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Chung-Lin Tsai Han-Chao Chang

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Evaluation of critical factors for the regional innovation system within the HsinChu science-based park

Chung-Lin Tsai
Bachelor's Degree Program in Management,
Chang Jung Christian University, Tainan, Taiwan, ROC, and
Han-Chao Chang
Instrument Technology Research Center,
National Applied Research Laboratories, HsinChu, Taiwan, ROC

Abstract

Purpose – The purpose of this paper is to collate relevant literature on the theoretical background of regional innovation systems and factors that impact the operational effectiveness of regional innovation systems.

Design/methodology/approach – The collated information is then used to determine the opinions of experts from industries within science-based parks, and the scholars on the researches of regional innovation systems in Taiwan. The analytic hierarchy process (AHP) is used to evaluate the critical factors of regional innovation systems.

Findings – This study finds that industry cluster effects constitute the most significant operating factor for regional innovation systems within the Taiwanese science-based parks. In addition, this study not only confirms that partners or parent firm location which were advocated by Tödtling *et al.* are also critical to Taiwanese regional innovation systems, but also verifies how well the relationships to partners or parent firm are equally important for expansion the regional innovation systems.

Research limitations/implications – The concepts of regional innovation system have been established since 1990, and related articles have been published from European and Asian scholars, however, seldom does literature offer questionnaires or research items to measure the operational effectiveness of a regional innovation system. Therefore this study has developed a questionnaire, by reviewing literature and verifying it by the AHP method, with Taiwan's HsinChu Science Park as the subject case. For the contribution on theories, this study inducted the construction of new innovation environments, new interactional behavior in regional organization innovation, and injection of new resources into regional innovation as the three main constructs to influence the operational effectiveness of regional innovation systems. In addition, this study has used experts' questionnaire answers and the AHP method to clarify the priority of factors to operate the regional innovation system.

Practical implications – Industry cluster effect, construction of knowledge infrastructure and how close partners or parent firm are (distance and relationship) are the top three factors in HsinChu Science Park. The duties of the government are not merely picking good firms for the regional innovation system, but also making policies and defining regimes, providing a good business environment for campus firms, universities, and research institutions, as well as offering plenty of R&D funding to encourage industry-academia cooperation. Governments must invest in infrastructures, such as: establishing databases, libraries, information networks, the national technical standards for certification, and other public services, to facilitate industry-academia cooperation.

JEL Classification — O32, R31, R58

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Social implications – These research results indicate the operating essentials of regional innovation systems are not limited to interactions among regional organizations. This study suggests that the success or failure of a new regional innovation system would instead, be dependent on the regional environment, as in software planning and support, as well as the relationship of innovation with policy implementation and administration.

Originality/value – Results showed that the top-five factors influencing the operational effectiveness of regional innovation systems are the industry cluster effect, the construction of knowledge infrastructure, how close to partner's or parent's firm (distance and relationship), import of foreign capital and technology, and the implementation of regional innovation policy.

Keywords Regional innovation system, Analytic hierarchy process (AHP), Parent firm location

Paper type Research paper

1. Introduction

In recent years, enterprises have begun focussing on the use of external resources to enhance innovation, including cooperation and interaction with other companies, research institutions, and university research units. These changes have led to a new generation of innovation systems. Innovation systems are developed based on interactive learning processes. Lundvall (2010) further emphasized that the diversity and proximity of the performance and knowledge sources of innovation systems are the factors that decide the success or failure of these systems. In the past, scholars conducted investigations on the spatial definition of innovation systems by using "nations" as units (Lundvall, 2010). However, most economists in the industry focus only on the national level, believing that innovation occurs in a particular state and is facilitated by designated research environments, education and financial systems, and national policies.

In addition, the concept of regional innovation systems is relatively new, having first appeared in the early 1990s (Cooke, 2002). Cooke (1998), viewed "regional innovation systems" as systems that promoted interactive learning between organizations in an embedded milieu. Doloreux (2002) indicated that, without further comparative studies on regional innovation systems, it would be very difficult to fully understand and capture the application possibilities of the analytic framework of regional innovation systems. Similarly, he argued that it would be challenging to identify the potential impact of the analytic framework of regional innovation systems on the regional and industrial development of different regions. However, the comparative case study method allows a more thorough investigation of variables that are usually implicit; that is, the observation of phenomena is conducive to the investigation of differing results between various regional applications. Cooke (2010) further stressed that regional innovation systems can enhance economic growth, employment, and competitiveness. Meanwhile, regional innovation systems can be seen as a vehicle for enterprise and regional development. Its role and performance can activate potential resources and information, enhance flexibility, and reduce uncertainty, thus optimizing the regional innovation environment.

For these reasons, the purpose of this paper is to collate relevant literature on the theoretical background of regional innovation systems and factors that impact the operational effectiveness of regional innovation systems. The collated information is then used to determine the opinions of experts from industries within science-based parks, and the scholars on the researches of the regional innovation system in Taiwan. The analytic hierarchy process (AHP) is used to evaluate the critical factors of regional innovation systems. The results of the study can serve as a reference for the development of regional innovation systems in East Asian science-based parks as well as for enhancing the performance of these systems.

2. Literature review

2.1 Background of regional innovation systems

The literature on innovation systems conceptualizes innovation as a process of evolution and society, suggesting that technological innovation is the product of the interaction between numerous actors. It also reflects the perception of technological innovation shaped by factors within and beyond the company and the change from a single enterprise and an internal network to multiple actors and the development of a network. Furthermore, a regional innovation system is defined in more general terms as, “the institutional infrastructure supporting innovation within the production structure of a region” (Cooke, 2010). Since the 1990s, “regional innovation,” which is considered an important tool for policy making, has been enjoying widespread success in developed countries.

Maskell and Malmberg (1999) suggested that three elements constitute regional innovation systems. The first element is “interactive learning,” which refers to the interactive process of knowledge generation wherein the actors create a shared asset in a production system. The second element is “environment,” which refers to clusters in an open territory and can include laws and regulations, standards, values, human resources, and material resources. The third element is “embeddedness,” which refers to the creation and production of the economy and knowledge by organizations inside and outside of the system. These different forms of creation and production are difficult to replicate because they require the application of a social interaction model.

The new regional science and modern regional development theory further emphasize the importance of collective learning and social and cultural environments (Zheng, 2014). The social interaction of innovative systems refers to the collective learning process involving various departments of a company. Through geographical proximity and aggregation, this environment facilitates mutual learning and technological innovation, diffusion, and accumulation between various actors (Asheim, 2007). In other words, regional innovation systems are characterized by cooperative innovation and support toward innovation activities. Tödtling and Kaufmann’s (2002) and Asheim *et al.* (2011) studies of regional innovation showed that partner’s locations also play a significant role in the innovation performance of firms. In some circumstances, it can also lead to the formation of regional innovation systems.

The latter, on the other hand, refers to the innovative culture that supports the continued evolution of the company and the system. It emphasizes the behavior of actors through inter-regional exchange and learning and the generation of knowledge commons through competition and cooperation, thus forging a number of formal and informal relationships to reduce uncertainty and lower transaction costs. Some scholars suggest that innovation stems from the network environment of local culture, including the underlying entrepreneurship, the system of competition and cooperation between enterprises, and the social structure (Asheim, 2007; Cooke, 2010; Fukugawa, 2008). These elements are characterized by their strong regional embeddedness (Maskell and Malmberg, 1999), which are greatly interoperable with regional innovation systems. The popularity of the concept of regional innovation systems is closely linked to the emergence of not only a large number of regional innovation policies but also regional industrial clusters and active regional industrial competitiveness worldwide. The next section investigates and summarizes the factors relevant to regional innovation systems through a review and analysis of literature.

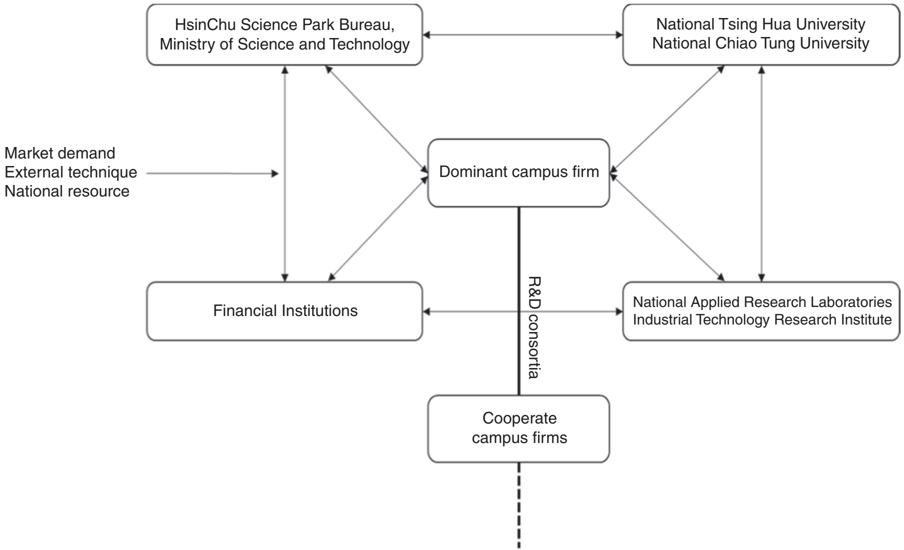
2.2 HsinChu science park (HSP): a high-tech industrial innovation system in Taiwan's silicon valley

HSP, also known as Taiwan's Silicon Valley, was established in 1980. The HSP is administratively subordinate to the Science Park Administration Bureau (Lee and Kang, 2008). Ever since the founding of the HSP, the local government has continually recruited enterprises and expropriated nearby land in an effort to develop the HSP into a center for high-tech technologies including integrated circuits, computers and peripherals, communications, optoelectronics, precision machinery, and biotechnology. Currently, the HSP is home to 517 firms and employs a workforce of more than 150,000 people , with a paid-in capital of over 1 trillion NTD, most employees in the park are university graduates or above. The Science Park Administration Bureau, in collaboration with universities and research institutions involved in the innovation system, has held various professional and technical training programs for employees, with the aim of maintaining the R&D capabilities of the innovation system (Chang *et al.*, 2012). From 2007 to 2012, a total of 55,881 people participated in the programs.

As of December 2014, the integrated circuit industry accounted for nearly 70 percent of the total revenue in the HSP, representing the largest industry in the science park. The revenue generated by the optoelectronics industry accounted for nearly 20 percent of the total, representing the second-largest industry in the HSP. The third-largest industry is the computer and peripherals sector, followed by communications, precision machinery, and biotechnology. Chang *et al.* (2012) attributed the success of the HSP innovation system to three key factors: first, as one of the world's semiconductor R&D centers, HSP houses as many as 195 semiconductor manufacturers including UMC, TSMC, and Winbond Electronics. Second, the development of its regional innovation systems is similar to that of Wales, where the government planned science and industrial parks within which, firms, research institutes, universities, intermediaries, and government-related organizations are located. Governmental research institutes such as the National Applied Research Laboratories, universities such as National Chiao Tung University and National Tsing Hua University, and the HSP Bureau and the Ministry of Science and Technology are located in the HSP area, and offer high-end experimental facilities, academic knowledge, and government support, for HSP campus manufacturers (Figure 1). Finally, the HSP owns the most integrated and complete industrial chain in the semiconductor field, and it offers a strong industrial model for the semiconductor industry. In addition, the campus manufacturers are not only key original equipment manufacturers of global computer and optoelectronics products, but also the main engines of Taiwan's foreign exchange reserve.

2.3 Complete R&D alliance system

Some scholars such as Fuller (2014), Yoon *et al.* (2015), and Chang *et al.* (2012) noted that, as an important center of the integrated circuits industry, the HSP has formed a complete R&D alliance system that covers the entire industry chain from upstream to downstream, backed by large-scale, government-supported research programs (Figure 1). Based on Dicken's (2011) global value chain framework, this study categorized firms in the value chain into three segments, namely, upstream (semiconductor material, production equipment manufacturers), midstream (IDM, passive electromechanical component manufacturers), and downstream (integrated circuit vendors). Representative upstream manufacturers include SunEdison (silicon wafer material), Chroma ATE Inc. (wafer testing equipment), and Germonic Inc. (wafer automation equipment). Representative midstream manufacturers include MediaTek Inc. (IC design), Qualcomm (IC design),



Source: Chang *et al*. (2012)

Figure 1.
The HSP regional innovation system

TSMC (IDM), UMC (foundry), Taiwan Mask Corp. (mask fabrication), Anpec Electronics Corp. (packaging and testing), and Phoenix Silicon International Corporation (passive electromechanical components). Representative downstream manufacturers include Winbond (DRAM) and Realtek (applied IC).

2.4 Factors that affect the operation of regional innovation systems

Asheim and Isaksen (2002), indicated that regional innovation systems are important tools in the study of regional development of the economy. The regional innovation system not only increases their collective innovative capacity, but may also serve to counteract technological "lock-in" (the inability to deviate from an established but outmoded technological trajectory) within regional clusters of firms (Asheim, 2007). Based on existing case studies of innovation systems, Achibugi and Michie (1997) concluded that the structure of innovation systems can be evaluated from six main components, education and training, basic science and technological capabilities, industrial structure, analysis of technology strengths and weaknesses, interaction within the system and topology, and technology introduction.

The regional contexts generated through different regional development trajectories form the unique characteristics of each region. These include the regulatory role of the public sector, culture, and language habits among other systems. In terms of regional innovation systems, these elements directly impact the development and modification of these innovative activities and systems. In the analytic framework of regional innovation, strategic policies and measures are formulated mainly through the concentration of resources, to improve the local business environment, and the strengthening of links between business actors in regional innovation platforms. Therefore Cooke *et al.* (2000), Asheim *et al.* (2011), and Treibich *et al.* (2013) found most of the spin-offs firms which are located near their partners or parent firms can follow a template for a regional innovation policy that aims to amplify the regional economies.

Through studies on science and technology policies and regional growth, Sternberg (1996) found that there are 10 main factors influencing high-tech regional developments. These factors are market proximity, regional human resources, the influence of big businesses, industrial networks, the regional environment, R&D institutions, venture capital, entrepreneurial spirits and related technology-based outcomes, technology systems, and primary innovators. Baptista and Swann (1998) indicated that clusters of enterprises within a region bring together professionals, instigate the exchange of expertise, and furthermore assist in knowledge and information flow, technology transfer, and technology diffusion and innovation among manufacturers. In addition, Albino's *et al.* (1998) study indicated that the leading manufacturer in a region equipped with sufficient resources and knowledge, as such, exerts substantial influence over establishing relationships between manufacturers.

Cooke (2010) suggested that when a group of companies or firms are concentrated within a small geographic area and are commonly members of the same or related industries, each cluster would include one or a small number of flagship companies. These companies play a dominant role in the cooperation with other manufacturers and in the establishment of a network system. Meanwhile, Tödtling and Kaufmann (2002) indicated that regional innovation systems should be equipped with the industrial cluster effect of the region's main manufacturers, including their downstream industries, research institutes, financial institutions, and industry associations and organizations, to enable them to overcome obstacles during the innovation process. Furman *et al.* (2002) indicated that industrial clusters were most advantageous for regional innovation. The competitive pressures and market opportunities experienced by geographically proximate firms within the cluster were more visible and the rapid flow of information and human resources was beneficial to introducing industry knowledge spillovers and strengthening the advantage of regional innovation. Lai *et al.* (2005) and Yoon *et al.* (2015) emphasized that industrial clusters that accumulated high levels of innovation had assembled information that facilitated the next round of innovation, since the ability to innovate fully would be a function of the technological levels already achieved.

Fritsch and Schwirten (1999) investigated the innovative roles of industry-university cooperation and public R&D institutions from the perspective of regional innovation systems and indicated that the policies introduced by public R&D institutions stimulate the development of the region and is therefore a major influencing factor for regional innovation systems. Fukugawa (2008) points out that it is important for regional innovation policymakers to design incentive mechanisms that promote knowledge transfer according to the characteristics of the regional innovation system. Albino *et al.* (1998) confirmed that geographical proximity is a key factor in the development of regional innovation systems. The study used industrial districts as an example for the development of regional innovation systems, indicating that the geographical proximity of the industrial areas provided a strategic advantage gained from the establishment of complementary resources and technology exchange. This contributes to the transfer and flow of knowledge between firms and accelerates the speed of transfer, whereby important knowledge is intercepted, and increases opportunities for innovation. According to Powell *et al.* (2002) and Zucker *et al.* (1998), venture capital funds are indispensable for innovation performances; these funds are crucial to the attainment of commerce. Additionally, if the enterprise is supported by ample venture capital, it would also be equipped with sufficient resources to achieve innovation objectives.

Therefore, this study has collected analyses of relevant literature on regional innovation systems showing that scholars have discussed and explored the construction of efficient regional innovation systems (Table I) on the following levels:

1. Construction of new regional innovation environments including the development of industrial structure and industry clusters and the application of the cluster effect, the governing role played by the public sector in regional innovation systems, the impact of institutional arrangements on regional innovation systems, the construction of knowledge infrastructure, and the development of key research institutions and universities (Achibugi and Michie, 1997; Albino *et al.*, 1998; Asheim, 2007; Chang *et al.*, 2012; Cooke, 1998; Doloreux, 2002; Fernandez-Ribas and Shapira, 2009; Fukugawa, 2008; Lai *et al.*, 2005; Maskell and Malmberg, 1999; Tödtling and Kaufmann, 2002).
2. Interaction behaviors in regional organization innovation including the nurturing and identifying of regional innovation culture, trust between enterprises, willingness to participate in knowledge sharing and interactive learning, the enhancement of the overall value of the region, the establishment of regional innovation alliances and innovation performance results, and the innovation leader's resources and ability to drive business innovation in the region (Asheim *et al.*, 2011; Baptista and Swann, 1998; Cooke, 1998, 2010; Fukugawa, 2008; Lundvall, 2010; Martín-de Castro *et al.*, 2013; Maskell and Malmberg, 1999; Sternberg, 2014; Treibich *et al.*, 2013).
3. Injection of new resources for regional innovation refers to the injection of regional innovation system funds from the public sector, the introduction of foreign investment and technology, and the cultivation and nurturing of technological innovation personnel (Achibugi and Michie, 1997; Chang *et al.*, 2012; Mangematin *et al.*, 2014; Maskell and Malmberg, 1999; Powell *et al.*, 2002; Treibich *et al.*, 2013; Zucker *et al.*, 1998; Khayyat and Lee, 2015).

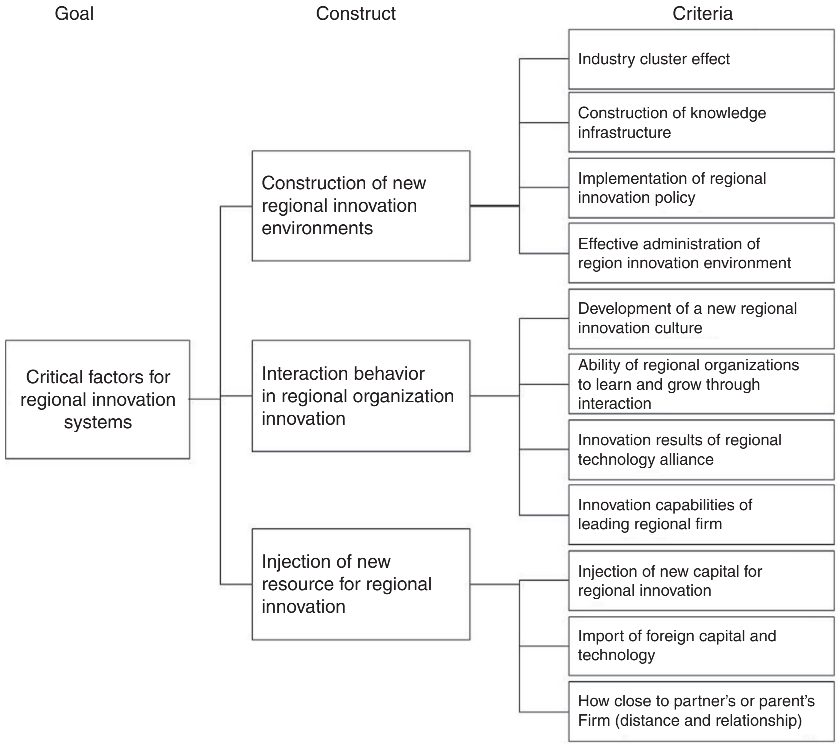
3. Research method and research subjects

A cross-sectional, descriptive, and inferential research study design was used in the current study. Purposive sampling techniques were employed, the expert-level respondents came from HSP Bureau (five government senior staff), National Chiao-Tung University (three professors), National Tsing-Hua University (six professors), the Industrial Economics and Knowledge Center of Industrial Technology Research Institute (five government researchers), National Applied Research Laboratories (three government researchers), and Hsinchu Science-Based Industrial Park campus firms (eight senior managers), all with sufficient knowledge regarding regional innovation systems.

When these experts and scholars agreed to fill in the questionnaire (Likert's five-point scale, Table I), the questionnaire was sent to the allocated e-mail address. Frequent follow-up calls were made when the questionnaire was not returned within ten days after having been issued. Finally, a total of 30 questionnaires were issued, and 30 were returned, a total of 30 surveys were distributed with 30 returned (100 percent). No adjusting for non-valid responses ($n = 0$), 30 were available for analysis. Figure 2 illustrates the factors affecting the operation of a regional innovation system. Through induction, a regional innovation system architecture has been constructed in this study based on a literature review (Figure 2). One-order confirmatory factor analysis was

Construct	Question items	Literature source
Construction of new innovation environments in the region	1. Our company may benefit from the presence of other similar firms within the region, which enable the mutual enhancement of innovation capacity	Asheim (2007); Lai *et al.* (2005)
	2. This region gathers top-class national research institutions and attracts blue-chip manufacturers	Chang *et al.* (2012); Tödtling and Kaufmann (2002)
	3. Industrial knowledge and information smoothly flow in the region	Maskell and Malmberg (1999)
	4. A knowledge base and hardware facilities (e.g. wireless networks, research institutions, and universities) in the region where our company is located have been comprehensively established	Achibugi and Michie (1997); Albino *et al.* (1998); Asheim (2007)
	5. I believe that the industrial innovation policies formulated by the government are conducive to innovation activities among firms	Cooke (1998); Fukugawa (2008)
	6. I think the government is committed to developing this region into an environment that facilitates innovation	Cooke (1998); Doloreux (2002); Fernandez-Ribas and Shapira (2009)
Interaction in regional organization innovation	1. I think most firms in this region are actively engaged in innovation	Sternberg (2014)
	2. I think most firms in this region can share the fruits of their innovation with one another	Baptista and Swann (1998); Martín-de Castro *et al.* (2013)
	3. Our company is currently cooperating with research organizations (e.g. universities, incubation centers, government agencies, and other research institutions) on innovation projects	Cooke (2010); Fukugawa (2008); Lundvall (2010)
	4. To facilitate innovation, there is an established mechanism through which firms operating in the region are closely linked	Asheim *et al.* (2011); Treibich *et al.* (2013); Tsai and Chang (2016)
	5. I believe that the firms operating in the region may learn from one another through exchange, and that fruitful innovations have been achieved	Baptista and Swann(1998); Cooke (1998); Maskell and Malmberg (1999)
Injection of new resources into regional innovation	1. I think that the industrial innovation policies formulated by the government can reduce our company's tax expenses while enhancing its innovation capability	Achibugi and Michie (1997); Khayyat and Lee (2015)
	2. I think the tax deduction policy provided by the government through the industrial innovation act will improve the region's level of innovation	Tsai and Chang (2016)
	3. Compared with other regions, more foreign-funded firms are located in the region where our company is situated	Chang *et al.* (2012); Powell *et al.* (2002); Zucker *et al.* (1998)
	4. I think that greater proximity between our company and the parent firm or partner firms promotes the introduction of their innovative technologies	Chang *et al.* (2012); Treibich *et al.* (2013)
	5. I think the parent firm or partner companies may, depending on need, provide our company with recommendations on policy making regarding personnel training	Maskell and Malmberg (1999); Tsai and Chang (2016)

Table I.
Questions and reference sources pertaining to the performance of the regional innovation system



Source: Tsai and Chang (2016)

Figure 2. Framework of factors affecting operation of a regional innovation system

conducted on the system using SPSS 15.0. AMOS 7.0 was used to perform second-order confirmatory factor analysis, reliability, and validity tests. Finally, expert technical analysis (AHP) was utilized to investigate the research topic.

3.1 Analysis of the framework of this study

3.1.1 Reliability analysis. To determine the reliability of this study, and to verify whether the results were consistent and stable, the Cronbach's α and composite reliability were computed to test the reliability of the scale. The results are shown in Table II. The Cronbach's α coefficient ranged from 0.812 to 0.885, by far exceeding

Construct	Quantity of questions	Mean	SD	Cronbach's α	Composite reliability
Regional innovation system performance	16	4.5458	0.8706	0.903	0.867
Construction of new innovation environments in the region	6	4.5125	0.9778	0.853	0.843
Interaction in regional organization innovation	5	4.7431	0.9453	0.812	0.870
Injection of new resources into regional innovation	5	4.3819	1.1582	0.885	0.856

Table II. Reliability analysis of regional innovation system performance scale the commonly accepted reliability standard of 0.7 (Cho and Kim, 2015). The composite reliability was between 0.843 and 0.870, which was far greater than the commonly accepted composite reliability standard of 0.6 (Cho and Kim, 2015). These results indicate that the regional innovation system performance scale had superior reliability. In other words, the results measured with the scale exhibited acceptable consistency and stability.

3.1.2 Validity analysis. To further measure the validity of the regional innovation system performance scale, this study explored the discriminant validity and convergent validity. Regarding the validity of the scale, this study performed confirmatory factor analysis to test the model fit of each construct and analyze the constructs' convergent validity. Fornell and Larcker (1981) argued that to have convergent validity, three characteristics must be present: first, all standardized factor loadings must be greater than 0.5 and significant; second, the composite reliability must be greater than 0.6; and finally, the average variance extracted (AVE) must be greater than 0.5. One-order confirmatory factor analysis was performed on the regional innovation system performance scale. The details are elaborated as follows.

3.2 AHP description

The AHP method was developed by Saaty (1990). This method has been used extensively since it was invented and is mainly suitable for planning, decision sequence, alternative solutions, and performance evaluation. It has been extensively used in behavioral science, marketing management and portfolio investment and is applied in decision-making issues under uncertain status with multiple evaluation criteria. The method systemizes the complicated issues and decomposes the issue with the hierarchy method and through an easy comparison to judge the weight and decide the sequence, decision makers can evaluate the multiple criteria.

AHP decomposes problems into a hierarchy of a goal, attributes, and alternatives. It enables decision-makers to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of quantitative and qualitative factors in a systematic manner under multiple conflicting criteria. AHP is a powerful decision analysis technique in the area of multi-criteria decision making. It also makes use of pair-wise comparisons, hierarchical structures, and nine-point ratio scaling to apply weights to attributes. The basic assumptions of AHP are as follows (Figure 3):

(1) a system (or issue) can be classified into many comparable hierarchies to form a hierarchy structure with orientation;

(2) the principles in each hierarchy can take the neighboring principle (hierarchy above) as the base for pair-wise comparison;

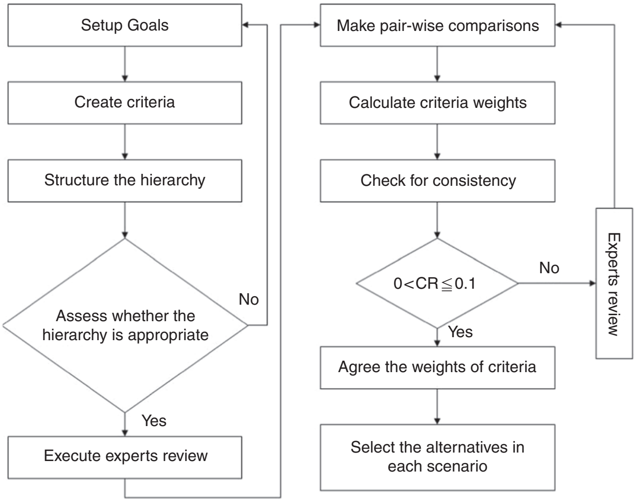
(3) the result of pair-wise comparisons can form a ratio with absolute number scale;

(4) after pair-wise comparisons, a pair-wise comparison matrix is positive and reciprocal is symmetric against diagonal; and

(5) the pair-wise matrix allows one which has no transitivity to test the degree of non-conformity.

According to (Saaty, 2012), when AHP is used to solve decision-making issues, it mainly involves seven steps, and two subordinate steps:

- Step 1: Establish hierarchy structure.



Source: Saaty (2012)

Figure 3. The AHP calculating process

- Step 2: Calculate the weight of the criteria of each hierarchy, which can be divided into three subordinate steps:
  - – Step 2.1: Establish a pair-wise comparison matrix.
  - – Step 2.2: Construct a pair-wise comparison matrix with a scale of relative importance.

An attribute compared with itself is always attributed to the value 1, so all the main diagonal entries of the pair-wise comparison matrix are 1. Numbers 3, 5, 7, and 9 mean moderate importance, strong importance, very important, and absolutely important; and 2, 4, 6, and 8 for compromise between 3, 5, 7 and 9. If there are m attributes, then the pair-wise comparisons would yield a square matrix as matrix A (Figure 4).

- Step 3: Find the relative normalized weight (w_j) of each attribute, by calculating the geometric mean (GM) of the row, normalizes the GMs of rows in the comparison matrix. The GM method of AHP is used to find out the relative normalized weights of the attributes because of its simplicity and ease to find out the maximum eigenvalue and reduce the inconsistency in judgments. At the same time, where Matrix is A, the problem involves assigning a set of numerical weights $w_1; w_2, \ldots, w_m$ to the m criteria $a_1; a_2, \ldots, a_m$ that " reflects the

$$A=[a_{ij}]=\begin{bmatrix} 1 & a_{12} & \cdots & a_{1m} \\ a_{21} & 1 & \cdots & a_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & 1 \end{bmatrix}=\begin{bmatrix} 1 & a_{12} & \cdots & a_{1m} \\ 1/a_{12} & 1 & \cdots & a_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1m} & 1/a_{2m} & \cdots & 1 \end{bmatrix}$$

Notes: $a_{ij}=1$; $a_{ji}=1/a_{ij}$; $i, j=1, 2, \ldots, m$

Figure 4. Pair-wise comparison matrix with a scale of relative importance

recorded judgments." If A is a consistency matrix, then the relations between weights wj and judgments a_{ij} would be simply given by $w_i/w_j = a_{ij}$ (for $i, j = 1, 2, \ldots, n$).

- Step 4: Find out the maximum eigenvalue "λ_{max}".
- Step 5: Calculate the consistency index as equation $CI = (\lambda_{max} - m)/(m-1)$. The smaller the value of CI, the smaller the deviation is from the consistency. The consistency in the judgments of relative importance of attributes reflects the cognition of the analyst.
- Step 6: Obtain the random index (RI) for the number of attributes used in decision making.
- Step 7: Calculate the consistency ratio $CR = CI/RI$. Usually, if $CR \leqq 0.10$ it implies a satisfactory degree of consistency in the pair-wise comparison matrix, but if $CR > 0.10$, serious inconsistencies might exist and AHP might not yield meaningful results (Saaty, 1990).

Regarding the AHP theory, which has been developed for many years, there are many software packages to assist with the calculation issues, however, each package has advantages and disadvantages. Ossadnik and Lange (1999) mentioned that there are three ways: "Auto Man," "Expert Choice" and "HIPRE" analysis AHP structure; they used a 12 dimensional study to determine the relative merits of these three software. Ossadnik and Lange (1999) found "Expert Choice" was better than "Auto Man" or "HIPRE," therefore, this study also utilized "Expert Choice" to analyze the returned questionnaires.

4. Results and discussion

The measurement results for the "regional innovation system performance" constructed in the one-order measurement model are shown in Table III, where $\chi^2/df = 1.192$ (less than 3), $RMR = 0.045$ (less than 0.05), $RMSEA = 0.043$ (less than 0.8), and the GFI, NFI, AGFI, and CFI values were greater than 0.9, indicating a satisfactory model fit. Additionally, the standardised factor loadings ranged between 0.621 and 0.861 (Table III), and all were greater than 0.5; the composite reliability scores ranged between 0.843 and 0.870, all exceeding 0.6. The AVE for each construct ranged between 0.520 and 0.629, all above 0.5 (Table IV). These results indicate that the regional innovation system performance scale has a favorable convergent validity in one-order measurement.

The regional innovation system architecture comprises three major constructs including "construction of new innovation environments in the region," "interaction in regional organization innovation," and "injection of new resources into regional innovation." Consequently, this study performed a second-order confirmatory factor analysis on the regional innovation system performance scale. In second-order measurement (as shown in Table V), $\chi^2/df = 2.633$ (less than 3), $RMR = 0.049$, $RMSE = 0.059$ (less than 0.8), and the GFI, NFI, AGFI, and CFI values exceeded 0.9, suggesting a favorable model fit. Additionally, the analytical results revealed that the composite reliability (Table II) of the performance scale of the regional innovation system architecture was 0.867 (greater than 0.6). The standardized factor loadings (Table V) ranged between 0.806 and 0.851 (far exceeding 0.5); and the AVE was 0.684 (over 0.5). These results indicate that the performance constructs of the regional innovation system had excellent convergent validity in second-order measurement.

Table III. One-order confirmatory factor analysis was performed on the regional innovation system performance scale

Construct	No. of questionnaire	Standardized factor loading	SE	*t*-value
Construction of new innovation environments in the region	REC1	0.621	0.093	50.955***
	REC2	0.831	0.096	47.661***
	REC3	0.719	0.085	54.577***
	REC4	0.700	0.082	51.661***
	REC5	0.720	0.085	51.133***
	REC6	0.753	0.088	49.652***
Interaction in regional organization innovation	ROI1	0.654	0.078	59.547***
	ROI2	0.861	0.080	55.266***
	ROI3	0.852	0.083	58.988***
	ROI4	0.787	0.078	60.042***
	ROI5	0.813	0.081	56.951***
Injection of new resources into regional innovation	RRI1	0.764	0.085	50.650***
	RRI2	0.799	0.082	52.173***
	RRI3	0.639	0.096	44.142***
	RRI4	0.751	0.096	46.298***
	RRI5	0.727	0.086	51.972***

Notes: $\chi^2 = 51.59$; df = 52; $\chi^2/\text{df} = 1.192$; RMR = 0.045; RMSEA = 0.043; GFI = 0.957; NFI = 0.961; AGFI = 0.928; CFI = 0.991. ***$p < 0.01$

Table IV. Correlation coefficient and AVE for each construct

	REC	ROI	RRI
REC	***0.520*** *(0.721)*		
ROI	0.502**	***0.629*** *(0.793)*	
RRI	0.614**	0.599**	***0.545*** *(0.738)*

Notes: REC stands for the construction of regional innovation environment, ROI represents the innovative interaction between organizations in the region, and RRI represents the injection of regional innovation resources. The numbers on the diagonal in bold italics represent the AVE. The parenthesized italic numbers on the diagonal represent the square root of AVE. **Significant at 0.01 level, denoting a significant correlation

Table V. Second-order confirmatory factor analysis on the regional innovation system performance scale

Goal	Construct	Standardized factor loading	SE	*t*-value
Critical factors for regional innovation system	Construction of new innovation environments in the region	0.806	0.071	78.573***
	Interaction in regional organization innovation	0.851	0.070	77.148***
	Injection of new resources into regional innovation	0.824	0.068	82.476***

Notes: $\chi^2 = 84.262$; df = 32; $\chi^2/\text{df} = 2.633$; RMR = 0.049; RMSEA = 0.059; GFI = 0.924; AGFI = 0.910; NFI = 0.932; CFI = 0.944; AVE = 0.684(0.827). ***$p < 0.01$

4.1 Data analysis of hierarchy

Table VI shows that the CI for the first hierarchical is 0.04 and the CR is 0.069 (CI ≦ 0.10 and CR ≦ 0.10 imply a satisfactory degree of consistency in AHP method; Saaty, 1990), indicating that the eigenvalue vectors of this hierarchical are consistent. Research results show that the construction of new environments for regional innovation is the key factor, with a relative weight of 59.2 percent. In other words, experts believe that the regional innovation requires the construction of complete hardware environments, as well as effective policy implementation and regulation. The second most important factor is the injection of new resources for regional innovation, with a relative weight of 29.7 percent. Experts believe that the relative weight of new regional innovation systems is roughly 30 percent, depending on the injection of innovation capital, novel technology and how good the relationships to partner's or parent's firm are.

Table VII shows that the eigenvalue vectors for the second hierarchical of the construction of regional innovation organizations are consistent; the CI and CR are 0.023 and 0.026, respectively (CI ≦ 0.10 and CR ≦ 0.10 imply a satisfactory degree of consistency in the AHP method; Saaty, 1990). Research results indicate that the interviewed experts held the promotion of industry cluster effects and construction of knowledge infrastructures in high regard, considering them to be important factors in completing the construction of new environments for regional innovation, with combined relative weights of 80.3 percent.

Table VIII shows that that the eigenvalue vectors of the second hierarchical for interactional behavior for innovation in regional organizations are consistent, with CI and CR values of 0.007 and 0.008, respectively (CI ≦ 0.10 and CR ≦ 0.10 imply a satisfactory degree of consistency in the AHP method; Saaty, 1990). Research results

Table VI.
Relative weights and rankings of the main criteria

First hierarchical (main criteria)	Weights	CI	CR	Eigenvalue	Ranking
Construction of new innovation environments	0.592	0.04	0.069	3.081	1
Interaction behavior in regional organization innovation	0.111				3
Injection of new resources into regional innovation	0.297				2

Table VII.
Relative weights and rankings in the construction of regional innovation environments

Second hierarchical (sub-criteria)	Weights	CI	CR	Eigenvalue	Ranking
Industry cluster effect	0.498	0.023	0.026	4.069	1
Construction of knowledge infrastructure	0.305				2
Implementation of regional innovation policy	0.133				3
Effective administration of regional innovation environment	0.064				4

Table VIII.
Relative weights and rankings for interaction behavior in regional organization innovation

Second hierarchical (sub-criteria)	Weights	CI	CR	Eigenvalue	Ranking
Development of a new regional innovative culture	0.412	0.007	0.008	4.022	1
Ability of regional organizations to learn and grow through interaction	0.325				2
Innovation results of regional technology alliance	0.168				3
Innovation capabilities of leading regional firms	0.095				4

indicate that the interviewed experts regarded developing a new innovative culture in the region and the ability of regional organizations to interactively learn and grow as important factors in increasing interactive behavior in regional organization innovation; these two factors have a combined relative weight of 73.7 percent.

Table IX also shows that the eigenvalue vectors for the injection of new resources in regional innovation are consistent, with CI and CR values of 0.057 and 0.098, respectively (CI ≦ 0.10 and CR ≦ 0.10 imply a satisfactory degree of consistency in the AHP method; Saaty, 1990). These research results indicate that the interviewed experts discovered that how close partners or parent firms are (distance and relationship) plays an important role in the injection of new resources into regional innovation, with a relative weight of 55.3 percent. The second most important factor is the attraction of foreign direct investment and outside technologies, with a relative weight of 30.5 percent. In other words, the experts attributed roughly a third to the injection of new resources (foreign capital and outside technology) into regional innovation.

Finally, a multiplied weighting was performed on the main weights of the first hierarchy and the secondary weights of the second hierarchy, obtaining the weights of combination index shown in Table X. It can be seen from Table X that the interviewed experts believed

Table IX. Relative weights and rankings for the injection of new resources into regional innovation

Second hierarchical (sub-criteria)	Weights	CI	CR	Eigenvalue	Ranking
Injection of new capital for regional innovation	0.142	0.057	0.098	3.116	3
Import of foreign capital and technology	0.305				2
How close to partner's or parent's firm (distance and relationship)	0.553				1

Table X. The AHP weight and ranking of constructs and sub-criteria

Constructs	Weights	Sub-criteria	Weights of combination	Ranking
Construction of new regional innovation environments	0.592	Industry cluster effect	0.2948	1
		Construction of knowledge infrastructure	0.1806	2
		Implementation of regional innovation policy	0.0787	5
		Effective administration of regional innovation environment	0.0379	8
Interaction behavior in regional organization innovation	0.111	Development of a new regional innovative culture	0.0457	6
		Ability of regional organizations to learn and grow through interaction	0.0361	9
		Innovation results of regional technology alliance	0.0186	10
		Innovation capabilities of leading regional firms	0.0105	11
Injection of new resources for regional innovation	0.297	Injection of new capital for regional innovation	0.0422	7
		Import of foreign capital and technology	0.0906	4
		How close partner's or parent's firm (distance and relationship)	0.1642	3

that the most important factors in the full operation of regional innovation systems are: industry cluster effects; the construction of knowledge infrastructure; how close partners or parent firms are (distance and relationship); the import of foreign capital and technology; and the implementation of regional innovation policy. The combined weight for these five indices is 80.89 percent, indicating that the construction of a complete regional innovation system can focus on these five indices to achieve over 80 percent of the benefits.

5. Conclusions

The concepts of regional innovation system have been established since 1990, and related articles have been published from European and Asian scholars, however, seldom does literature offer questionnaires or research items to measure the operational effectiveness of a regional innovation system. Therefore this study has developed a questionnaire, by reviewing literature and verifying it by the AHP method, with Taiwan's HsinChu Science Park as the subject case. For the contribution on theories, this study inducted the construction of new innovation environments, new interactional behavior in regional organization innovation and injection of new resources into regional innovation as the three main constructs to influence the operational effectiveness of regional innovation systems. In addition, this study has used experts' questionnaire answers and the AHP method to clarify the priority of factors to operate the regional innovation system. Industry cluster effect, construction of knowledge infrastructure and how close partners or parent firm are (distance and relationship) are the top three factors in HSP. The duties of the government are not merely picking good firms for the regional innovation system, but also making policies and defining regimes, providing a good business environment for campus firms, universities, and research institutions, as well as offering plenty of R&D funding to encourage industry-academia cooperation. Governments must invest in infrastructures, such as: establishing databases, libraries, information networks, the national technical standards for certification and other public services, to facilitate industry-academia cooperation.

These research results indicate the operating essentials of regional innovation systems are not limited to interactions among regional organizations. This study suggests that the success or failure of a new regional innovation system would instead, be dependent on the regional environment, as in software planning and support, as well as the relationship of innovation with policy implementation and administration.

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About the authors

Chung-Lin Tsai obtained his PhD Degree from the Department of Business Administration, National Cheng Kung University, Taiwan. He is the Director for Bachelor's Degree Program in Management at the Chang Jung Christian University.

Han-Chao Chang received his PhD Degree from the Nottingham Business School, Nottingham Trent University, Nottingham, UK, and his MSc Degree from the Materials Department, Imperial College London, London, UK. He is currently working as a Research Fellow for innovation management and optical medical device with the National Applied Research Laboratories, Taiwan. Han-Chao Chang is the corresponding author and can be contacted at: roman@itrc.narl.org.tw

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