225*** (6.04)	0.1407272*** (6.61)	0.1405794*** (6.60)
Network Centrality	0.0314175** (1.91)	0.0330315** (2.00)	0.4618671*** (8.17)	0.4609247*** (8.13)
Established Time	0.0353938*** (3.55)	0.0348263*** (3.49)	0.117115*** (3.40)	0.1167162*** (3.39)
TBI Size	0.0358701*** (4.22)	0.0360057*** (4.24)	0.2869996*** (9.59)	0.2871107*** (9.60)
The Nature of the TBI	0.0319637*** (3.27)	0.0316414*** (3.23)	0.0318413 (0.90)	0.0320767 (0.91)
Geographical Location	0.0114352 (0.88)	0.0115649 (0.89)	0.0712452* (1.61)	0.0711626* (1.60)
The Reputation of the TBI	0.0123126*** (2.61)	0.0122044*** (2.58)	0.0826661*** (4.92)	0.082594*** (4.90)
LR	985.55	984.44	764.84	762.88
p	0	0	0	0
Wald	94.95	96.88	877.72	878.10
p	0	0	0	0

Note: *** means significant at the level of 1%, ** means significant at the level of 5%, and * means significant at the level of 10%. The numbers in parentheses are Z test values.

4.4. Regional Difference Analysis

Table 7 reports the results about the analysis of regional differences. In the central and western regions, network tie strength is significant at the level of 5%, higher than that in the eastern and northeast regions. Moreover, the network size has a significant positive correlation with the operating efficiency of TBIs in the four regions, however, for eastern and central regions compared to western and northeast regions, the expansion of network size has a more significant effect on the operating efficiency of TBIs, statistically significant at the level of 1%. Additionally, there is a positive correlation between network centrality and TBI operating efficiency in the central and western regions, but there is no significant correlation between network centrality and TBI operating efficiency in the eastern and northeast regions. Next, the geographical location of the western region is positively correlated with the operating efficiency of the TBI at a significance level of 1%, indicating that, in the western region, the TBI located in the high-tech zone has a higher operating efficiency, different from other regions. Finally, it is worth noting that in the northeastern region, there is a

negative correlation between the nature of the TBI and the operating efficiency of the TBI at a significance level of 10%, indicating that the operating efficiency of TBIs in the form of state-owned enterprises and institutions in the northeastern region is lower than that of other TBIs, signifying the low efficiency of state-owned enterprises and institutions in the northeastern region.

Table 7. Analysis of regional differences.

Region	Eastern Region	Central Region	Western Region	Northeastern Region
Network Tie Strength	0.0022883* (1.73)	0.0227959** (1.93)	0.0082213** (1.86)	0.0000454* (1.64)
Quadratic Term of the Network Tie Strength	0.0002782 (0.49)	-0.0013129 (-1.19)	-0.0009702** (-1.93)	-0.0007404* (-1.52)
Network Size	0.0366698*** (4.68)	0.0396741*** (2.47)	0.023477* (1.70)	0.0409108** (2.05)
Network Centrality	0.0164582 (0.77)	0.0906958** (2.16)	0.0639835* (1.65)	0.005989 (0.11)
Established Time	0.0513695*** (4.00)	-0.0307795 (-1.10)	0.0110135 (0.48)	0.0224551 (0.76)
TBI Size	0.0249634*** (2.21)	0.0523204*** (2.34)	0.0586894*** (3.26)	0.0132899 (0.50)
The Nature of the TBI	0.0300466*** (2.31)	0.0526463 ** (1.96)	0.0529882*** (2.59)	-0.0170238* (-1.58)
Geographical Location	0.0064158 (0.39)	-0.0211423 (-0.62)	0.0783859*** (2.40)	0.0190025 (0.46)
The Reputation of the TBI	0.0123613*** (2.02)	0.012664 (0.271)	0.0107147 (1.03)	0.0219872 (1.01)
LR	535.80	116.26	191.23	88.28
p	0	0	0	0
Wald	60.40	33.62	35.58	36.62
p	0	0	0	0

Note: *** means significant at the level of 1%, ** means significant at the level of 5%, and * means significant at the level of 10%. The numbers in parentheses are Z test values.

5. Discussion and Conclusions

This investigation mainly focuses on the in-depth scientific analysis of the impact of social networks on the operating performance of TBIs, which is valuable in promoting research on social network theory and operating performance of TBIs. The conclusions put forward by this study may be summarized as follows:

First, we used the DEA model to measure the operation efficiency of China's TBIs, finding that the operating efficiency of TBIs in China demonstrates an increasing trend. The average operating efficiency of TBIs in the eastern region has increased annually, reaching its highest level in China in 2018, and the average operating efficiency of TBIs in the northeastern and western regions is low.

Second, we analyzed the impact of network tie strength, network size and network centrality on the operating efficiency of TBIs through Tobit. Network size has a significant positive impact on the overall operating efficiency of an TBI. Therefore, as mentioned in social network literature, TBIs should use their ties to cooperate and overcome their disadvantages in size [76]. Accordingly, TBIs should actively build a perfect entrepreneurial incubation ecosystem, strengthen cooperation with third-party service agencies like intermediaries and industrial TBIs, expand the number and types of collaborative agents, and realize information exchange and sharing with other collaborative agents over time while enhancing the integration and intercommunication among various entities [77]. Network centrality has a significant positive impact on the operating efficiency of an TBI. TBIs at the national level have better operating efficiency. This confirms the previous conclusion, TBIs certified by public authorities will benefit from favorable financial and economic measures to better meet the specific quality requirements of the physical infrastructure, management, services, and facilities of innovative start-ups, so as to achieve higher operating efficiency [78]. TBIs that are not at the national level should take measures to improve its network centrality in social networks, such as expanding

its brand to generate a more beneficial impact [77]. The social network tie strength confers an inverted U-shape effect on the overall operating efficiency of TBIs. Stam et al. (2014) [7] found that weak ties and network diversity in small firms were positively correlated to performance. Hence, this study confirmed that the operating efficiency of TBIs will not continue to improve as ties are strengthened; strong ties will lead to the decline of operating efficiency. This may be due to the higher motivation associated with strong ties generating diminishing returns [79]. Moreover, strong ties may require additional resources to maintain. Thus, actors may benefit from strong ties only when they require information to constantly flow to them [80]. Therefore, Inspirations for TBIs may include that one may more freely transmit information via weak ties, and TBIs should organize special events and rallies to strengthen such weak ties [81].

In addition, the results also show that the established time, size, nature and reputation of the TBI have a significant positive impact on the operating efficiency. In terms of the established time of TBI, the older generation of TBIs generally have better operating efficiency. The newer generation of TBIs should have a stronger focus on high-tech, ICT, and the most promising innovative start-ups [74], and could take the form of increasingly popular accelerators inspired by the success of Y Combinator (Pauwels et al., 2016) [82], these methods may help new incubators improve operating efficiency. TBIs whose size are bigger should benefit from “agglomeration economies.” Agglomeration supports the initiation and development of inter-firm relationships due to the increased possibility of casual meetings and conversations, allowing the identification of shared interests, and the reduction of uncertainty and transaction costs (Vásquez-Urriago et al., 2016) [83]. A TBI with a lower number of incubated enterprises should provide broader opportunities for networking, knowledge transfer, and experience sharing [84], such as organize or actively participate in more cooperation and exchange activities and joint training with other TBIs. TBIs can make use of media [85], implement symbolic activities, invest in human capital, invest in product development and other actions, which are conducive to the accumulation of reputation of TBIs [86].

Third, we discussed regional differences. Compared with eastern and northeast China, the positive correlation between network tie strength and TBI operation efficiency in central and Western China is more significant. For eastern and central regions compared to western and northeast regions, the expansion of network size has a more significant effect on the operating efficiency of TBIs. There is a positive correlation between network centrality and TBI operating efficiency in the central and western regions, however, there is no significant correlation between network centrality and TBI operating efficiency in the eastern and northeast regions. Moreover, the western region’s geographical location is positively associated with the operating efficiency of the TBI. This confirms Corsi’s view that the local context features play a positive effect on the incubators’ performance [87]. In the specific situation of this article, high-tech zones in the western region have a promotive effect on the operating efficiency of the TBI. Therefore, the western region should actively promote the construction and development of high-tech zones and further implement entrepreneurial incubation policies in high-tech zones. In the northeastern region, there is a negative correlation between the nature of an TBI and its operating efficiency, indicating that TBIs in the form of state-owned enterprises and institutions in the northeastern region have a low operating efficiency. According to previous studies, political ties may have a double-edged sword effect on entrepreneurial innovative performance [88]. Political ties provide TBIs with useful resources and governmental support, however, overreliance on political ties may heavily burden TBIs as excessive resources are required to establish and maintain such ties [89]. TBIs in the form of state-owned enterprises and institutions should further improve their management to provide more professional incubation services for incubated enterprises [90]. For example, putting much more effort into the attraction of promising applicants [91] introduces a selection logic that emphasizes retention based on performance more frequently [92] and tracking incubated enterprises’ business records during the time of incubation and after graduation [93].

Our findings suggest that social networks have a positive impact on the operating efficiency of TBIs. Earlier, some incubation models have been accused of merely acting as life support and keeping tenants alive in order to secure rent and fill their incubation space [82]. However, today’s TBIs have

become the first station for many technology innovation start-ups, providing assistance for science and technology innovation and economic development and easing employment pressure. We think that our study has at least three social implications. First, from the conclusion of the research on the network size, the role of intermediaries has been ignored in the past. In China, the development of intermediaries is not enough—most of them are still in the initial stage, and the government should release positive signals to encourage intermediaries to enter the incubation market. Second, according to the conclusion of the research on the network centrality, it suggests that the gap between the national-level TBIs and non-national-level TBIs is likely to be further widened. The inclination of government policy resources owned by national-level TBIs may prevent private incubators from entering the incubator market. Thirdly, the research result on the network tie strength shows that strong connection will also have a negative impact on the operating efficiency of TBIs. The incubator policy should pay more attention to the management of the amount of venture capital obtained. The incubator managers need to control the cooperation and communication with other actors in the network according to their own situation.

6. Limitations and Future Research

This research possesses some limitations, First, the subject of this study is TBIs in China, which are not classified. Therefore, the differences in TBIs among different industries are ignored. For example, Barbero et al. discussed the classification of incubators and divided them into four types: basic research incubator, university business incubator, economic development incubator and private incubator, and identified the differences in the performance of the four incubator type firms [94], classification research will make the conclusion more specific. Second, in the previous literature, the impact of social networks on enterprises was mostly concentrated in one or several enterprises, and the data mostly used survey data. This study attempts to analyze the impact of social networks on the operating efficiency of TBIs using large samples, hence, the selection of indicators is inevitably not as specific and accurate as the survey data.

Future research should be conducted according to the following aspects. First, future research can analyze the impact of social networks on the operation performance of different types of incubators to attain more targeted conclusions. Second, exploring the limits of motivation associated with strong ties. Specifically, why are strong ties sometimes less helpful than weak ties, even though actors sharing strong ties are more motivated to help one another? Why does connection strength have a negative impact on an TBI's performance when it reaches a certain degree? Additionally, what is the value of this inflection point? Third, it is also valuable to study the impact of social networks on the operating efficiency of TBIs from other aspects, such as network power, network heterogeneity, network density, etc. Finally, a social network's conduction in regard to the operating efficiency of the TBI may be analyzed, that is, how social networks affect the operating efficiency of the TBI? Conducting such analyses may be helpful for further research into social networks in order to propose further recommendations in scientific policy.

Author Contributions: Conceptualization, C.G.; Data curation, Y.F.; Project administration, C.G.; Supervision, C.G.; Writing – original draft, Y.F.; Writing – review & editing, Y.F.

Funding: The APC was funded by School of Economics and Resource Management, Beijing Normal University

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

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