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Importance of Clusters in Industry Development: A Case of Singapore's Petrochemical Industry

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Summary

This paper rejuvenates the existing discussion on the importance of cluster approach to industry development strategies. Current evidences suggest that the shape of economic policy and practice is changing significantly around the world. Governments continually search for new tools and policy formulas to improve economic performance and create economic prosperity for all citizens. In this context a more proactive and strategic role for government in support of the cluster-based economic development model has emerged.

This paper uses Singapore's petrochemical industry as an example to study the cluster approach to industry development. In doing so, there is much optimism to the importance of state and its institutions to play a significant role on industry development. Nevertheless, the study also raises doubts on whether the cluster-based strategy is due to the concept itself or due to other important factors.

Key Words: clusters, institutes, petrochemical, diamond model, Porter

1. Introduction

At present, evidences suggest that the shape of economic policy and practice is changing significantly around the world. Globalization, rapidly changing technology, intense competition and the rising public expectations for a higher standard of living create significant challenges to conventional economic development approaches. Governments continually search for new tools and policy formulas to improve economic performance and create economic prosperity for all citizens.

* I thank two anonymous referees for their comments on my initial drafts. All final views and errors are of the authors and the usual caveat applies.

In this context a more proactive and strategic role for government in support of the cluster-based economic development model has emerged. There is a growing consensus that if done right, this model can provide a foundation for sustainable economic growth and the way forward to greater prosperity. That said this paper does not wish to bore readers on all the voluminous academic or non-academic debates on industry cluster development. Rather the main theme is directed in applying the cluster-based approach to meticulous and successful development of an industry.

Over the last decade, clusters have drawn substantial interest from policy makers, legislatures, business leaders, academics, economic development practitioners and development agencies. Many countries around the world have based their industry development strategies on cluster models. Approximately, thirty countries, thirty-two American states and all of the Nordic countries have implemented cluster initiatives to position their economies to meet the challenges of the new economy.[1] Clusters are present in the economies of developed and developing nations, large and small, urban and rural, and across jurisdictions (e.g., nations, states, metropolitan areas, regions and cities).

Governments with widely differing ideologies and philosophies have instituted cluster promotion policies. In the United States and Canada, governments have adopted cluster-based strategies (Enright, 1999). European governments, across the wide range of industry spectrum, have employed cluster form of industry development. In the Asia Pacific region, national and local governments from Australia and Malaysia, to New Zealand and Singapore have adopted cluster strategies. These brings us to the objectives of this paper and are three-fold: firstly, paper presents arguments on the effectiveness of creating clusters; secondly, it argues on the premises of whether government can stimulate clusters, and thirdly, it shares the experiences of how the Singapore government mobilized cluster participants in petrochemical industry.

While the focus of this paper is on state's role and actions, the study recognises other organizations such as firms, educational and research institutions (polytechnics and universities), non-profit organizations, trade associations or chamber of commerce all play important roles in guiding the success of cluster development and have influencing effect on clusters.[2] In Singapore,

1) Other organizations that promote and support cluster based economic development include: World Bank, Agency for International Development, United Nations Economic Commission for Latin America and the Caribbean, Organization for Economic Cooperation and Development, International Development Research Centre, Social Sciences and Humanities Research Council of Canada, the US Council on Competitiveness, the Nelson A. Rockefeller Institute of Government, the SNS Economic Policy Group of Sweden and the European Union. www.btimes.co.za/97/0817/survey/survey5.htm

2) Many geographers, urban and regional planners, sociologists, and political scientists, as well as some economists, approach the study of business location from a social and institutional perspective. Rather than focusing on the

Government-Linked Companies (GLCs) and MNCs play a disproportionately large role in seeding and upgrading clusters, acting as a magnet for other companies and supporting projects that improve the overall business environment. Educational and research institutions play pivotal roles in cluster development as they form the incubator for innovative ideas and activities. It is worth noting that the majority of clusters either originated at educational institutes or in close proximity to universities (ex. Taiwan Science Park and Singapore Science Park 1-3). Specialized workforce essential to the cluster's success originate initially from vocational colleges and training institutes.

Accordingly, the paper is organized as follows: Section 2 discusses what a cluster is, what makes a cluster successful, some of the concerns about the cluster approach and why cluster-based economic development is effective. Section 3 describes the government's role in cluster development, identifies specific examples of government actions and their impact on clusters and recommends areas for government action to strengthen clusters. Section 4 presents a Singaporean example of how the government mobilized cluster participants and covers differing viewpoints for why this cluster approach appealed to a broad spectrum of audience; and section 5 provides concluding remarks.

2. Clusters as Economic Development Model

2.1. What are 'Clusters', Their Success and Concerns

Cluster is a broad concept rather than a precise term. A cluster consists of firms and related economic actors and institutions that draw productive advantage from their mutual proximity and connections. The past 20 years have seen an explosion of interest in clusters. Hundreds of cluster studies have been undertaken around the world (van der Linde, 2002). A variety of academic disciplines have rediscovered an interest in the subject and at least one new field, 'the new economic geography,' has been spawned.

This academic interest has been reflected in a wide range of policy innovation and experimentation, as practitioners have adopted the terminology and tried to make practical use of the concept. Much ink has been spilled in a largely futile effort to define narrowly—and in some cases

response of individual firms and consumers to economic incentives, these authors emphasize the effects of social forces and relationships that, in their view, cannot be fully reduced to the market decisions of individuals. Among the most important of these forces are customs, technological change, organizations, and social networks. These scholars do not assume that markets are the major organizing principle of economic life, but rather that the market itself is embedded in non-market social relationships.

to brand—the term cluster. Rather than trying to agree on a single definition, theorists and practitioners should focus on more carefully observing and understanding the different aspects of clustering and clusters. This paper favours this idea, using it as a guide to study the petrochemical cluster in Singapore.

Varying definitions of clusters exists to suit different country's competitiveness but mostly incorporate the following ideas:

> 'A geographically proximate group of inter-connected companies and associated institutions in a particular field, linked by commonalties and complementarities··· or inter-related industries that drive wealth creation in a region primarily through the export of goods and services'. (Porter & Stern, 2001)

Many others have offered their own variations. Martin and Sunley (2003) catalog 10 different ways of defining clusters. Typical of the alternatives is Rosenfeld (2002: 10), who defines a cluster as

> 'a spatially limited critical mass (that is sufficient to attract specialized services, resources, and suppliers) of companies that have some systemic relationships to one another based on complementarities or similarities.'

The origins and trajectories of clusters differ. The initial stimuli for a cluster may have been the availability of raw material; suitable climate conditions; proximity to markets; chance events; R&D facilities; an educated workforce; a culture of entrepreneurship; or a culture that values higher education. It may take decades for a cluster to reach maturity. The evolution of the world's largest clusters has occurred over a long period. These are not planned per se and went unnoticed until they reached a level of activity that warranted attention. Major examples are the Silicon Valley North electronics industries or the Malaysian Multimedia Supercorrider.

A cluster may progress through different stages including birth, potential, emerging, sustainable, mature and declining. This is not to imply that all clusters experience all of these phases. Clusters also vary in size from large to small, highly specialised clusters that pursue global markets and generate wealth well beyond many other localities in their country. So what makes a cluster successful?

A number of important factors include: the availability of venture capital; critical mass; technical infrastructure; presence of higher education and research institutions; entrepreneurial drive; influence of champions; presence of an anchor firm(s); networks and quality of linkages; social capital;

and, diversity. An intriguing aspect is that the factors that distinguish 'over-achieving' from 'under-achieving' clusters are so-called intangible assets. Clusters possessing strong inter-firm relationships, trust and social capital are more competitive and dynamic. According to Enright (1999), 'over-achieving' clusters are aware of the interdependence of their players and, in essence, produce more than the sum of their parts. On the other hand, 'under-achieving' clusters have opportunities but synergies not yet realized, while potential clusters have some of the requirements but lack social capital.

While these intangible assets promote and cultivate collaboration, a high degree of competition plays a pivotal role in successful clusters. However, literature notes that, clusters that rely on competition and rivalry are significantly more competitive than clusters that rely on factor conditions, such as climate, stock of natural resources and geography. Some argue that the reasons for the widespread popularity of the cluster approach are: a) fascination with and desire to emulate the Silicon Valley model of success; and, b) Porter's and others' effective marketing of the cluster approach (Martin & Sunley, 2003). While some cluster initiatives formed by the success of Silicon Valley, interest in clusters should have waned with the burst of the technology bubble. According to Jocelyn Ghent-Mallet (2002),

> 'clusters are attractive for many reasons. They catalyze economic transformation. They drive growth and enhance stability. Once they are rooted, they are remarkably self-generating. In the recent downturn in information technology, the Ottawa community lost 25,000 jobs and then quickly recovered almost all of them. Clusters look like a good bet for economic success. No wonder everyone wants one'.

It is true that Porter's persona as the celebrated architect and promoter of the cluster concept have influenced the reception of cluster approach. It is true there has been a proliferation of cluster practitioners and international consulting firms who provide expertise and have marketed the cluster model effectively. On the other hand, one can argue that the main reason for the appeal of the cluster approach is its association with productivity growth and prosperity. Another reason, as Bibbens (1995) notes, the stability of clusters as,

> 'Clusters are impossible for other regions to steal. Even if one or two companies are tempted away, they will most likely be replaced by others'.

The above note could be contrasted with the activities that are making way into Chennai (South India), where state initiatives are attracting software activities from Banglore.

Some of the concerns expressed with the cluster approach include:

1) Definitions received in the existing literature are broad and ambiguous;
2) It may not be applicable to rural areas as they could lack the necessary scale for a cluster;
3) Communication technology is replacing the need for spatial or geographic clustering; and,
4) Scarcity of research on the effectiveness of the cluster approach in generating economic benefits.

However, as mentioned earlier, such concerns are reviewed widely in the literature and moreover, to keep these paper intact of its aims, it will not review these concerns and will rather concentrate on the effectiveness of clusters in the next section.

2.2. Effectiveness and Benefits of Clusters

The cluster model is effective for several reasons. First, conventional economic development approaches, such as a sector or industry-specific strategy, are compartmentalized and isolated activity. In contrast, the cluster approach is integrative, bringing coherence to disparate activities and projects (see Singapore's petrochemical industry). Clusters are defined by interdependencies and are inclusive of other economic development approaches.

Secondly, clusters drive innovation and innovation drives productivity. Porter and Stern (2001) note that,

> 'Innovation and the commercialization of new technology take place disproportionately in clusters'.

The argument follows that to move a concept to a commercialized product, many organizations must cooperate and collaborate. Clusters provide the critical mass for this to occur by facilitating interaction by participants. Few companies have all the necessary skills to develop unique products and services by themselves, therefore clusters, rather than single companies or industries, are the sources for income, jobs and export growth.

Thirdly, the cluster approach is about inclusion, collaboration and cooperation and there are benefits to all participants. The cluster approach breaks down organizational, geographic and sector silos, promotes social capital (inclusive of social network) and facilitates tacit knowledge, all critical ingredients for a creating a virtuous cycle of sustainable economic growth. From a public official's point of view, the cluster approach promotes horizontal collaboration and

strategic partnerships. It breaks down silos that separate firms, institutions, jurisdictions and people. It contributes to the strengthening of economic foundations such as infrastructure and workforce development. The cluster strategy brings coherence and coordination to various programmes and funding at various levels of government that usually exist in isolation and lack cumulative impact.

Fourthly, clusters provide benefits to all involved. From a firm's perspective, firms in a cluster share hard and soft infrastructure, energy, transportation, R&D, and health and safety standards. It provides them with access to all players, attracting brainpower, expertise and local suppliers. In turn, it makes the industry more innovative to adopt technology and enables them to develop and export unique products and services. Major multinational firms can transfer benefits of innovation to their foreign subsidiaries (see Singapore petrochemical industry). Businesses in a cluster have a stronger voice compared with individual firms in targeting government funding for R&D, infrastructure, skills development, legislation and so forth.

From the educational institutions and researcher's point of view, clusters gel together critical mass for brainpower, talent, funding for R&D and access to industry. The Research Triangle Park at the University of Duke, North Carolina State at Raleigh, University of North Carolina at Chapel Hill, Biotechnology Clusters at University of California at San Diego and BIO 21 at The University of Melbourne, strengthened research capabilities, promoted incubators initiatives and promoted entrepreneurship.[3] Being part of a cluster allows universities to translate concepts and ideas into commercialized products.

In a nutshell, the cluster approach is not a traditional economic entity. It offers a way to better understand how the dynamics of an economy work. Clusters are not isolated, but are rather highly connected. By recognizing this connectivity, the government and private sector can be more effective in their respective roles.

3. Government Role

Policy makers, practitioners, academics and business leaders agree that in an economy, government plays three basic roles in providing suitable macro economic conditions, improving microeconomic capacity and, establishing a supportive and progressive regulatory environment.

3) While the BIO 21 in Melbourne is a incubator, it is situated within a cluster-based framework, which situates within the vicinity of major players, such as university, companies related to biotech activities, etc. Authors' field analysis.

Porter (1998) argues that these are necessary roles but may not be sufficient in and of them. The government role should also include facilitating and upgrading cluster development and creating opportunities for productive dialogue to bring cluster participants together.

Some of the key government functions are to play a role as 'broker', 'facilitator', 'initiator', 'participant' and 'listener' to engage partners in a productive dialogue and create a sense of urgency to cause action; conduct ongoing cluster assessments to determine their viability and relative strength to ensure global competitiveness; institutionalize cluster upgrading (e.g. restructuring government programmes and services, diffusing new knowledge, and collecting and disseminating data/information by clusters); directly invest in and provide investment incentives for technical, physical and knowledge infrastructure; and finally, sponsor cluster conferences and forums to promote 'social capital' opportunities for participants (Porter, 2000). Rosenfeld et.al. (2003) supportively note that,

> 'The intervention of an organization··· can influence the development of clusters'.

On the other hand, Porter (2001) claims that

> 'Cluster development can be enhanced by conscious private and public action'.

Both deliberate and unintentional government actions have proven to be catalysts for clusters. In the past, government actions may not have been designed to promote clusters per se but did have a catalytic affect on them. More recently, government actions have been intended to accelerate cluster growth. Even in clusters like the Singapore's electronics industry, which evolved just less than 30 years, government actions, such as R&D spending, tax incentives, and government procurement, proved to be beneficial. Heavy state-intervention or state's entrepreneurial actions have allowed for the creation of the electronics cluster in Singapore. These early actions, while never targeted, had the implicit impact of spawning off other electronics clusters initiatives. Similarly, the government of Karnataka catalyzed Bangalore's Software Cluster through deliberate state-led initiatives.

3.1. Examples of Government-led Cluster Development

3.1.1. India's Bangalore Software Cluster

This is an example of a deliberate public policy to support moving from application software to systems design cluster. In 1991, the government initiated 15 Software Technology Parks

instrumental in creating a critical mass of 180 companies with 20,000 skilled professional workers. It exported 85% of its software products as merchant exports US$350M in 1996-1997, growing at a 64% rate in 2002. While Information Technology Cluster growth worldwide has waned, the Bangalore Cluster continues to grow. Bangalore attracts talented expatriates, foreign investment and major corporations. Oracle, Microsoft and GE have opened offices in Bangalore. It is interesting to note that Bangalore's Software Cluster evolved under a semi-controlled economy.The establishment of the Indian Institute of Science and Hindustan Aircraft Limited were two government actions that provided the initial stimuli for the cluster.

3.1.2. Taiwan's Semi-Conductor and Telecommunications Clusters

Taiwan's Hsinchu Science-Based Industrial Park is an example of government intervention cluster development. The government has invested US$1 billion since 1980, and provided tax exemptions, generous grants and government laboratories (e.g. ITRI) specialising in computer semi-conductors and telecommunications. The Park was established in 1980 and now has over 334 firms with 98,616 employees generating over US$7,054,000 million in annual sales.[4] The government reached its break-even point on the project's annual US$40 million running costs in 1996. The cluster attracts foreign investment and entices talented expatriate workers back to the region.

3.2. Examples of Government Actions Leading to Cluster Success

The Scandinavian government's early action to support experimentation with mobile telephony helped create a strong, globally competitive cluster, having a transformative impact on the economy. The Nordic mobile telephone program was a cooperative effort of the Scandinavian nations to establish mobile telephone systems in each nation well before they were common elsewhere (Porter, 1990). Similarly, the Japanese government's policy helped to speed up the growth of the facsimile industry, compared to elsewhere in the world (Porter, 1990). Early demand for facsimile machines for example was created when the government approved the use of faxed documents for legal purposes.

The examples highlighted above show that government actions can vary from: adopting a national policy of cluster-based economic development; funding cluster assessment/analysis and strategy development; increasing R&D spending and tax incentives; infusing technology through incubation/industrial/research parks; utilizing laboratory facilities; funding, marketing and

4) Figures noted are as of 2002.

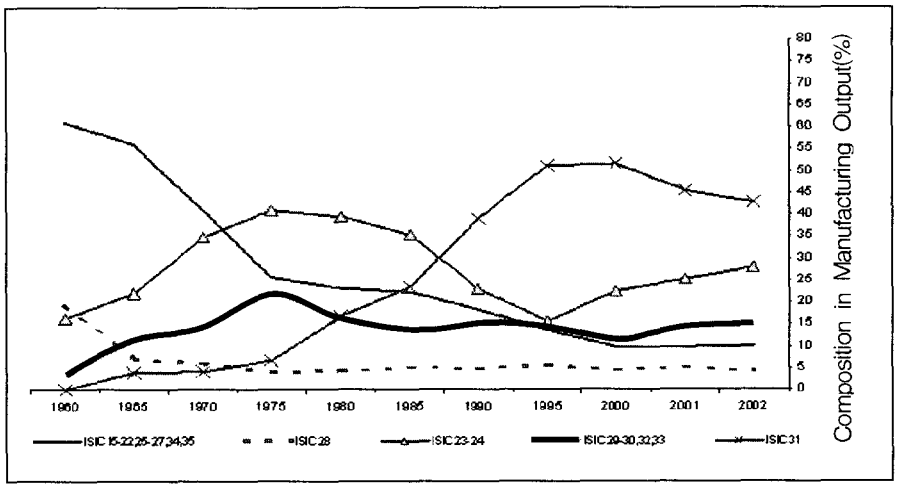
advertising; and, government procurement and restructuring programs and services. Specific areas where the government can contribute to cluster strength recognizing that:

- No other economic development model with such wide spread appeal to a broad spectrum of academic disciplines, professions and lay people has emerged yet;
- Examples from around the globe show that clusters, rather than single companies or industries, are the main sources of income, jobs and export growth; and,
- Economic development policies that target individual firms or industries are no longer viable options for regions.

Government and its army of institutions occupy a unique position. They are best suited to apply their influence and resources to advance clusters where it can be difficult or expensive for any single firm or organization to. The effectiveness of the government role in cluster development noted under Section 3 can be enhanced in various ways. Assessing and benchmarking of clusters, investing in cluster development, restructuring industry policy to support programs and services, have data / information available by clusters (SITC and ISIC classification) and promoting technology in competitive industry sectors. This leads to the next section on how states play a crucial role in creating and sustaining competitiveness of clusters, via the Singaporean industry cluster case.

4. A Singapore Initiative on Cluster Development: The Petrochemical Industry Using the Diamond Model of Analysis

In the context of cluster development, the diamond model of analysis will be used as a framework to discuss in the context of changing landscape of Singapore's petrochemical industry. However, importantly, the petrochemical industry is often difficult to segregate from overall chemical industry. For the discussion here, the paper segregates the industry into mainly Petroleum, Petrochemical, Specialty chemicals and Pharmaceutical segments. Figure 1 provides a good snap-short on Singapore's manufacturing sector.



Notes: ISIC codes are as follows: 15/16 food, beverage & tobacco, 17 textile & textile manufactures, 18 wearing apparel except footwear, 19 leather, leather products & footwear, 20 wood & wood products, 21 printing & paper products, 22 printing & reproduction of recorded media, 23 refined petroleum products, 24 chemicals/chemical products, 25 rubber & plastic products, 26 non-metallic mineral products, 27 basic metals, 28 fabricated metal products except and machinery & apparatus, 29 machinery equipment, 30 electrical machinery & apparatus, 31 electronic products & components, 32 medical, precision & optical instruments, watches & clocks, 33 transport equipment, 34 other manufacturing industries, 35 recycling of metal/non-metal waste & scrap.

Source: Economic Development Board (2002), *Report on the Census of Industrial Production, 1960-2002*; Singapore Department of Statistics, *Yearbook of Statistics Singapore*, 1960-2002.

Figure 1: Composition of Output in Manufacturing, 1960-2002

Briefly, after the electronics sector, the petrochemical sector (ISIC 23-24) contributes approximately 30% of output to the total manufacturing output. Compared to the electronics industry, it is evident from the figure that, Singapore's petroleum sector has a historical existence since the 1960s, and has been a major composition of manufacturing output. In 2003, the export value of petroleum and petroleum products totaled more than $16 billion, which was about 11% of the total value of exports. The Government planned to increase the output share of the petrochemical products in the manufacturing industry to 30% in 2010 compared with 25% in 2003.

Petroleum refining accounted for 57% of the chemical sector's production. The four oil refining companies—ExxonMobil Corp., Royal Dutch/Shell Co., Singapore Petroleum Co., and Singapore Refinery Co.—had a combined output capacity of about 1.3 million barrels per day. Major multinational petrochemical companies, such as BASF, ChevronTexaco Corp., ExxonMobil Corp., Mitsui Chemical Co., Royal Dutch/Shell Co., and Sumitomo Chemical Co., had set up plants on the island. In 2003, the chemical sector accounted for 21% of total manufacturing fixed asset investment commitments, which rose to 23% in 2005 (see table 1). Most chemical products

were for export, although some were used as critical raw materials for the electronics sector in Singapore (Asian Chemical News, 2004: 2).

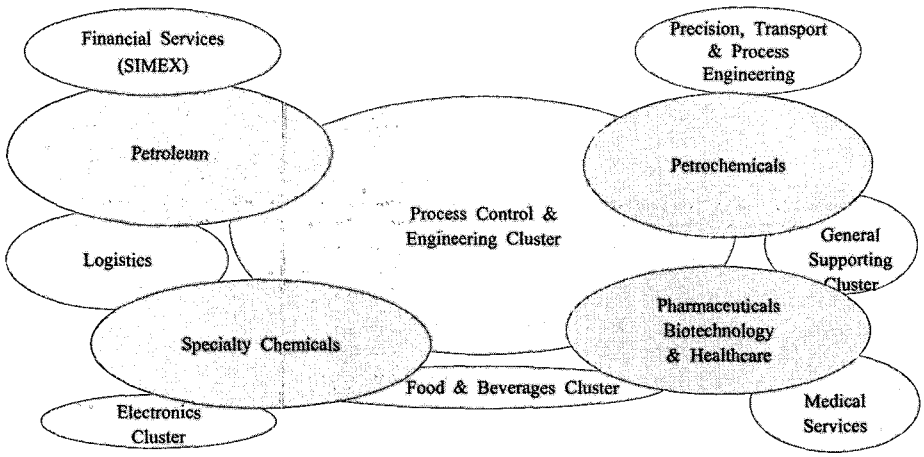
Table 1: Investment Commitments in Manufacturing Industry by Clusters, 2002-2005

(Unit: S$ millions)

Clusters	2002	2003	2004	2005
Electronics	4625.2	4224.1	4571.1	4354.2
Chemicals	2027.1	1571.4	1643.0	1979.6
Biomedical Engineering	853.5	851.5	849.2	859.5
Precision Engineering	960.6	423.4	368.2	418.2
Transport Engineering	302.1	205.9	484.5	597.5
General Manufacturing	213.2	234.7	342.0	309.8
Total	8981.7	7511.0	8258.0	8518.8

Source: Economic Development Board (2006), *Economic Survey*, First Quarter 2006.

The Figure 2 provides an overview of the Singapore chemical cluster. The Economic Development Board (EDB) is the lead agency for developing the manufacturing sector in Singapore. Its strategic intent for the chemical industry cluster is to develop Singapore into an integrated world-scale petroleum and petrochemical hub. Under the M2000 programme, the EDB has adopted a cluster development strategy to improve competitiveness through the establishment of linkages and integration, within a cluster, as well as between industry clusters.[5)]



Source: Economic Development Board (2000).

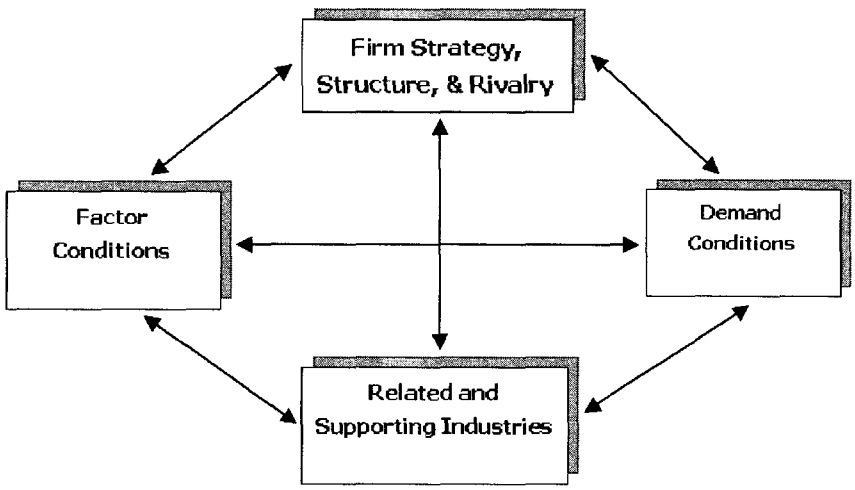
Figure 2: Singapore's Chemical Cluster

5) M2000 programme stands for "Manufacturing 2000".

4.1. Diamond Model Analysis

The main analysis of the petrochemical cluster is done using diamond model, the most widely used tool for cluster analysis. In a simple explanation, the Diamond Model analysis assists in evaluating the competitiveness of a cluster, which is defined as geographically, bounded concentration of similar, related or complementary businesses. A competitive cluster creates competitive advantage for firms co-located in the cluster.

The diamond model proposes four interrelated facets, each of which representing a determinant of the cluster is competitive advantages (and thus also of the firms and industries therein). The four facets are: (1) factor inputs (2) demand conditions; (3) related and supporting industries and (4) firm strategy and rivalry. The other two factors that influence these four determinants, but are not determinants themselves, are 'Government' and 'Chance'. Together these six factors form a system that differs from location to location, thus explaining why some firms (or industries) succeed in a particular location. All six factors need not to be optimal for firms or industries to be successful. Academic literature on the diamond model is widely available and as such will be not be reiterated here. In the following analysis, all the four diamond factors are discussed first, followed by the factor of 'government', which is extremely important in the development of the petrochemical cluster in Singapore. Figure 3 represents this scenario.



Source: Porter, M. (1990: 72)

Figure 3: Diamond Model of Competitive Advantage

The Petrochemical industry really took off with the discovery of plastics that led to the huge increase in demand for ethylene. This growth has been mainly due to petrochemical products substituting traditional material such as metals, glass, paper and wood in numerous applications in industries like automobiles, bottling and packaging to name a few. Another reason for the growth has been due to the development of some new applications that did not exist before like in the electronics industry.

In recent times, the markets in many western and developed countries have reached maturity plateau and thus, the petrochemical industry growth is stagnated. Due to rising environmental concerns, the trend has been also towards the use of other biodegradable materials adversely affecting the demand for these products.

According to McKinsey and Company et.al, (2001) study, the average profitability of petrochemical and chemical industry, barring the petroleum segment, has been lower than the average total market profitability after the Asian crisis. The study also projects low industry growth at 3.4 percent CAGR (compound annual growth rate) from 1996-2010 in an indication that industry has reached a mature stage. The total market share of top ten chemical companies in overall industry is only 16 percent indicating a fragmented and competitive industry.

However, globally the petrochemical industry has some reprieve with the high growth rates coming from the Asian region to counter the declining margins and higher competition in the industry. Recently China has been the reason for all the optimism as its economy grows creating an enormous demand for petrochemical products. As more manufacturing industries move to Asia to save costs, the need to produce more of the raw materials like petrochemical products in the region becomes a necessity. This enthusiasm has also led to issues of production overcapacity and falling industry margins, which are more apparent especially in the economic slumps. But, it has been also argued that as long as China and India, the twin growth engines of Asia, keep growing the industry products will find enough demand to be fulfilled. All the major players have shifted focus towards Asia.

The fact that the industry is capital intensive, technology dependent and scale-of-economies driven would mean that all the major players are mostly multinationals and big corporations. Many of these like Exxon and Shell are also vertically integrated starting from oil exploration right up to producing feedstock for their own petrochemical business. There are also horizontally integrated companies like BASF, DOW and ICI that have operations in bulk chemicals. Nevertheless, there is intense competition from local players too. Many of the less integrated local companies are also expanding their operations and moving towards fully integrated complexes as against just petrochemical facilities. Yet, many others in the region, in the process, might fear of being

'crowded-out' or marginalized, especially as more trade barriers are reduced gradually or totally extinguished.

Singapore has a long history in the chemical industry and is the third largest refining hub in the world despite having no natural resources of its own. The root of the industry was laid as early as the 1890's when Shell and Mobil established themselves in this once British colony. The existence of the refining industry led to the natural development towards downstream integration as the need for more value added products in the region became more apparent and developing countries also entered the refining industry increasing the competition. Today, Singapore offers a full range of chemical industry services such as refining, bunkering, petrochemical production, fine and specialty chemicals, oil trading and oil rig manufacturing to companies in the region and worldwide. In 1984, the government along with a consortium of companies commissioned the Petrochemical Corporation of Singapore to build the Pulau Ayer Merbau petrochemical complex. Singapore had a dedicated plan to ensure that at least 25% of the country's income is achieved from the manufacturing sector and chose to develop the chemical industry cluster as they felt they had a lot of factors that could help the growth of the industry. Central to this industry is our focus industry, namely the petrochemical industry.

The petrochemical industry started growing very rapidly in the 1990's and by 1994; it had become the fastest growing sector registering an annual growth rate of 20%. As the demand in the region grew, the plants in Singapore ran at full capacity to match the demands of the region. Although the growth rate is not as high for 2002, it was still a healthy 11%.

The manufacturing output of Singapore accounted for 25% of GDP in 2002 out of which the chemical industry accounts for 22% of the total GDP in 2001. It is expected that the share of contribution will increase to 30% by 2010. Within the chemical industry, although the petroleum sector had the highest output with 60% in 2001, in terms of value added it only accounts for 33%, while the petrochemical industry accounts for 23% behind the specialty chemicals which accounts for 38% of the value added. The chemical industry has had a strong period of growth right throughout the 1990's both in terms of output and value added with a high of more than 30% falling slightly in 2001 due to the economic recession which had its affect worldwide.

4.2. Competitiveness from a Cluster Perspective

Today Singapore is much recognized around the world as one of the most competitive nations in the world. Singapore ranks fifth in World competitive Scoreboard for 2002 released by IMD and top in labor laws and regulations that allowed labor flexibility in terms of labour organization.

Singapore's economy is highly dependent on trade and it has the highest trade to GDP ratio in the world. Although Singapore firmly supports the WTO multi trading system, they also favor regional trade agreements as in ASEAN and bilateral FTAs. Singapore chose to use FDI as its principal source of external capital for growth since its independence unlike Taiwan and South Korea that shunned FDI's and depended on loans and borrowings. Although FDI's has been a key to Singapore's rapid growth till this stage, it is argued that for the innovation stage of growth, Taiwan and South Korea may have technological and innovation advantage over Singapore.

Jurong Island－The Concept

Towards the development of Singapore Petrochemical industry, the development of Jurong Island based on cluster approach plays a central role. The location of feedstock and multiple upstream and downstream companies integrated with linkages at one dedicated location makes this very attractive for individual companies. Multinational companies from all over the world have invested on the island as the demand for petrochemical and specialty chemicals in the region has substantially increased. Today there are over 70 companies on the island with investments well over S$21 billion. The island aims to have five ethylene crackers by 2010 serving more than 150 downstream companies attracting a total of about S$40 billion.

State of the art infrastructure has been put into place by the government as well as common utility facilities keeping safety as a top most priority. The availability of supporting industries such as logistics industry, common berths and jetties, waste treatment facilities and chemical warehouses all add to attracting prospective investors. There are many optimists and pessimists constantly arguing about the long-term feasibility of this cluster concept on Jurong Island.

4.2.1. Factor Inputs

The obvious and general reasons for attracting investments in Singapore are not listed here. The factors such as political stability, sound macro & fiscal policy, financial incentives, good transportation network, sound legal framework, good telecommunication infrastructure and pro business environment are already well understood. The focus here is on specialized factor inputs that are created around the cluster.

- **Existence of Oil Refineries**

Singapore has one of the largest oil refineries in the world and it is the world third largest refining center. The four main refinery companies, Shell, Exxon Mobil, Singapore Petroleum Company (SPC) and Singapore Refinery Company (SRC) have a total capacity of over 1 million

barrels per day (b/d). Being geographically located in the heart of South East Asia (SEA) had helped Singapore to attract refinery companies to invest in the country as early as in the 1800s. As the output of the oil refineries (such as naphtha, NGL and LPG) are used as feedstock in the petrochemical process, their existences in Singapore will likely to attract other companies to set up petrochemical plants close to these sources to reduce the cost of transportation. It is the motivation that the Government of Singapore (GOS) initiated the idea of constructing closely integrated petroleum and petrochemical complexes on Jurong Island (JI).

- **Petrochemical Infrastructure**

The reason for locating petrochemical plants close to or even integration into their feedstock production bases is cost. According to 'Guide to the Petrochemical and Chemical Industry in Singapore 1998' report, feedstock is the largest cost component and integration with oil refineries helps to bring about savings in storage, logistics and productivity through better refining process. It is even estimated that an integrated petrochemical refineries will add US$2-US$5 per ton of crude to the refinery margins excluding petrochemical profits.

- **Shared Facilities**

Recognizing the need for companies to operate in a cost efficient environment (especially in huge capital investment industry such as petrochemical), Jurong Island was created. With an eventual land area of about 2,790 hectares, Jurong Island was built by linking seven small islands (The seven small islands are Pulau Merlimau, Pulau Ayer Chawan, Pulau Ayer Merbau, Pulau Seraya, Pulau Sakra, Pulau Pesek and Pulau Pesek Kecil) together so that petrochemical and chemical plants can co-locate with their sources (the oil refineries) to reduce logistic cost. In addition, companies that support the petrochemical industry were also found on the Jurong Island and this has provided additional benefits.

Companies on the island are able to share marine facilities (jetties and berthing), waste treatment, warehousing, fire fighting, medical and emergency response service, roads and drain infrastructure and service pipelines. Service pipelines are a form of common service corridor that runs round Jurong Island so that companies located at any part of the island can have easy access to the service corridor. By 'plugging in' to the service pipeline, companies can transfer raw materials, finished products and obtain utilities services seamlessly (SembCorp Utilities Terminals helps to control the flow to companies). 'Plug and play' capability is a key element of the Jurong Island's strategic advantage. According to Economic Development Board, the concept of being able to share common facilities by locating close to one another helps companies to save up to 20% in their capital cost. Besides eliminating the needs of individual company to worry

about complex infrastructure development and high costs, the 'plug and play' feature will also mean that new operations can now be set up more speedily.

- **Human Resource Development**

In 1992, the GOS set up a Chemical Industry Manpower Advisory Committee (CHIMAC). It was established to advice on matters such as industry's best practices, training and education, and manpower development. The committee had put forth three important strategies in developing human resources in the industry,

a. Universities to increase intake by 20%
b. Develop training classes of core manufacturing techniques for plant people
c. Attract overseas talents

These recommendations set the stage for Singapore to ensure an adequate supply of qualified manpower to fuel the growth in this industry. To further breach the gap between academic training and on the job know how, GOS has built S$40 million facility called the Chemical Process Technology Center (CPTC) on Jurong Island. CPTC has the capacity to train 800 students and 8,000 workers annually for both the chemical and pharmaceutical industries. The trainings in CPTC are more realistic as it gives the trainees the opportunity to operate a 'live size' plant in a classroom environment. This facility not only helps to shorten the time required for on the job training but also provides a platform for workers in the industry to continuously upgrade their skills.

In order that the industry can attract the best people in the country, a school outreach program has also been launched to promote better understanding of the industry and to foster awareness of career opportunities. Schools are encouraged to visit the chemgallery@JurongIsland to raise the students' interest and awareness. EDB also gives out overseas scholarships to top 'A' levels students to study chemical engineering.[6] Singapore is also eager to attract skilled workers to the country to work in this industry. Besides formulating immigration laws that are attractive to foreign skilled workers, GOS has also been making effort to constantly improve the living environment in Singapore both economically and socially.

6) Refers to Cambridge General Certificate of Education at Advanced Levels (GCE 'A' Levels), an equivalent to Year 12.

4.2.2. Demand Conditions

The presence of a sophisticated domestic demand is extremely important in pushing firms to innovate faster and gain competitive advantages over its rivals. Therefore, the existence of a domestic demand for the petrochemical industry is vital. The biggest demand emanates from having the advantage of being sited close to their buyers within the Jurong cluster in an integrated complex. Apart from that, the important demand comes from plastics, electronics and pharmaceutical industries. For instance, there is noticeable demand of different plastics that are being used in a wide range of industries such as in the production of the finished electronics goods, medical equipment, packaging, audio video items, computer parts, pharmaceuticals, aerospace and even construction in the engineering plastics segment. Hence, the existence of such industries, which are mostly multinational companies, became large consumer base for the petrochemical firms. However, at the same time, Singapore has limitation in terms of variety, sophistication or volume of demand that it can offer. The size of the domestic market is very limited and sophistication or variety is constrained due to limited economic industrial activities in specialty industry segments.

4.2.3. Related and Supporting Industries

The key industries that provide supports to petrochemical firms are logistics, utilities, engineering and finance industry. They play a vital role in supporting the petrochemical firms in their operations in Singapore. This section discusses the capabilities and the support functions of some of these companies indicating the existence of strong related and supporting industries.

- **Engineering Industry**

Engineering industry is another key supporting industry for the petrochemical firms. This industry is of great importance such that in the Industry21 plan, GOS wanted to develop Singapore into an engineering hub with new capabilities to support other industry clusters. The supporting role played by the engineering industry includes design, construction and maintenance of plants and pipelines for the petrochemical firms.

The oil and petrochemical industry in Singapore is expected to spend S$1 billion on plant maintenance in the next few years ('Guide to the Petrochemical and Chemical Industry in Singapore 2000'). The increase is largely due to outsourcing of maintenance work to third party contractors. A large proportion of the engineering industry is the existence of the marine industry in Singapore due to its role as a transshipment port in Asia. Marine industry includes shipbuilding, ship repairing and oil rig construction. The competency of the engineering firms supporting the marine

industry is a skill that can be transferred to support the petrochemical industry. One of the examples of an active engineering support company is Rotary Engineering Ltd. This Company was established in 1972 and today it is listed in the Singapore stock exchange. It occupies S$26 million integrated maintenance complex on Jurong Island. The complex is designed to offer total maintenance, engineering design and centralized warehousing services. The key customers are Eastman Chemical, Singapore Gas, Celanese, Gesso and Chevron. It has operations in China, India, Indonesia, Malaysia and Thailand.

- **Utilities Industry**

This industry helps to power and supply utilities services for operating the petrochemical plants. The services include supply of gas, steam, cooling water, de-mineralized water and process water, as well as providing wastewater treatment. Some of the firms in this supporting industry are:

PowerSeraya Ltd - A divested company from Singapore Power operates both the Pulau Seraya Power Station and Jurong Power Station with a total licensed generating capacity of 3,100-mega watt.

SembCorp Cogen (SembCogen) - The Company commenced full commercial operation on September1, 2001, producing electricity for dispatch into the Singapore Electricity Pool and steam for industrial consumers on Jurong Island, Singapore. SembCorp Cogen operates 815-megawatt plant to generate electricity and processes steam.

SembCorp Gas Pte Ltd (SembGas) - It is a member of SembCorp utilities, is the first importer and retailer of natural gas in Singapore. The natural gas is imported from the West Natuna Sea in Indonesia directly to SembGas's receiving terminal at Sakra in Jurong Island via a 640-kilometre armored sub-sea pipeline. Under the agreement signed in 1998, Partamina of Indonesia will supply 325 million cubic feet per day of natural gas to Singapore for 22 years. Besides using the natural gas to power the MW of energy supply to companies on JURONG ISLAND, SembCorp will also supply the excess capacity to be used as cooling agent or feedstock.

Messer Grieshein－It is the industrial gas arm of Germany's Hoechst AG. It operated an S$25 million specialty gas center in Singapore's Senoko industrial district that is capable of producing 40,000 cylinders of gas every month. The plant produces helium, high purity gases and gaseous liquid hydrocarbon mixtures. Products will be shipped in cylinders to petrochemical, chemical, electronic and industrial customers in Singapore and the region. The company also has a joint venture with Texaco (USA) in a company called Singapore Syngas Pte Ltd located on JURONG ISLAND to provide Hydrogen, Carbon Monoxide and Synthesis Gas feedstock to petrochemical and refining customers.

- **Logistics Industry**

With a population of 4 million people packed onto a 640 square kilometers area, Singapore has to take extreme caution of risks posed by the growing presence of the petroleum, petrochemical and chemicals industries. Safety in the transport, storage and handling of hazardous and toxic materials becomes important. The demanding standard requires a highly specialized logistic support industry. Few global logistics companies exist in the world who specialise in handling of hazardous materials and key ones are listed below to highlight their capabilities:

- ▸ Kato Natie SembCorp Pte Ltd (KNS) - KNS is a joint venture between Katoen Natie (51%) and SembCorp Logistics. Kato Natie is a world leader in logistics solutions with head office in Antwerp, Belgium and over 6,000 employees worldwide. KNS has several fully owned subsidiaries, such as KNS Thailand, KNS Jurong, KNS Chemical and KNS China. KNS provides packaging, storage in warehouses and silo's, for plastics and fine and specialty chemicals, both hazardous and non-hazardous, as well as handling of overflows volumes. In addition, a wide range of value-added logistics and specialized services for liquids and solids, such as (de) bagging, blending, drumming, grinding, sieving, flaking, de-dusting, dosing and weighing, compounding are also offered.
- ▸ The Oil tanking Odfjell Terminal Singapore (OOTS)－This is a 50%-50% joint venture between Odfjell and Oil tanking. Oil tanking, a Netherlands company, is one of the world's leading independent storage partners for oils, chemicals and gases. Oil tanking owns and operates 69 terminals with a total storage capacity of 9.6 million cubic meters in 16 countries. Odfjell currently operates a substantial share of the world intercontinental core chemical tanker fleet. Their fleet consists of 63 vessels and operates 12 vessels out of Singapore in Asia. The terminal operated by the company is dedicated to the storage of chemicals on Pulau Seraya. Of the total capacity OOTS has dedicated 100,000 cubic meters as off-site storage for the Seraya SM/PO plant (Shell and BASF) located on Jurong Island. The remaining chemical storage capacity (30,000 cbm) is offered to a wide variety of clients for product distribution throughout the Asia Pacific region.

- **Financial Sector**

Singapore has a very strong financial sector, which is required to fund the huge projects in this very capital-intensive industry as well as the cost to maintain these huge operations. It is estimated that it will cost US$20 to US$25 billion to build a refinery. Banks and financial institutions also derive substantial business servicing the accounts of more than 100 active oil

companies with operations in Singapore in the areas of oil trading. [Guide to Petrochemical and Chemical Industry 1997; Ng Weng Hoong, The Strategist, October 1996]. As such, a huge network of international banks from Dutch, French, American and Japan have emerged.

4.2.4. Context for Firm Rivalry

One way to evaluate the effectiveness of the rivalry context is to look at the number of firms in the same industry. Today, there are 70 companies located on the Jurong Island. However, not all the companies produce identical products. Due to integrated complex concept and high capital intensity, only few companies end up with identical product lines limiting the rivalry. In addition, supplies agreements in this industry are usually long term and it is common to see competitors collaborate with one another for certain products. Therefore, low duplication of products lines and the existence of long term supply agreement tend to limit the domestic rivalry in this industry. The rivalry typically is among the key integrated petrochemical feedstock suppliers such as Shell, Exxon Mobil and Singapore Refineries Company (SRC).

4.2.5. Institutions and Associations

The needs and problems of the chemical manufacturers in Singapore are being addressed by Singapore Chemical Industry Council (SCIC), which was set up in 1979 under the Singapore Manufacturers Association (SMA). SMA became the Singapore Confederation of Industries (SCI) in 1996 and its chemical industry group merged with the SCIC. Today SCIC is the sole representative of the manufacturers in the industry in Singapore and includes the petroleum sector and companies from other supporting industries. SCIC is affiliated to the ASEAN Chemical Industries Club and it represents the industry globally in an effort to promote investment into Singapore for continued growth. It also promotes work place safety and health program in the industry. The set up of this association has elevated the importance of this industry in Singapore and in the region. It plays an important role in forging a link between the companies, addressing both the individual company and industry needs to the government. These interactions also help to spur growth through exchanges of information and ideas.

4.2.6. Role of the Government

The government has been an important driver in the development of Singapore's economy. The main attractions of Singapore are its excellent infrastructure, political stability, efficient and clean administration, a pro-market environment, a skilled workforce, industrial peace and

a high commitment to excellence. In this section, key roles that the Government of Singapore (GOS) took in aiding the formation of the petrochemical industry is highlighted.

The GOS has practiced a 'pick and select' approach in promoting industries, which includes petrochemical industry. This has an enormous impact in the formation of the petrochemical industry, because once selected, the industry has received all of Singapore's government resources to grow and prosper. The development of Jurong Island for petrochemical and related industry says it all. Though there has been some debate over the years for adopting this strategy of 'hand picking' the industry that it deems fit.

4.3. Cluster Strategy

The added advantage that the GOS brings to the petrochemical industry is the EDB's cluster strategy (refer to figure 2). Under this pursuant, the concept of an integrated petrochemical complex on Jurong Island was born. Economic Development Board (EDB) views the integration strategy as an important element in attracting investments. By being closer to the sources of materials (the oil refiners) and support facilities, the companies are expected to achieve a reduction in cost and a rise in productivity. Such an analogy can be understood via a comment from the EDB chairman:

> 'We cannot artificially suppress costs in Singapore, but we can increase the value that an investor gets out of Singapore. No company operates in isolation. It has to deal with various suppliers; it needs access to the right type of qualified manpower and competence centers in relevant technologies, as well as efficient infrastructure and other services. Our aim is to build up these components together to a standard comparable to OECD countries. This is the essence of the cluster strategy for industry and business services'. [Philip Yeo Chairman, Economic Development Board 1997]

4.3.1. Stakeholder

In capital-intensive industry such as in petrochemical, the GOS through its pilot agency, the Economic Development Board (EDB), is prepared to jump start projects by buying up minority stakes in the ventures. For instance, in Singapore's first ethylene cracker project, which is worth S$2 billion, GOS took a stake with Sumitomo Corporation to form the Petrochemical Corporation in Singapore (PCS), which was launched in 1984. This first cracker had a chain effect such that Philips petroleum and later Exxon Mobil followed suit in setting up the ethylene cracker in Singapore as well.

4.3.2. Free Trade Agreement (FTA)

GOS had embarked on a series of bilateral FTA with individual countries in 2002. To date, the state has secured 20 FTAs, which includes those it had secured with Japan, United States, New Zealand, Switzerland, Iceland, Norway and Liechtenstein, Australia and is in talks with Canada and Mexico. Signing such FTAs is another important role that the government had taken to boost investment into the country. For instance, plastic resin maker Teijin Polycarbonate will save $500,000 in 2003 in tariff concessions, following the signing of the Japan-Singapore free trade agreement (FTA) late last year. In addition, it expects to save another $4 million to $5 million when Singapore's FTA with the United States comes into effect next year. Moreover, in view of these potential savings, the Japan-based company is looking to transfer part of its production from its factory in Japan to its plant here on Jurong Island as it can enjoy economies of scale. Hence, the pursuit of bilateral FTA does have a positive impact in attracting companies to invest in Singapore.

4.4. Preliminary Conclusion

Using the diamond model as a framework of analysis, the factors that have helped in the development of the petrochemical cluster in Singapore have been discussed above. The evidence of competitiveness of the Singapore petrochemical industry can be seen from its contribution to Singapore's GDP and the FDI as mentioned in earlier sections. These factors have direct and greater impact on the nurturing of the petrochemical cluster itself. Summarizing the diamond model for petrochemical industry in Singapore, the strongest driver that had led to the existence of the industry is the factor input condition. Singapore's history and its leading position as an oil refinery center in Asia leads to numerous downstream players co-locating here for cost competitiveness reasons. In addition, the government's role in pushing for the development of the petrochemical industry through its cluster strategy has also created a positive impact. These 'created' factor inputs attracted the downstream players to make up for the demand conditions for the petrochemical industry.

The supporting and related industries are largely driven by key government linked companies, in this case the Sembawang Corporation, through collaboration with international companies to service the needs of the industry. Context for firm rivalry is considered to have moderate presence in this case owing to various reasons as high capital-intensity, industry practice of long-term supply relationship and highly integrated and shared infrastructure facilities on the island.

5. Conclusion

Cluster-based economic development is at the forefront of promoting innovation, productivity growth and prosperity and clusters have attracted the attention of government officials, business leaders, academics and practitioners alike. While the origins and trajectory of clusters can differ, the key contributing factors to cluster success are intangible assets such as social capital. Clusters have been shown to promote collaboration and to create tacit knowledge.

As such, government has an enduring role in a productive economy and cluster development offers a new model for governments to organize their industrial programs and services. This paper has discussed government actions and how they have contributed to cluster success in Singapore. Actions vary from adopting cluster-based economic development as a national policy, providing funding for cluster assessment and strategies, increasing R&D spending, infusing technology and being a demanding customer for clusters. The experience of Singapore's petrochemical sector suggests that government is a facilitator, not a master strategist, creates opportunities for cluster participants to organize, identify and solve common problems, and then the private sector leadership will emerge to drive the process.

Whilst the petrochemical industry development approximates the cluster-based development model, more research needs to be done, in particular about the idea of the cluster-based approach to development. Cluster strategy does not eventuate out of isolation. Rather the question is on whether success of industries might be due to good business strategies, locational advantages or capitalizing on a nation's competitive advantages and astute planning by governments / states around the world. As such, cluster outcome might have been due to the above-mentioned factors and it might not have been a strategy but rather an outcome of strategies. More research needs to be undertaken to confirm the impetus of cluster-based strategy leading to economic development.

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