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Driving industrial clusters to be nationally competitive

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Industrial clusters have received considerable attention from economists and industrial analysts. The main purpose of this paper is to contribute to the understanding of the driving forces behind the growth of industrial clusters. Another core viewpoint anchored in this paper is that national competitive advantages can be achieved by industrial clusters. We examine the impacts of and determine the relationships among different driving forces. Taiwan's Hsinchu Science Park, because of its connection with innovative participants, is a prime example for this paper. This research adopts the Decision Making Trial and Evaluation Laboratory (DEMATEL) as the main analytical tool. Our research results show that local demand conditions and factor conditions (which are specialised factors of production such as skilled labour, capital and information infrastructure) are the main causal driving forces for advancing Taiwan's industrial cluster performance. This paper concludes by discussing managerial implications for industry and government.

Keywords: industrial cluster; driving force; Taiwan Hsinchu Science Park; Decision Making Trial and Evaluation Laboratory (DEMATEL)

1. Introduction

The increasing competition and globalisation of industries, markets and technologies has raised the demand for outside-in innovation and acquisition of technology through integrated innovation clusters (Becker and Gassmann 2006). Companies need to develop cluster competence in order to link their organisations to other players in the market to allow interactions beyond organisational boundaries (Ritter and Gemunden 2004). The formation of clusters of innovation is a useful concept for transforming both tangible and intangible knowledge into embodied and disembodied technical change (Liyanage 1995).

Clusters are defined as selected sets of multiple autonomous organisations, which interact directly or indirectly, based on one or more agreements between them. The aim of clusters is to gain a competitive advantage for the individual organisations involved and occasionally for the entire cluster as well. Cluster competence enables a company to establish and use relationships with other organisations (Ritter and Gemunden 2004).

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Previous studies also have examined the cluster structure (Ritter and Gemunden 2004; Gemunden, Ritter, and Heydebreck 1996; Clark and Guy 1998), and some studies have addressed the cluster effect (Teng, Tseng, and Chiang 2006). A number of empirical studies have also provided evidence that clusters affect innovation performance (Colombo and Delmastro 2002). Particularly, in past studies scholars in the field of innovation systems have found it most useful to compare innovation systems between different industries or countries (Chang and Shih 2004).

Some scholars have drawn attention to the Taiwanese innovation system (Hu, Lin, and Chang 2005; Lee and Tunzelmann 2005; Lai and Shyu 2005; Tasi and Wang 2005; Yang, Cheng, and Shyu 2006). Taiwan is one of the world's largest manufacturers of high-technology components and products. According to the World Economic Forum's '2007–2008 Global Competitiveness Report', Taiwan has again taken first place in the world in the 'State of Cluster Development' index (see Appendix Table A1) (Chen 2007). The Hsinchu Science Park (HSP) of Taiwan is now one of the world's most significant areas for semiconductor manufacturing. It is home to the world's top two semiconductor foundries, Taiwan Semiconductor Manufacturing Company (TSMC) and United Microelectronics Corporation (UMC) (Tasi and Wang 2005; Lai and Shyu 2005; Chen 2007). The HSP, established by the government of Taiwan in 1980, straddles Hsinchu City and Hsinchu County on the island of Taiwan. Industries in the HSP cover primarily six spheres – semiconductors, computer peripherals, communications, opto-electronics, biotechnology and precision machinery. Firms in the science park bring in high-tech industries and, in addition, help transform Taiwan's labour-intensive industries into technology-intensive industries.

On the other hand, while a number of studies have documented the significant role of innovation system as well as its possible cluster drivers, little is so far known about the reflection of a link between national competitiveness and industrial cluster drivers. That said, related researches are mostly concerned with the topics of innovation and cluster development. Drivers of industrial clusters are seldom explored from the perspective of national competitive advantages as a whole. For instance, Lai, Chiu, and Leu (2005) explored the effects of industrial cluster on innovation capacity, and to study the impact of external resources on firms' innovation capacity especially under Chinese regional economic policy. Cortright (2006) proposed seven drivers for the foundation of clusters, which include labour market pooling, supplier specialisation, knowledge spillovers, entrepreneurship, path dependence and lock-in, culture and local demand.

Accordingly, in Section 2 we will then particularly introduce Porter's diamond model, targeting the issue of measuring as well as analysing industrial clustering linked to national competitiveness enhancement.

The DEMATEL is a suitable method that helps us in gathering group knowledge for forming a structural model, as well as in visualising the causal relationship of subsystems through a causal diagram (Wu and Lee 2007). The other thing is that its diagrams are more useful than directionless graphs because diagrams can demonstrate the directed relationships of sub-systems. Moreover, the diagram portrays a basic concept of contextual relation among the elements of the system, in which the numeral represents the strength of influence (Wu and Lee 2007).

We take the HSP of Taiwan as our case study. By discussing the relationship between different drivers and making a causal map that allows us to find out the causal group and effect group, this research provides Taiwan industries and government with some strategic recommendations. It is because we believe that Taiwan can be viewed as an appropriate case demonstrating how her industrial clustering has resulted in particular national competitiveness that from this perspective we wish to find out how those drivers associate with each other, finally leading to successful forms of clusters.

Section 2 of this paper briefly outlines the national competitiveness related factors driving the growth of industry clusters as rooted in important prior research. Section 3 presents how we adopt the DEMATEL methodology. Section 4 displays our empirical results along with some discussion relating to managerial implications. Concluding remarks are given in Section 5.

2. What factors drive industrial clusters to be nationally competitive?

Kao et al. (2008) applied four dimensions to measure the national competitiveness, such as economy, technology, human resource and management. Önsel et al. (2008) adopted a basic requirements factor, an efficiency enhancers factor and an innovation and sophistication factor to estimate the national competitiveness. Wang, Chien, and Kao (2007) examined the influence of technology development on national competitiveness. They thought that technology development plays a key role in national competitiveness. Cho, Moon, and Kim (2008) used eight variables to evaluate the national competitiveness that include factor conditions, business context, related and supporting industries, demand conditions, human factors, politicians and bureaucrats, entrepreneurs, and professionals.

We believe that most of the above chiefly issue from a major breakthrough for the cluster concept derived from Porter's (1998) *Competitive Advantage of Nations*, which advocated specialisation according to historical strength by emphasising the power of industrial clusters. Porter highlighted that multiple factors beyond those internal to the firm may improve its performance. In his 'diamond model', four sets of interrelated forces are brought forward to explain industrial clusters: factor input conditions; local demand conditions; related and supported industries; and firm structure, strategy and rivalry.

The industrial clusters stimulate innovation and improve productivity; they are a critical element of national competitiveness (Cooke 2001; Porter 1998). The core viewpoint anchored in this paper is that national competitive advantages can be achieved by industrial clusters (Cooke 2001; Porter 1998; Enright 1992, 1993). Embracing more vivid and straightforward dimensions comparing to other approaches, the diamond model is therefore deemed our most fitting analytic framework while we are pursuing effective measurement of industrial cluster drivers from the viewpoint of national competitive advantages. Our research also attempts to provoke discussion on the value of looking at the cultural influences on the growth of clusters. This approach could be used to help determine the catalytic role that such development organisations should be playing by emphasising the need to base decision-making on cultural as well as on economic factors in order to stimulate cluster formation and enable innovation by optimising cultural interchange.

The below describes key dimensions of national competitiveness, mainly derived from the Porter's diamond model. Following the above arguments, these dimensions can be also regarded as drivers of industrial clustering.

2.1. Factor conditions

Porter agreed that a state's or nation's endowment of factors for encouraging production has a role in determining competitive advantage. However, Porter broadened the definition of factors for production into five major categories: human resources, physical resources, knowledge resources, capital resources and infrastructure (Rojas 2007).

Abundant natural resources, which are factors of production, could provide the original momentum for establishing an industry. Their presence might also have enticed a predecessor industry to the location, thereby creating the initial framework for a subsequent industry (Porter 1998).

The fact that competitive pressure compels firms to innovate in order to overcome their micro-economic environment's disadvantages represents a major theme in Porter's work. The remaining fundamental determinants in the model play an important and powerful role in inciting firms to innovate so as to remain competitive players in their industries. Specialised factors of production are skilled labor, capital, and information infrastructure. Specialised factors involve heavy, sustained investment and they are more difficult to duplicate. These factors include entrepreneurship and venture capital.

2.2. *Local demand conditions*

Consumer demand plays possibly the most important role in forming and building up an industrial cluster. A large number of industrial customers in the nearby area create sufficient demand to enable suppliers to acquire and operate expensive specialised machinery.

Porter (1998) has argued that a sophisticated domestic market is an important element for producing competitiveness. Firms that face a sophisticated domestic market are likely to sell superior products because the market demands high quality, and a close proximity to such consumers enables the firm to better understand the needs and desires of the customers (Lai and Shyu 2005). As a result, demand conditions can stimulate an industry through local demand for a product that also proves viable in regional, national and international markets (Woodward 2004).

2.3. *Related and supporting industries*

Spatial proximity of upstream or downstream industries facilitates the exchange of information and promotes a continuous exchange of ideas and innovations. The availability, density and inter-connectedness of vertically and horizontally related industries are important drivers for industrial clusters (Lai and Shyu 2005). This includes suppliers and related industries.

Related industries refer to firms that provide complementary products or services to one another. While competing on the basis of their value chain management within their product- or service-specific industry, they might share or coordinate certain activities, such as distribution, technology development, manufacturing, or marketing (Porter 1998). Competitive related industries can provide opportunities for technological exchanges and, possibly, can accelerate the development of competitive local supplier industries serving both. However, close working relationships among related industries do not happen automatically. Related industries must explicitly seek to forge alliances that will add to their competitive advantage (Rojas 2007).

2.4. *Firm structure, strategy, and rivalry*

Porter (1998) argues that intense competition spurs innovation. The world is dominated by dynamic conditions. Direct competition impels firms to work for increases in productivity and innovation. Firm strategy, structure and rivalry refer to the various approaches to a firm's inception, organisation and management that establish the context for local rivalry and competitive advantage.

Differences in management systems and organisational structure offer opportunities for establishing competitive advantage. Relationships between labour and management represent a particularly important element for the firm, given their powerful impact on the process of innovation and improvements (Porter 1998). Porter established that rivalry with domestic firms proves to be more beneficial than other factors in terms of innovation and improvements. Local rivals

compel one another to seek effective cost-cutting measures, product/service innovations, and organisational improvements. Local competitive pressure also leads to commercially successful firms, which in turn, lures new firms to the industry.

2.5. Government support

The role of government in Porter's diamond model is to act as a catalyst and challenger; it is to encourage – or even push – companies to raise their aspirations and move to higher levels of competitive performance. Government must encourage companies to raise their performance, to stimulate early demand for advanced products, to focus on specialised factor creation, and to stimulate local rivalry by limiting direct cooperation and enforcing anti-trust regulations.

Besides, government must provide the required infrastructural needs of the developing industrial cluster. The role of the government in a regional economy is necessarily a variable over the life cycle of the industry cluster, and as a result it needs to have the capability to identify and monitor the set of natural industries that exist within the region and their stages of development (Porter 1998).

2.6. Culture

Innovation is an outcome of an innovative culture. Clusters with an innovative culture will increase the life-expectancy and productivity of the infrastructure and business capital that they host, and the productivity and prosperity of their community (Porter 1998). Hall (1976) argued that cultures vary greatly in the processing of information and patterns of communication. Cultural differences were found to predict stress, negative attitudes toward mergers and the lack of cooperation between firms subsequent to a merger (Weber, Shenkar, and Raveh 1996). More relevant to our study, Olie (1994) has argued that the blending of diverse cultures tends to be a challenging obstacle to successful collaboration.

2.7. Cluster drivers and system-effects

In this model, each industrial cluster driver not only interacts with the others but also affects the industrial cluster. The industrial clusters affect each driver correspondingly.

In fact, these elements exhibit system-effects where the weakest element sometimes has the strongest impact on the overall quality (Ketels 2003). Porter (2000) concludes that 'the cluster is the manifestation of the diamond at work. Proximity, arising from the co-location of companies, customers, suppliers and other institutions, amplifies all of the pressures to innovate and upgrade'.

Regions need to activate their clusters, address crosscutting weaknesses in their general business environments, create an institutional structure to focus on competitiveness beyond the life cycle of specific administrations and define an overall understanding of the unique value they intend to provide relative to other locations (Ketels 2003).

3. The Decision Making Trial and Evaluation Laboratory (DEMATEL) method

The DEMATEL method was developed to study the structural relations in a complex system (Liou, Yen, and Tzeng 2008). The mathematical concepts are borrowed from Liou, Yen, and Tzeng (2008) and Wu (2008). DEMATEL has been adapted in many academic fields, such as industry analysis.

Wu and Lee (2007) combined DEMATEL and fuzzy theory to segment required competencies for better promoting the competency development of global managers. Liou, Yen, and Tzeng (2007) used fuzzy logic and DEMATEL to build an effective safety management system for airlines. Huang, Shyu, and Tzeng (2007) used DEMATEL and grey relational analysis to reconfigure innovation policy portfolios presented for the Taiwanese government’s policy definition.

The DEMATEL model construction process is described below.

Step 1: Generating the direct-relation matrix

To measure the relationship between criteria requires that the comparison scale be constructed according to the following four levels: No influence (0), Low influence (1), Medium influence (2), High influence (3), and Very high influence (4). The integer score that the k th expert gives to indicate the degree that factor i has on factor j is x_{ij}^k . The $n \times n$ matrix A is found by averaging all experts’ scores.

$$a_{ij} = \frac{1}{H} \sum_{k=1}^H x_{ij}^k. \tag{1}$$

Step 2: Normalising the direct-relation matrix

On the base of the direct-relation matrix A , the normalised direct-relation matrix X can be obtained by the following formulas:

Let

$$s = \max \left(\max_{1 \leq i \leq n} \sum_{j=1}^n a_{ij}, \max_{1 \leq j \leq n} \sum_{i=1}^n a_{ij} \right). \tag{2}$$

Then

$$X = \frac{A}{s}. \tag{3}$$

The sum of each row j of matrix A represents the direct effects that factor i gives to the other factors; $\max(\max_{1 \leq i \leq n} \sum_{j=1}^n a_{ij}, \max_{1 \leq j \leq n} \sum_{i=1}^n a_{ij})$ represents the direct effects on others.

Step 3: Attaining the total-relation matrix

Once the normalised direct-relation X is obtained, the total-relation matrix T can be calculated by applying the following formula, (4), in which I is denoted as the identity matrix

$$T = X(I - X)^{-1}. \tag{4}$$

Step 4: Producing a causal diagram

The sum of rows and the sum of columns are separately denoted as vector D and vector R . The horizontal axis vector $(D + R)$, named ‘Prominence’, is made by adding D to R , which represents how much importance the criterion has. Equally, the vertical axis $(D - R)$, named ‘Relation’, is made by subtracting D from R , which may divide criteria into a cause group and an effect group. Based on the above statements, when $(D - R)$ is positive, the criterion belongs to the cause group.

Otherwise, when $(D - R)$ is negative, the criterion belongs to the effect group. Therefore, the causal diagram can be acquired by mapping the dataset of $(D + R, D - R)$.

$$T = [t_{ij}]_{n \times n} \quad i, j = 1, 2, \dots, n \quad (5)$$

$$D = \left[\sum_{j=1}^n t_{ij} \right] = [t_{i \cdot}]_{n \times 1} \quad (6)$$

$$R = \left[\sum_{i=1}^n t_{ij} \right]_{1 \times n}^t = [t_{\cdot j}]_{n \times 1}. \quad (7)$$

Step 5: Setting a threshold value and obtaining the inner dependence matrix

To explain the structural relation among factors while keeping the complexity of the whole system at a manageable level, it is necessary to set a threshold value p to filter out negligible effects in matrix T . Only the factors whose effect in matrix T is greater than the threshold value will be shown in an inner dependence matrix. Here the threshold value p has been chosen by the experts and the results of the literature review.

4. Empirical evidence from Hsinchu Science Park

Cooke (2001) states that clusters are the key determinants of economic growth because they can improve regional productivity, innovation and new business. Consequently, cluster thinking offers important lessons for economic development and practice (Cortright 2006).

According to the World Economic Forum's '2007–2008 Global Competitiveness Report', Taiwan has taken first place in the world in the 'State of Cluster Development' index (Chen 2007), as noted before. Besides, Furman, Porter, and Stern (2002) have given Taiwan a Cluster Innovation Environment Subindex of 9.6, giving it a reasonable rank of eighth in the economies surveyed.

Industrial parks have been the cornerstone of Taiwan's industrial development since their creation in the 1970s and are a foundation of the island's economic success (Lee 2006). The greatest contribution of industrial clusters is their ability to stabilise Taiwan's industrial development and to allow the industries to upgrade their technological level. Industrial clusters have also stimulated the economy of Taiwan, particularly the service-oriented industry, and have created a mutually beneficial relationship between high-tech and traditional industries. The importance of this cluster to innovation cannot be underestimated since, according to Porter, the electronics cluster in Taiwan accounts for 80% of all USPTO patent filings (Porter 2000).

Given the above, we may well believe that the industrial country Taiwan has mainly derived its competitiveness from the strength of industrial clusters. Among these, its 'local industrial clustering' has been often cited as the major source of Taiwan's success (Kraemer et al. 1996; Kim and Tunzelmann 1998).

4.1. Research framework

This study attempts to find out the impact of the major driving forces behind Taiwan's HSP clustering and to measure the relationships among those forces. These factors of industrial clusters also exist for improving national competitiveness. To this end, we adopt the diamond model

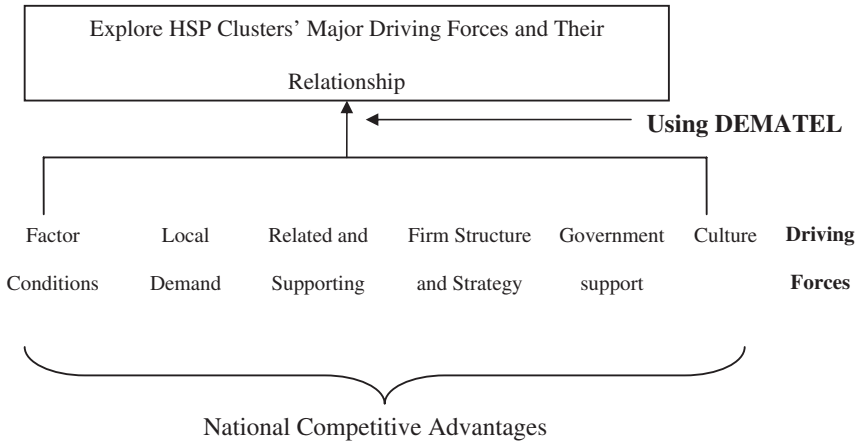


Figure 1. Research framework.

(Porter 1998) in addition to the concept of culture to give the priority to these driving forces. Based on deductions from the prior literature, the driving forces in question are factor conditions, local demand conditions, related and supporting industries, firm structure and strategy and rivalry, government support and culture. This research then applies the Decision Making Trial and Evaluation Laboratory (DEMATEL) to address the related issues. Figure 1 denotes our research framework.

4.2. Identify relationship between factors using DEMATEL

Our purpose is not only to find out the most important driving force for the growth of industrial clusters but also to measure the relationships among these driving forces. Ten experts helped us with the survey, including four industrial analysts from the Industrial Technology Research Institute, four managers of high-tech companies, one professor of management and one government representative from the Bureau of Urban Development of the Hsinchu City government. These experts followed our proposed method with a three-step procedure.

First, we made the decision goal and set up a committee. Through literature investigation and studying experts' opinions, the committee finally adopted five dimensions. More specifically, an expert validity survey was designed for the invited experts to evaluate the criteria by providing their suggestions and revisions. It is believed that a panel of experts can further enhance the quality of the chosen criteria. The purpose of the interviews was to obtain more specific ideas about the evaluation criteria from experienced in-cluster patricians' points of view. Based on the significant viewpoints received from the interviews, we confirmed the expert validity of the preliminary criteria.

As noted, we adopted the factors of the diamond model (Porter 1998) in addition to the cultural concept as our driving forces. Table 1 provides the details of their definitions. Based on the above dimensions, we employed the DEMATEL method for capturing the complex relationships among these evaluation criteria.

We then obtained the collected pair-wise comparison results (the comparison mechanism has been described at step 1 of section 3); the preliminary average direct-influence matrix is shown in Table 2. Based on the direct-influence matrix, we continually normalised these numbers into what is shown in Table 3 – the direct-relation matrix (calculated by formula (2) and (3)). Tables 4 and 5

Table 1. Dimensions of the driving forces for the growth of industrial clusters.

Dimension	Dimension description	
Factor conditions	D1	Specialised factors of production are skilled labour, capital and information infrastructure. The factors include entrepreneurship and venture capital. Entrepreneurship is the engine of cluster development growth. Venture capital markets create a positive impact on industrial development. The science and information infrastructure means that a country or region should establish a science and technology platform for improving or upgrading science linkage between players, such as science parks or information centres.
Local demand conditions	D2	Consumer demand plays an important role in forming and building up an industrial cluster. A large market also enables suppliers to provide specialised products and services.
Related and supporting industries	D3	Suppliers gain from the nearby market for their output, while the client firms in the cluster gain from easy access to a range of services. Spatial proximity of upstream or downstream industries facilitates the exchange of information and promotes a continuous exchange of ideas and innovations. The availability, density and interconnectedness of vertically and horizontally related industries are an important driver for industrial clusters.
Firm structure, strategy, and rivalry	D4	Intense competition spurs innovation. The world is dominated by dynamic conditions. Direct competition impels firms to work for increases in productivity and innovation.
Government support	D5	Government must provide the required infrastructural needs for a developing industrial cluster. Government also encourages companies to raise their performance, to stimulate early demand for advanced products, and to focus on specialised factor creation; government can stimulate local rivalry by limiting direct cooperation and enforcing anti-trust regulations.
Culture	D6	Innovation is an outcome of an innovative culture. Clusters with an innovative culture will increase the life-expectancy and productivity of the infrastructure.

Table 2. Direct-influence matrix.

	D1	D2	D3	D4	D5	D6
D1	0.00	1.60	3.40	3.40	3.10	2.00
D2	1.40	0.00	2.80	2.80	2.50	2.00
D3	3.20	2.40	0.00	3.70	2.80	1.90
D4	3.40	2.50	3.60	0.00	3.00	1.90
D5	3.40	2.30	2.70	2.90	0.00	1.90
D6	1.60	2.20	1.70	1.90	2.00	0.00

provide the ‘total-influence matrix’ and ‘total effects and net effects for each factor’, respectively. Then we used formula (5)–(7) as based on the normalised matrix to produce the causal diagram by mapping a dataset of $(D + R, D - R)$, as displayed in Figure 2.

We can then clearly and intuitively discover the importance order of these dimensions for driving industrial cluster growth, according to the resulting causal diagram. Also looking at this

Table 3. Direct-relation matrix.

	D1	D2	D3	D4	D5	D6
D1	0.000	0.111	0.236	0.236	0.215	0.139
D2	0.097	0.000	0.194	0.194	0.174	0.139
D3	0.222	0.167	0.000	0.257	0.194	0.132
D4	0.236	0.174	0.250	0.000	0.208	0.132
D5	0.236	0.160	0.188	0.201	0.000	0.132
D6	0.111	0.153	0.118	0.132	0.139	0.000

Table 4. Total-influence matrix.

	D1	D2	D3	D4	D5	D6
D1	1.4197	1.2877	1.6942	1.7345	1.5989	1.1783
D2	1.3061	1.0200	1.4500	1.4847	1.3661	1.0294
D3	1.6378	1.3603	1.5454	1.7910	1.6239	1.2028
D4	1.6801	1.3924	1.7805	1.6225	1.6665	1.2276
D5	1.5707	1.2909	1.6219	1.6701	1.3848	1.1465
D6	1.1016	0.9753	1.1705	1.2090	1.1292	0.7514**

Table 5. Total effects and net effects for each factor.

	<i>D</i>	<i>R</i>	<i>D + R</i>	<i>D - R</i>
D1	8.91	8.72	17.63	0.20
D2	7.66	7.33	14.98	0.33
D3	9.16	9.26	18.42	-0.10
D4	9.37	9.51	18.88	-0.14
D5	8.68	8.77	17.45	-0.08

causal diagram, these driving forces can be divided into a causal group, which includes D1 and D2, along with an effect group, which includes D3, D4, D5, and D6.

4.3. Discussions

In this empirical study, we try to discover the major driving forces for the growth of industrial clusters and to find out the relationships among these driving forces. We take Hsinchu Science Park of Taiwan as our case for study. According to the empirical results, this research concludes with some managerial implications, as follows.

We can find out the relationships among these driving forces based on Table 4 and Figure 2. From the results, we understand that most of the driving forces form a system and also are self-reinforcing. Founded on step 5 as described in Section 3, self-reinforcing implies that within the system the impact levels of any factor can not be lower than the benchmark value and that activating the factor not only improves other driving forces' effectiveness but also affects itself. That said, these driving forces influence each other and have a self-relation, except for D6 (culture dimension), as only the value of D6-D6 is 0.7514 (see Table 4), which is smaller than the benchmark value '1', decided by the experts in this research. Using the DEMATEL, we decided to

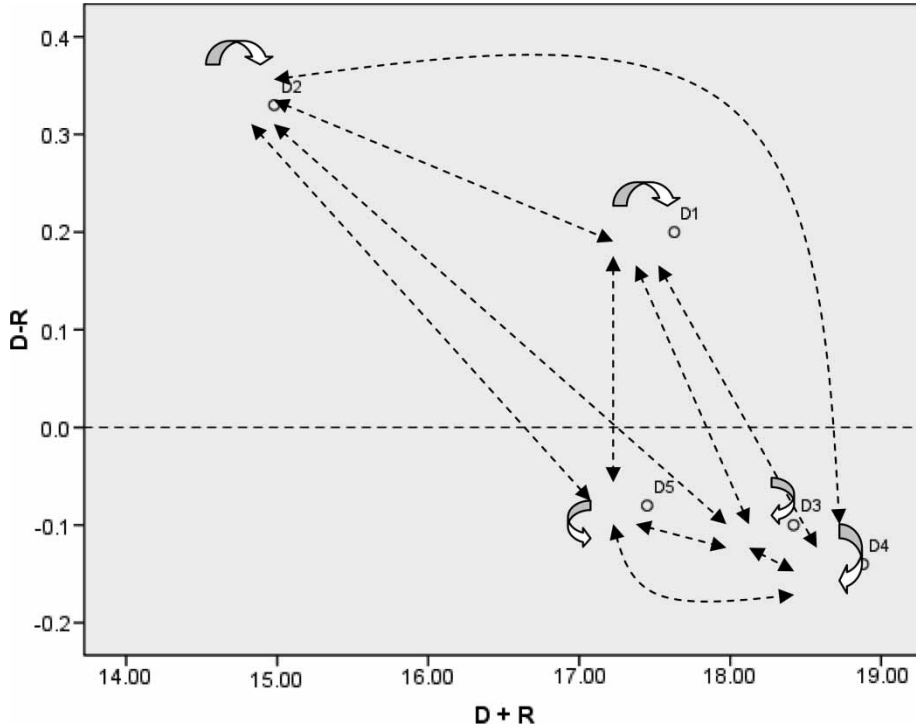


Figure 2. Impact-relationship map.

neglect D6 and exclude it from the set of driving forces of the industrial clusters for this case, Taiwan's HSP (see Table 5 and Figure 2).

The main reason why culture is a weak driving force behind Taiwan's industrial clustering is that Taiwan's industry is mainly export-oriented and more and more globalised due to its original design manufacturing (ODM) mode. A weaker culture may therefore result from the gradual spread of higher internationalisation within the science park. However, according to our observation there is little blending of diverse cultures, which tends to be a challenging obstacle to successful collaboration within the cluster. This research outcome also accords with previous studies. For instance, Porter (1998) believed that the clustering of industry would lead towards vigorous competition and would result in the rapid development of skilled workers, the creation of related technological industries and specialised infrastructure that would give each firm within the cluster a competitive advantage. The rivalry for final goods stimulates the emergence of an industry that provides specialised intermediate goods. Keen domestic competition leads to more sophisticated consumers, who come to expect upgrading and innovation. Also, as mentioned before, each industrial cluster driver should not only interact with the others but also affect the industrial cluster. The industrial clusters affect each driver correspondingly (Ketels 2003).

4.3.1. Causal group forces

In addition, our research results from using the DEMATEL method point out that the major causal dimensions are D2 (local demand conditions) and D1 (factor conditions). See Table 5 for their positive ($D - R$) values and relatively lower ($D + R$) values. As noted before, positive ($D - R$)

values imply a causal group and lower ($D + R$) values mean more depressed prominence, so that the existence of such drivers involves imperfection or insufficiency. In other words, the two dimensions of forces entail greater room for improvement, compared with other forces, resulting in more vivid and effective cluster development. Equally, D2 and D1 are strong direct influencers on all other dimensions with Taiwan's cluster formation/growth, including affecting themselves. We will interpret why these two drivers are causal and how Taiwan should advance its industrial clustering performance through stimulating them.

First, the experts identify local demand conditions as the most contributory and determinative driving force for the growth of industrial clusters. From the perspective of national competitiveness, in Taiwan, a large market enables suppliers to provide specialised products and services. Suppliers gain from a nearby market for their output, while the client firms in the cluster gain from easy access to a range of services. This interaction can get the most immediate and the newest responses regarding technical problems or market demand. Proximity to a local market also plays a key role in potentially increasing a firm's competitive advantage. Timeframes tend to be shorter for responding to local demand pressures and the firms tend to be more confident in understanding and satisfying local demand requests. Porter indicated that local market size is most important for enhancing competitive advantage in industries with substantial research and development requirements, major economies of scale in production, or significant generational leaps in technology (Porter 1998). A rapidly growing local demand provides firms with the incentive to incorporate new technologies faster and to upgrade or expand their capacity with the necessary conviction that they will be used. This pulling force for innovations from the demand side has its complementary pushing force located among related and supporting industries (Rojas 2007). That is why the pressure for Taiwan's local industry markets is high.

Krugman (1981) argues that scale economies provide a foundation for backward and forward linkages and for horizontal differentiation of products as well. Since Taiwan is a small economy, the domestic market cannot provide the kind of scale economies. As a result, it has to link to some major external markets to realise such scale economies. Also the technological depth for Taiwan's clusters was perhaps not enough to produce such a kind of positive cumulative effect (Saxenian 2001). In the Silicon Valley, in contrast, it is mainly innovation driving successful scale economies, contributing to the agglomeration of industrial clusters. Therefore, what needs to be mentioned particularly is that Taiwan's local demand factor should more and more involve the condition of cooperation and global networking. In Taiwan, hundreds of other relatively unknown firms are partners in the success of high-profile companies like the Taiwan Semiconductor Manufacturing Corporation (TSMC), Acer and Quanta, who have direct links to major multinational markets. These companies have developed their own capabilities by collaborating with customers and suppliers to develop new products or improve existing products (Saxenian 2006). So the adaptive capacity of Taiwan's technology base derives from collaborations among local producers as well as from their long-distance partnerships. In particular, the fragmentation and localisation of production in the Hsinchu region are key to the flexibility, speed and innovative learning-by-doing of its IC firms (Saxenian 2006).

Second, the committee observes that 'factor conditions' are also a causal driving force for the growth of industrial clusters. The factor conditions refer to the specific factors. These are more difficult than other conditions to duplicate. This can lead to a competitive advantage, because if other firms cannot easily duplicate these factors, they are valuable. Based on our definition of factor conditions, specialised factors of production are skilled labour, capital and information infrastructure. The main factor conditions include entrepreneurship, venture capital, science parks and incubators for the growth of the industrial cluster.

Taiwan is an island country with shortage of many natural resources. Therefore, the economic development relies heavily on the international trade and specialisation. In order to supplement such factor lacks in fostering stronger industrial clusters and achieving country competitiveness, Taiwan industries need to accumulate unique expertise and capabilities in doing business worldwide. Accordingly, Taiwan's business sectors, distinguished by its manufacturing technology and management know-how, are now trying to be an integral part of the supply chain of many global products and are also beginning to serve as an integrator of global resources by expanding their operations worldwide, especially in most Asian countries, including mainland China (Wong 2007). Also, Taiwan has been faced with a relative shortage of the capital resources (Huang 2008), which is detrimental in terms of developing its industrial clusters. The suggestion is that Taiwan's government should be opening up the domestic monetary market. This would help to cultivate an investment environment for foreign businesses to pull together multi-national capital resources. Furthermore, to ease and improve the transmission of funding, the government should also allow international financial firms to set up bases in Taiwan, therefore enabling more active transnational inward investments in Taiwan (Huang 2008).

4.3.2. *Effect group forces*

On the other hand, as shown in Table 5 and Figure 2, dimensions 4, 3 and 5 denote the effect dimensions in the order of negative ($D - R$) values. These effect dimensions can also be regarded as indirect factors for the growth of industrial clusters in Taiwan. Thus, the factors of cure, firm structure, strategy, and rivalry, related and supporting industries, and government support will be affected by the two causal factors as noted. However, these dimensions have relatively higher ($D + R$) values and this says that the existence of such factors involves more perfection and sufficiency.

The HSP, established by the government of Taiwan in 1980, straddles Hsinchu City and Hsinchu County on the island of Taiwan. Industries in the HSP cover primarily six industries (Chen 2007). Firms in the science park bring in high-tech industries and, in addition, help transform Taiwan's labour-intensive industries into technology-intensive industries (Chen 2007). In Taiwan, innovation alliances have been organised as a means of spreading the R&D risk between firms and securing first mover advantages (Tsai and Wang 2005). The scope of the government-sponsored Industrial Technology Research Institute (ITRI) has been expanded to serve as a channel for technology transfer within the private sector; the majority of the budget for national science and technology projects (NSTPs) has also been allocated to ITRI in an effort to boost the institute's innovative capacity. In addition, tax incentives have been made available to absorb some of the R&D costs of firms and to encourage them to engage in R&D activities (Tsai and Wang 2005).

Concerning government support, the Taiwanese government undertook a more direct role in the direction of the economy, taking steps to ensure that private entrepreneurs would invest in certain areas. The government helped establish industries, including plastics, textiles, fibers, steel and electronics (Wade 1990).

4.3.3. *Summary*

When policy makers are considering how to drive or improve their industrial clusters as a whole, they must take into account the key influential factors and their affects upon the other indirect dimensions. Generally speaking, activating influential factors can more easily result in expected improvement results, but indirect factors can only have limited contributions to stimulating the continual growth of these industrial clusters, from the viewpoint of country comparative advantages.

5. Concluding remarks

Carroll and Reid (2004) contend that clustering brings a variety of benefits to firms and the local economy. They believe that cluster-based economic development represents an opportunity for industries in the region to reach unprecedented levels of competitiveness. Industrial clusters then provide sourcing companies with a greater depth to their supply chain and allow for the potential of inter-firm learning and co-operation. Clusters also give firms the ability to draw together complementary skills in order to bid for large contracts for which, as individual units, they would be unable to compete successfully (Carroll and Reid 2004). Productivity, innovation, and new business formation are enhanced under such circumstances. As a result, clusters work by acting as economic communities based on informal and formal, hard and soft forms of networking between firms and agencies (Cooke 2001).

We have proposed the DEMATEL method to discover the direct and indirect driving forces for the growth of industrial clusters, using the Taiwan HSP as an example. We also measure the relationships among these driving forces. This research has beneficial results and implications for industries and policy makers as follows.

First, this research helps divide all dimensions into causal groups and effect groups in terms of the driving forces behind industrial clustering. According to our research results, local demand conditions and factor conditions are the major causal driving forces for the growth of industrial clusters. As a side note, research results indicate that most of the driving forces form a system and also are self-reinforcing. This implies that Taiwan's clustering of industry has led toward vigorous competition that would result in the rapid development of skilled workers, the creation of related technological industries, and development of a specialised infrastructure that gives the cluster a competitive advantage.

Industrial clusters can be seen as a source of national competitiveness, serving to upgrade productivity, new business formation and innovation, and advance marketing/customer relations. Potentially, however, a different cluster form of development may derive from a mix of different participating levels of the driving forces behind the growth of industrial clusters. The case of Taiwan is a decent example used by this research.

The Taiwan's experience might appear to be a classic case of the benefits of national competitiveness, with Taiwan specialising in IC and PC manufacturing and Silicon Valley leading in more advanced IC design and electronic system definition (Saxenian 2006). This also observes that the implemented clustering policy in Taiwan involves the importance attached to policies targeting specific industries and providing related support to these industries. The results of this are seen in the specialisations of science parks and strong cluster formations.

The policy implication would be that as a small economy, Taiwan government's top-down innovation policy at the initial stages might be beneficial in terms of the cluster formation leading to country competitiveness. Particularly, our observation is that the Taiwan government support is a matter of influence; that is, local demands and factor conditions as the causal drivers can result in specified government plans in growing and developing the industrial cluster located in the HSP although the effect is not so strong. On the other hand, as just noted, in the past the Taiwan government has engaged itself considerably in promoting national innovation and cluster development. Therefore as a driving force, 'government support' at present plays a less significant role in view of its lower improvement effects and hence, for all concerned, becomes an indirect contributor to Taiwan's industrial cluster growth.

As a short summary, the connecting driving forces behind Taiwan's growth of industrial clusters are meant to be local demands and factor conditions. Other factors such as related and supporting

industries, firm structure, strategy, rivalry and government support are classified as effect group factors based on our research results. They can also be viewed as indirect forces leading to Taiwan's cluster development, in contrast to the causal driving forces. They do not have much room for further improvement in order to trigger extended cluster growth. Therefore the other policy implication lies in that if Taiwan's policy makers wish to improve cluster development more efficiently, they should consider these two sides of factors and take appropriate action according to the above-mentioned evaluation results.

From an international angle, the Hsinchu industrial system contrasts, for instance, Irish cluster policy with early foreign direct investment-led approaches taken by the Irish government, which provide incentives to attract high-tech inward investment in or near Dublin to take advantage of forces of labour and logistics. As another small island country, Ireland's participation in the EU's programmes, which have provided various research funds, has also helped to facilitate high-tech spin-offs from university incubators and so gradually form clusters in Dublin, Cork, Galway, and other cities in recent years (Grimes and Collins 2003). This also implies that a combination of different kinds or levels of driving forces may contribute to different effects of cluster development.

Last, this research might have some limitations. The Hsinchu Science Park is our research objective. As noted, science parks located in different places or countries probably have different clustering features and characteristics. Therefore, an expanded comparison among different science parks can be a meaningful and interesting research topic regarding the aspect of industrial clustering.

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Appendix

Table A1. WEF ranking of the competitiveness of industrial clusters.

	2007–2008		2006–2007		2005–2006	
	Score	Global ranking	Score	Global ranking	Score	Global ranking
Taiwan	5.7	1	5.52	1	5.39	2
United States	5.3	2	5.22	2	5.19	4
South Korea	5.1	3	4.19	31	4.38	21
Singapore	5.1	4	4.92	7	5.15	6
England	4.8	9	5.06	4	4.63	14
Germany	4.8	10	4.90	8	4.45	17
Finland	4.8	11	5.07	3	5.33	3
Japan	4.7	12	4.33	27	5.46	1
Switzerland	4.7	13	4.67	15	4.31	23
Hong Kong	4.7	14	4.75	12	4.68	11
Italy	4.5	21	3.19	85	5.16	5

Source: Chen (2007).