CHANGING LANES

The evolution of the E&E Industry in Singapore

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Preface

This report is the product of an extensive research done in Singapore between March 2015 and August 2015. It is part of the finalization of our Master's program at the Utrecht University. The subject of this thesis was proposed by our professor in the Netherlands, Leo van Grunsven, and his research partner at ISEAS Yusuf Ishak Institute in Singapore, Francis Hutchinson. The research subject is the evolution of the electrical & electronics industry in Singapore and is part of a larger research project about the evolution of the E&E industry in Southeast Asia.

Preparations for the fieldwork started back in the Netherlands in February 2015, when we commenced with the theoretical framework and the background of the subject. The structure of the research brought up some difficulties, as initial plans to conduct surveys in order to collect data on the firm-level appeared to be unsuccessful. This proved to be challenging, but was solved by changing the point of view of this research.

We would like to thank our teacher, professor Leo van Grunsven, for his professional and social commentary, advice and guiding during the research and for visiting us in Asia. We would also like to thank our local supervisor, professor Francis Hutchinson, for his advice during our stay in Singapore. Also, we would like to thank all the employees of ISEAS, who were helpful with their insights and have provided us with the help needed to conduct this research. Finally, we would like to thank all Singaporeans who helped making the research and stay in Singapore very exciting.

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Bas Fleuren and Hjarald Janssen

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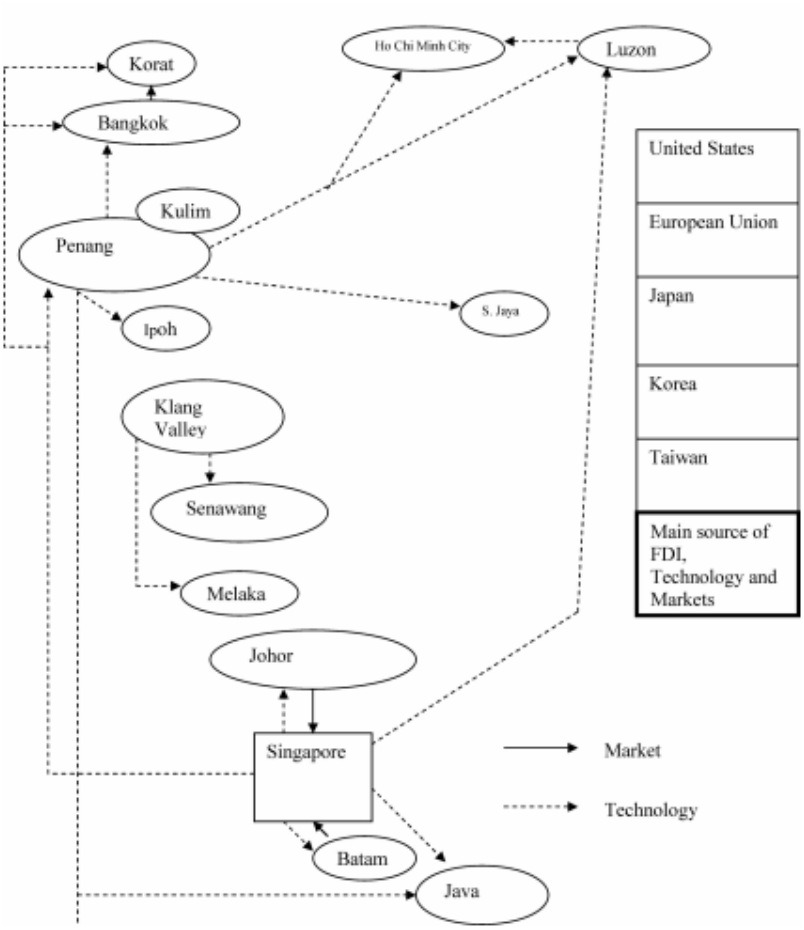
1. Introduction

The industrialisation process in the Southeast and East Asian region emerged four decades ago in Japan, followed by the so-called 'Asian Tigers' of Hong Kong, Taiwan, South Korea and Singapore. In this process, the electrical and electronics (E&E) industry was a major pillar. Following the example of the Asian Tigers, the industrialisation process emerged in other Asian countries. The industrialisation process of Southeast Asia differentiates from Northeast Asia, as the role of foreign direct investments (FDIs) from multinational companies (MNCs) was more dominant (Felker, 2003; Yeung, 2009).

The first region in Southeast Asia experiencing waves of FDIs in the E&E industry 30 to 35 years ago was Singapore, followed by Penang, Klang Valley and Bangkok. Firm behaviour has been a prevailing reason for the development of the E&E industry in regions in Southeast Asia, as MNCs affiliates functioned as forerunning firms, shifting and distributing activities across regions (Van Grunsven & Hutchinson, 2014). The role of the government has been vital, as the government actively promoted the economic activities of MNCs. Nowadays, the E&E industry is an important pillar of several Southeast Asian countries. E&E products have dominated the manufacturing exports of Singapore, Thailand, Malaysia, Philippines and Indonesia for several decades (Rasiah & Yun, 2009). In 2014, the Southeast Asian region exported nearly $300 billion of E&E products (ITC, 2014).

Over the decades, the economic activities in the E&E industry in Southeast Asia dispersed spatially with a geographically variation of degrees of sophistication, strongly influenced by external factors as MNCs' strategic relocation decisions, and internal factors like the role of governments (Yeung & Coe, 2015). In the MNC networks, regions assume a certain position ('node') determined by a hierarchy of value, varying from low-order to high-order activities. The position of nodes in the network are not definite, as they are able to move up or down the hierarchy of by attracting or losing more advanced activities, processes or functions. The most important nodes with varying degrees of sophistication and their relationships with each other in Southeast Asia are mapped by Rasiah (2009). Figure 1.1 illustrates the main concentration of the E&E industry in Southeast Asia. Singapore is the most important node, with the most sophisticated sector and operating as a hub with the E&E based MNCs transferring technologies towards the whole region, directly and indirectly. Another sophisticated node is Penang, which among others transfers the technologies coming from Singapore towards other regions. Furthermore, the market relations show that regions like Penang, Klang Valley, Bangkok and Luzon mainly export directly to integrated final markets abroad. On the contrary, firms from certain locations (e.g. Batam & Johor) export their products through other locations (in this case Singapore). This is mostly because these locations produce components or assemble final products (Rasiah, 2009).

Figure 1.1: Nature of integration geographically, 2001.



Source: Rasiah, 2009.

This research tries to map the evolution of the E&E industry in Singapore between 1990 and 2014, in which the influence of the government has been valuated. The research aims to identify the dynamics processes, as well as the different trajectories and growth paths in the E&E industry. A detailed analysis on how Singapore has become a regional hub in Southeast Asia has been carried out, as well as whether the policies to promote Singapore have affected the city-state as a manufacturing location. This research zoomed in the current position of Singapore in the networks of some (lead) MNCs, in order to better understand the evolution of the industry. The independent position of the local firms in the E&E industry has been analysed, which has been an inadequate adduced topic in the existing literature.

The research will be carried out from an industry and evolutionary perspective, linking past and present. The evolutionary approach will be executed by means of a longitudinal database, constructed with secondary source material. More secondary source material will be used to get a better understanding of the evolution and composition of the E&E industry; MNC and local firm development; and regional production networks. The addressed topics and perspectives result in the formation of research questions.

1.1 Research questions

The main research question is as follows:

1. “How has the structure and the size of the E&E industry evolved in Singapore from 1990 to 2014, given the internal and external factors?”

In order to answer the main research question, the supportive sub questions are as follows:

2. “How can the trajectory of the E&E industry in Singapore from 1990 to 2014 be characterised?”

3. “Has the evolution of the E&E industry in Singapore from 1990 to 2014 led to industrial upgrading?”

4. “Are there differences between evolutionary trajectories of branches, and which factors explain these differences?”

5. “Are there differences between nationalities in terms of entry and exit patterns of foreign firms, and which factors explain these differences?”

6. “How has the position of Singapore in the networks of foreign MNCs in the E&E industry evolved between 1990 and 2014?”

7. “How has the role and position of local firms in the E&E industry evolved between 1990 and 2014?”

1.2 Relevance

Research on the evolution of the E&E industry in Singapore has mainly focussed on the influence of FDIs and MNCs (e.g. Borrus et al., 2000; Rasiah, 2009; Rasiah et al., 2014); subindustries, such as the hard disk drive or semiconductor (e.g. Cooke et al., 2013; McKendrick et al., 2000); origin of firms, like Japan (e.g. Edgington & Hayter, 2013); or the variation of governmental policies (e.g. Toh, 2014). The majority of previous researches illustrates a smaller piece or segment of the E&E industry, but has not mapped the evolution of the industry as a whole.

According to Neffke et al. (2011), the research on how regions diversify over time and how new growth paths develop has been limited. This thesis attempts to map the evolution of the E&E industry in Singapore on a highly detailed level, by illustrating the different growth paths of (related) product groups. Additionally, this research focussed on the trajectories of MNCs in the city-state, as Kuchiki & Tsuji (2011) argue that there has been little research on the long-term development of MNCs.

There has been little attention in the literature regarding the role and functions of local firms, their structure, transformation and behaviour and their interaction with foreign MNCs. Local firms inevitably are crucial links in dynamics of industries, often taking up the position as suppliers of lead firms. Therefore, this research aims to contribute to the insights within the scientific field which concentrate on these themes in the E&E industry.

Aside from the scientific relevance, this thesis attempts to address the role of the government in developing and steering the evolution of the E&E industry. Scholars and

other nations have valuated the policies implemented by the Singapore government to develop the E&E industry as a success story. Singapore has, in contrast to other countries in SEA, successfully left the 'middle-income range', through implementing policies that realised upgrading processes towards higher value added activities (Gill et al., 2007; Kharas & Kohli, 2011; Yusuf & Nabeshima, 2009;).

Finally, the E&E industry has taken up an important role in the development of the Singaporean economy, and is therefore described as 'the backbone of the economy' as it has largely contributed to the economic growth of the city-state. The first phase of industrialisation included the assembly and manufacturing of E&E products. The transformation of the E&E industry on the island towards R&D and RHQ activities, and a regional hub in Southeast Asia, represent the successful policy implementations by the government. In 2014 the E&E industry contributed to a large percentage of the total manufacturing value-add (29%); accounted for a large amount of total investments (14%); represented 17 per cent with 69 thousand of total manufacturing jobs; and has created spin-offs in other segments of the economy. However, the share and leverage of the E&E industry in the economy has been decreasing over the last years (EDB, 2014). Government investments have been shifting towards the biomedical, pharmaceutical and the life sciences sectors, as part of the upgrading process of the economy. Therefore, the future prospects of the E&E industry in Singapore have been addressed.

1.3 Methodological approach

The research focused on the evolution and the upgrading of the E&E industry and is executed on the macro-level and meso-level. In order to analyse this evolution, a database is constructed, using the Times Directories of Singapore Electronics Industry between 1990 and 2014. This database includes data per year about the presence of establishments and their line of business. All the firm establishments that were involved in manufacturing, assembly, R&D or RHQ activities in Singapore between 1990 and 2014 have been included. The database was further completed through consulting secondary sources.

Unfortunately, interviews with representatives of E&E establishments by means of a questionnaire, planned to collect data at the micro-level, turned out to be unsuccessful as the response rate was not suitable to carry out a proper analysis. The limited response implied that the outcomes of the questionnaires were not representative, and thereby not suitable for general assumptions regarding the evolution of the E&E industry. Therefore, the conducted surveys have been implemented as illustrative cases. Additional interviews with members of institutions involved in the E&E industry have been conducted.

1.4 Structure

In the following chapter, the theoretical framework has been elaborated in which theoretical concepts such as branching, growth paths, upgrading, production networks and innovation systems are explained. Besides the introduced theories, the industrial development of Northeast and Southeast Asia is also described from a theoretical perspective. In this explanation, there is also attention for the drivers behind these concepts. Chapter 3 provides the background on the industrialisation process of Singapore, with a main focus on industrial policies and regional characteristics. This chapter concludes with a conceptual model and several expectations about the evolution of the E&E industry in Singapore, which

will be further examined in the analysis. The fourth chapter presents the research design and modes of data collection and analysis.

The analysis is reported in four chapters. Chapter 5 focuses on the more general evolution of the E&E industry, including number of firms, industry indicators, entry and exit rates, and firm nationalities. Chapter 6 provides a more detailed description of the trajectories of branches, in which the evolution of the semiconductor, HDD branch and consumer electronics are individually described. In chapter 7, the role and evolution of MNCs in Singapore has been analysed. Some detailed cases that describe the changes of the position of Singapore in the networks of MNCs are presented. The final chapter of the analysis emphasises the evolution and the changing role of the local firms in the industry. The regionalisation patterns of endogenous firm are also discussed. The last chapter draws a conclusion from all the above, a discussion on the future perspective of the E&E industry in Singapore, and some future research recommendations.

2. Theoretical framework

In order to understand the evolution of the E&E industry in Singapore, it is necessary to interpret the dynamic processes and mechanisms behind this evolution. To understand and analyse this processes and mechanisms, a variety of theoretical concepts have been addressed in this chapter. This chapter is divided into four paragraphs including multiple subparagraphs, each comprising of concepts, and the drivers and mechanisms behind these concepts. The first paragraph contains the concept of industry trajectories, which serve as the theoretical background of the overall evolution of the E&E industry in Singapore. It further elopes with branching, which provides a theoretical way of identifying the trajectory of an industry.

The second paragraph elaborates on branching in the context of the industrialisation process in Southeast Asia. Here, strategic coupling is introduced, which emerged in the era of globalisation, and can be used as a tool to understand the evolution of industries. The third paragraph is comprised of the regional environment and assets, which are crucial aspects for the strategic coupling process. Business ecosystems and local innovative systems are described as strategies of government institutions to create such regional environments. The final paragraph concludes with upgrading, which is a possible outcome of the evolution of the composition of an industry.

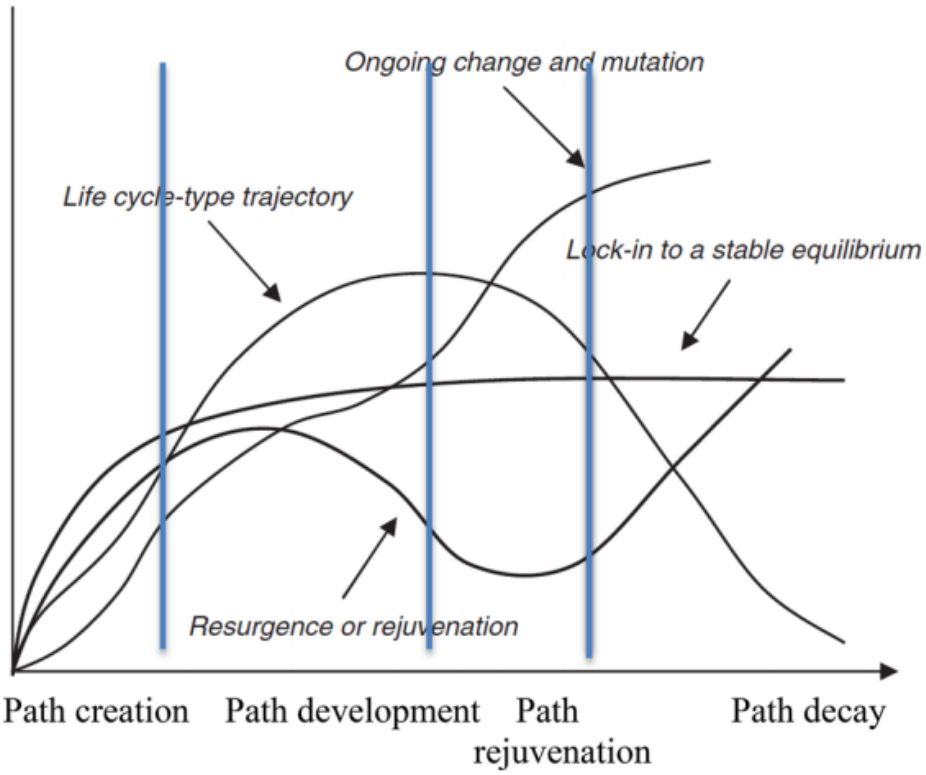
2.1 Industrial evolution

Industries appear to go through a series of historical stages, in which they show different stages of development, with different degrees of economic success. In short, industries evolve. The evolution of industries has been a central point in studies of evolutionary economic geographers, who tried to characterise and analyse this economic phenomenon by creating theoretical models (Martin & Sunley, 2011). In these evolutionary studies, two concepts have been dominant to characterise the evolution of industries: the 'life cycle' concept, in which the classical concept is used as a metaphor to describe how industries evolve over time and pass through the 'life stages' of birth, growth, maturity, decline and death; and the 'path dependence' model, introduced by David & Arthur (1985), in which small historical changes eventually steer an industry into a 'lock-in' (Arthur, 1994; David, 2005; Boschma & Frenken, 2006; Martin, 2010; Martin & Sunley, 2011).

According to Martin, economic geographers have not been given enough critical attention to the assumptions, implications and limitations of these concepts. A limitation of the path dependence theory, with its key concept of lock-in and the thinking of evolution towards stable equilibriums, is that is has a restrictive and narrowly applicable account of regional and local industrial evolution (Martin, 2010, p. 3). Martin questions the interpretation of the concept of lock-in, which severely constrains the path dependence model as a conceptualisation of economic evolution. What is a solid arbitrary state of an equilibrium and how is this determined: by indicators such as the number of firms; total number of workers; output; share of market; or value added activities? Even if a certain industry developed for a long time and reached the state that is described as a lock-in, the (remaining) companies still continue to compete with each other and develop new technologies and products, through which the industry keeps evolving. Likewise, the classical 'life cycle' concept lacks evolutionary possibilities, as it implies that an industry

eventually 'dies' and stops evolving. Therefore, Martin argues that the theories of path dependency and classical life cycle emphasise continuity and stability instead of change. Hence, Martin's (2010) introduced a model (figure 2.1), presenting other possible trajectories of industries as alternatives for the path dependence and classical 'life cycle' concepts (Martin, 2010; Martin & Sunley, 2011).

Figure 2.1: Alternative industry trajectories.



Source: Martin, 2010.

Martin illustrates some possible trajectories for industries. On the one hand, there are industries that were once thriving, but lost dynamism. This trajectory corresponds with the classic 'life cycle' concept and comprises an archetypical pattern in which the industry follows a path with initial growth, but eventually 'dies'. At the other hand, other industries managed to reinvent or rejuvenate, after losing size and importance and break through this pattern. Also, there are industries that exhibit a lock-in to a stable equilibrium, integrated in the path dependence theory. Still further, other industries maintain growth for an extended period or are still in the process of formation, and at an earlier stage of development (Martin & Sunley, 2011). The industries are in a continuous process of mutation and evolution. These shapes of the industry trajectories vary over time from industry to industry, and from region to region. However, this model ignores intra-industry heterogeneity. The internal structure of industries is characterised by a configuration of lower-level components, which are firms and their activities. These components are heterogeneous as they vary in their performance and development trajectories. Therefore, one industry can follow multiple trajectories (Martin, 2010). These components can be organised in branches, which are addressed in further detail in the next paragraph.

2.1.1 Branching

Industries can maintain growth for an extended period, which can be achieved by adaptation through mutation, like the successive development of new branches (Van Grunsven & Huthinson, 2015). In the standard definition, each industry consists of a group of related branches, and each branch consists of related firms producing strongly related products. Branching is a process in which diversification of an industry leads to the emergence and development of new related branches, changing the configuration of an industry over time (Boschma & Frenken, 2009). This concept is therefore useful to identify the evolution of industries, and applied by evolutionary economic scholars (Boschma & Frenken, 2009; Neffke et al., 2011; Van Grunsven & Hutchinson, 2014). Following the definition of Boschma & Frenken, branches can emerge in two different ways. First, a branch can emerge out of a related established branch, in which firms that are related in terms of products, processes or technology are more likely to enter the industry and firms that are non-related are more likely to leave the industry. The second is through the recombination of different competences from several related branches, in which regional diversification can lead to new combinations. Here, the emergence of a new branch is influenced by the composition of the industry (Neffke et al., 2011). In both ways, branches are more likely to emerge if they are technologically related to existing branches present in that region. This concept is referred to as related variety (Boschma, 2005). Related branches with a high degree of variety will generate more local knowledge spill-overs and more learning opportunities than related branches with a low degree of variety (Boschma et al., 2012, p 10).

Figure 2.1 is applied on the evolution of alternative industry trajectories. While, this model may also apply on the evolution of (related) branches, which determine the configuration of an industry over time (Boschma & Frenken, 2009). If the branches, experience decline, this will influence the evolution of the industry in a negative way, possibly leading to the end of an industry. When the related branches experience a successful development or even the development of new branches, the industry will illustrate the trajectory of 'ongoing change and mutation'.

2.1.2 Factors influencing the branching process

The changes in the composition of branches, that together form a certain industry, are influenced by a number of factors. This paragraph elaborates on three of these factors that have been addressed in the literature (Boschma et al., 2002; Boschma & Frenken, 2011; Klepper, 2001, 2002, 2007; Neffke et al., 2011). An important factor influencing the branching process is the entry and exit of firms. Firms are more likely to enter a region if they are technologically close to the portfolio of the industry. Simultaneously, firms that are established in an industry with many unrelated firms are more likely the leave the industry (Neffke et al., 2011). The entry and exit of firms is addressed in more detail in the next subparagraphs.

A second factor that influences the composition of branches are changes within the product portfolios of firms. The product portfolios of firms change under the influence of the global economic dynamics. At the same time, firms try to outperform their competitors by developing new products. A firm can 'invent' a product, which can change the development of a branch, or can be at the start of the creation of a new branch. Especially lead firms have a

central position in the development of new products (Van Grunsven & Witte, 2012). Also spin-offs can be at the start of a new branch and industry bifurcation, identifying an opportunity in the market to develop a new product (Klepper, 2007).

The third factor that can influence regional branching is the subjection to path dependencies, conceived and developed in the evolutionary theory (Boschma et al., 2002; Boschma & Frenken, 2011; Neffke et al., 2011). The process of evolutionary branching that underlies industrial development is path dependent, which means that developments and decisions in the past determine events that occur in the future. The evolutionary theory on the firm state that firms developed cognitive capabilities, in conjunction with decisions and developments made in the past, that determine the contemporary development and product-specific routines which are used in the production of a particular product (Boschma & Frenken, 2011b). The present state of an industry is influenced by capabilities obtained, or experience gained, and decisions made by firms in the past (Boschma et al., 2002). Especially, the product-specific routines are generally related to the current products, making related variety to occur more likely. Also, the moment of the firms entry into a branch is determined for its success, in which firms that enter the branch at an early states are more likely to succeed than firms that enter the branch at a later stage (Klepper, 2002).

2.1.3 Intra-industry branching

The configuration of an industry evolves over time through the emergence of new and disappearance of existing branches. Simultaneously, the composition of branches within an industry evolve as well. This is referred to as intra-industry branching (Boschma & Frenken, 2009). According to Klepper (2001, 2002), there are three ways in which branches within an industry emerge and evolve. First, the scope of products and/or activities are diversified by existing firms. Second, spin-offs started by former employees who left their employers to start their new business in the same industry provide many insights into the forces underlying the formation of branches. They implement former gained knowledge in their new company, which may lead to the development of new products. Spin-offs can 'feed off' the innovation efforts of their parent companies, aided by capital to get them started, only to become more innovative and grow notably larger than their parents. In this way, the behaviour of spin-offs is sometimes characterised as parasitizing. For example, in the disk drives industry in Silicon Valley, a number of spin-offs ventured into new branches before their parents did, at the same time appearing to have drawn on prior innovation efforts of their parents (Klepper, 2001). Third, an industry can also diversify through the entrance of firms from related industries and the entrance of so-called *novo-firms*, of which the founder is not from the industry or a related industry. According to Klepper (2002), firms that have diversified out of the same or an existing industry are almost always more successful than *novo-firms*. This is because they have more knowledge of the market, better access to capital and take gained routines from their parent company to their new company. Although, there have been cases in which *novo-firms* have outperformed spin-offs (Klepper, 2002). In this research, the concept of intra-industry branching is addressed to analyse the development of the E&E industry in Singapore.

The above addressed branching theories of Klepper and Boschma & Frenken, concentrate on the entry of firms from *within* the region, which is referred to as endogenous

development. Van Grunsven & Witte (2012) distinguish endogenous development and exogenous implantation, in which the latter refers to the establishment of product lines by foreign MNCs. Van Grunsven & Witte (2012) argue that for late-industrialisation countries the impact of exogenous implantation in the form of foreign direct investment by MNCs is more effective to realise industrial development. FDIs of foreign MNCs have played a vital role in the industrial development of countries in Southeast Asia, predominantly following the strategy described as exogenous implantation. The following subparagraph further elaborates on the development of different strategies applied in East Asian countries.

2.1.4 East Asian 'development models'

With regard to the emergence and development of industries in Southeast Asia, Japan was the pioneer, creating the 'East Asian development model'. This model was later adapted by the second cohort of countries which rapidly industrialised - the so-called 'Asian Tigers', consisting of South Korea, Taiwan, Hong Kong and Singapore - and converted to each economies own political conditions and resource endowments (Huff, 1995; Roy et al., 2012; Yusuf & Nabeshima, 2009;). Key elements of this development model were state control over finance; direct support by the government for state-owned enterprises in 'strategic sectors of the economy'; promoting industrialisation; a high dependence on export markets; and a high rate of domestic savings (Beak, 2005). In these Asian Tiger countries, following the example of Japan, government institutions had a central role in the development of the national economy, referred to as the 'developmental state'. However, the modes of development differed over these countries. Unlike Japan, FDIs served as an important source for industrial development in mainly Hong Kong and Singapore (Yusuf & Nabeshima, 2009).

The previous subparagraph mentioned the distinction Van Grunsven & Witte (2012) make between endogenous development and exogenous implantation. On the one hand, South Korea and Taiwan (which remained close to the example set by Japan), focussed on the development of domestic firms, predominantly following the strategy of endogenous development. Whilst on the other hand, Singapore and Hong Kong rather focussed on the attraction of FDIs by MNCs, which can be described as exogenous implantation (Beeson, 2004). Although in the latter the role of the government and other institutions in the industrialisation process should not be underestimated (Coe et al., 2004; Felker, 2003, 2009; Yeung, 2009, 2014a, 2014b).

The government (and other institutions) is an important actor in the exogenous implantation strategy, as they can attract and develop branches through implementing various policies. These policies shape and transform the region's characteristics, such as the labour market and policy environment, as well as the corporate objectives of MNCs. These characteristics determine whether a branch (or industry) can emerge in a region. If a branch has entered the region, the further development and mutation of the branch in the region is dependent on a variety of events, in which the interaction between firms and the regional advantages takes up a central position (Van Grunsven & Hutchinson, 2015). There are numerous examples in which governments (and its institutions) have played a role in branch development, influencing the evolution of an industry (Ernst, 2005; Felker 2003, 2009; Van Grunsven & Witte, 2012; Yeung, 2009, 2015). In the literature, scholars have addressed the

concept of 'strategic coupling' to analyse the central role of the government and its institutions in the evolution of regions and industries.

2.2 Strategic coupling

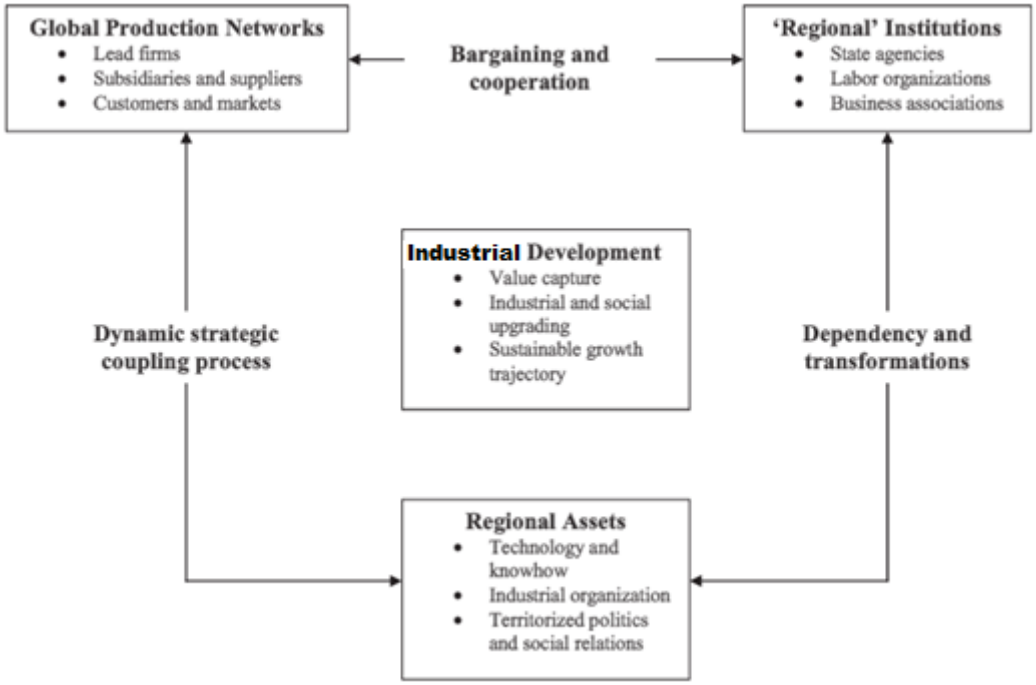
Figure 2.1 of Martin (2010) proposes four stages in the development of industries. During the first phase, the emergence of industries takes place. As mentioned in the previous paragraph, the concept of branching might be useful for the identification of the development of industries and is therefore proposed by evolutionary economic geographers as a mode of industrial emergence and development (Boschma & Frenken, 2012; Van Grunsven & Witte, 2012; Van Grunsven & Hutchinson, 2015). These scholars studied the emergence and development of industries through the process of branching.

2.2.1 Strategic coupling: definition and framework

According to the World Bank Report 2013, 80 per cent of the international trade is estimated to be coordinated through the global production networks (GPNs) of lead MNCs, since these firms distribute their activities over a global scale (Catteneo et al., 2010, p. 2). Since the 1990s, GPNs have increasingly become organisationally fragmented and spatially dispersed, often identified being correlated with the economic globalisation process (Yeung, 2015). The strategic coupling framework was introduced by Coe et al. (2004), in order to understand the complexity of the geographical distribution in the globalised economy (figure 2.2). The interactions between GPNs and the local economy are conceptualised in the framework, which analyses the drivers for industrial development through the processes of value creation, enhancement and capture. The inter-firms networks give a fundamental insight on how the production, distribution and consumption of goods and services are spatially organised. Industrial development is here conceptualised as "*a dynamic outcome of the complex interaction between territorialized relational networks and global production networks within the context of changing regional governance structures*" (Coe et al., 2004, p. 469). In their framework, industrial development in regions is determined by the successful degree of linking GPNs with regional assets and thereby integrating GPNs into the region. In these networks, a variety of actors are interrelated, influencing strategic coupling processes on the economic, political, institutional and social space. For example, large firms and their supplier firms have a dual relationship, in which the balance of power is dynamic and may shift from time to time (Coe et al., 2008; Yeung, 2015). According to Coe et al. (2008), the assumption that the larger firm automatically dominates and exploits the smaller firm is more complex and entangled than meets the eye. This is also the case for the relations between firms and government institutions, that may be intertwined in a mutual beneficial relationship, in which the interdependency is complex and dynamic.

Definition global production network = *"We define global production networks as the globally organized nexus of interconnected functions and operations by firms and non-firm institutions through which goods and services are produced and distributed"* (Coe et al., 2004, p. 471).

Figure 2.2: A framework for analysing industrial development and global production networks.



Source: adapted from Coe et al., 2004; Yeung, 2015.

In the framework of Coe et al. (2004), the coupling processes can be enhanced and exploited through implantation of local/regional/national institutions, which are not the 'designers' of industrial development, but have a determined role as intermediaries in the coupling processes between localised growth factors and the strategic needs of trans-local actors; and have a navigating role in steering the direction of industrial development in regions. The institutions do not merely have a role in the strategic coupling processes of the strategic needs of GPNs of MNCs, but can also influence the regional assets which are a precondition for strategic coupling processes to occur (Coe et al., 2004). Hereby, government institutions can create an economic environment that provides certain regional advantages which are attractive for MNCs to carry out their economic activities. This economic environment needs to 'fit' the specific demands required by the MNCs (Coe et al., 2004, 2008; Yeung, 2014b). It is important to empathise that the strategic coupling process is a dynamic outcome of the strategies of a variety of actors, active in the international production networks, operating in the specific regions (Yeung, 2009; Yeung & Coe, 2015).

According to Yeung & Coe (2015, p. 32), actor-specific strategies and structural competitive dynamics have become increasingly relevant in the shaping of GPNs and their organisational configurations within and across various industries and locations. Compared to Coe's framework, the role of (economic) actors in the dynamics of GPNs is much more emphasised, in which actors include all kinds of institutions, labour market indicators, organisations and even consumers. The most important actors are (lead) firms, which are the main drivers in the GPNs, coordinating investments in cross-border productive assets and trading inputs and outputs with suppliers, partners and customers worldwide. The conceptualisation of the competitive dynamics include sustaining market development, working with financial discipline and cost-capability ratios. The strategies of firms are

dependent on each regions unique combination of competitive dynamics, which have the ability to constantly change. Therefore, in search of lowering costs and optimising production processes, lead firms constantly relocate and outsource activities on a global scale, in which they have become the key actors in transnational production networks.

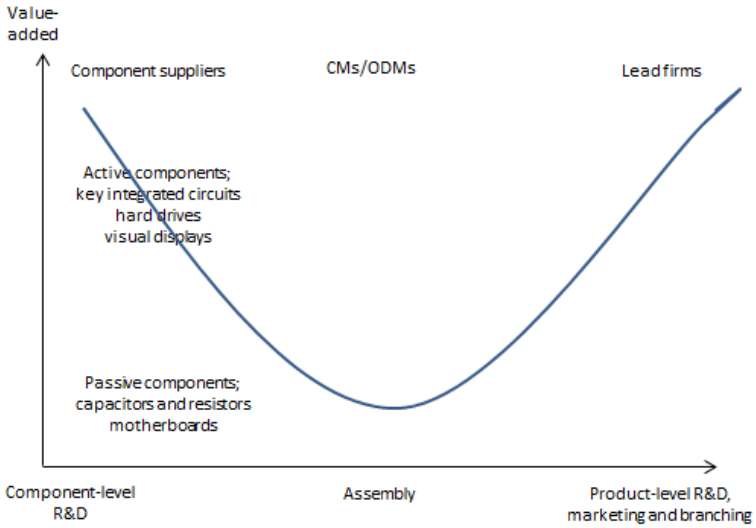
2.2.2 Networks of MNCs

The previous subparagraph describes the strategic coupling of GPNs with local actors, and the ability of the government and institutions to influence the context in which this process takes place in order to realise development through processes of value creation, enhancement and capture. Before the strategic coupling process is discussed further, the GPNs of lead MNCs are discussed, and how their networks have fragmented and internationalised since the 1990s. In order to deal with the hierarchy of GPNs, scholars used insights from the global value chain (GVC) perspectives (Coe et al., 2008; Yeung, 2009). Actors in different regional and national economies in the GPN compete and cooperate for a greater share of value creation, transformation and capture through geographically dispersed economic activities (Yeung & Coe, 2015).

The leading global firms are often branded as original brand manufacturers (OBMs), which outsource products or even product development to the global network of original design manufacturers (ODM), original equipment manufacturers (OEM) (or component suppliers), and also towards firms labelled as contract manufacturers (CEM) and electronics manufacturing services (EMS) (Shin et al., 2012; Yeung, 2009). The OBMs capture a significant portion of the value chain, specialised in high-value activities such as R&D, sales, marketing, product design and marketing. Other firms capture value to a lesser extent, dependent on their position in the network (figure 2.3). The upstream component suppliers (or OEMs) generate sustainable higher profits by possessing high-value resources such as superior design skills, intellectual property and the ability to commercialise new technologies. Therefore, the lead firms and components are higher up in the value chain than the CEMs and ODMs. However, because the OEMs have to invest heavily in R&D and pursue high levels of knowledge and innovation, compared to CEMs and ODMs, the net margins are often not significantly higher (Shin et al., 2012). Firms can shift their position and increase their value-capture in the GPN by engaging in different activities. Assembly activities can be expanded with design activities for the global MNCs, in which a higher degree of value is captured.

The global lead firms rely on their supporting/supplier firms for design, manufacturing and logistics services. Since the 1990s, global lead firms in the E&E industry have shifted their business model towards increasing specialisation in the value chain activities. Global lead firms have relocated a wide range of value-adding activities in the manufacturing process, stretching from product and component design to testing. At the same time these ODMs, CEMs and EMSs engage in networks of separate subcontractors for the manufacturing of different components and parts, resulting in a GPN over multiple links and levels (Yeung, 2009).

Figure 2.3: Smile curve of division of firms.



Source: Shin et al., 2012, adapted from Shih, 1996.

In their theoretical concept, Shin et al. (2012) also subscribe differences in value capturing to the *differences* in the level of sophistication of products (figure 2.3). In this case the manufacturers of active components which are more sophisticated, such as hard disk drives (HDD), capture higher value than the producers of passive components, such as capacitators and resistors (Shin et al., 2012, p. 93-94). These differences can be applied on the concept of branching, introduced in the previous paragraph. In a specific industry, some branches are more sophisticated than other branches, containing more sophisticated and higher value added products (Shin et al., 2012).

The value activities in the GPN have been shifted down the line from the leading MNCs that perform high value activities, to small supplier firms that perform low value activities. This also results in a hierarchal geographical network of regions: high value added activities are performed in high-skilled regions and the low value added activities are carried out in low-skilled regions (Felker, 2009; Shin et al., 2012; Yeung, 2009). According to Shin et al. (2012), high value added activities are largely concentrated in advanced countries, while low value added activities have mostly shifted to emerging economies. Some emerging economies have realised to capture higher value activities of OBMs and compete in certain component markets, such as Samsung and LG in South Korea, but these cases are mostly exceptions (Shin et al., 2012).

2.2.3 Strategic coupling in East Asia

The previous two subparagraphs introduced the concept of strategic coupling and the dynamics of GPNs, which influence the strategic coupling process for government, institutions and MNCs, as the concept provides a framework for the hierarchy of activities. The industrial development of East Asia cannot be understood independently of the changing dynamics of GPNs (Coe et al., 2008; Yeung, 2009; 2014a; 2014b). According to Yeung (2009) the role of the 'developmental state', that attempted to govern the market and to steer industrial transformation through direct policy interventions, has diminished due to the dynamics that commenced with the era of globalisation since the 1990s. Figure 2.2 illustrated the dynamic strategic coupling process between GPNs and regional assets. As

mentioned in this chapter, the role of the dynamic GPNs of lead firms have become increasingly dominant in the strategic coupling process, shaping the regional development (Yeung 2009; Yeung & Coe, 2015).

According to Yeung (2009, 2014a), there have been three ways of strategic coupling in East Asia. First, strategic coupling through international partnership, in which development takes place through the direct articulation of the region into critical GPNs. This has been the case in Taiwan and to a lesser extent in Singapore and Hong Kong. In Taiwan the indigenous firms served as strategic partners for lead firms' GPNs; in Singapore and Hong Kong, the direct FDIs of lead MNCs were more dominant. Singapore successfully attracted economic activities of lead MNCs by establishing a direct presence of research and development facilities and manufacturing operations, and providing MNC subsidiaries with fiscal incentives. Secondly, strategic coupling through indigenous innovation, in which indigenous firms have been supported by the government in their technological development for decades and have evolved into lead MNCs in their GPNs. Endogenous development may occur if a specific region has sufficient innovative capacity presence. The government and its institutions have a supporting role to the indigenous firms in their development of new products and processes. A numerous amount of these lead MNCs have been realised in East Asia, such as Samsung, Hyundai and Singapore Airlines. In the above mentioned two types of strategic coupling the success of the dynamic process are strongly dependent on institutions, technological development of local firms, significant financial commitments and the presence of an effective transnational community. The third way of strategic coupling, through production platforms, is less dependent on the above adduced indicators. The success of strategic coupling of major (low-sophisticated) manufacturing activities of MNCs with production platforms is dependent on labour supply, stable policy environment, and to a lesser extent fiscal and financial incentives. In recent years this way of strategic coupling have mostly taken place in China, Malaysia and Thailand.

2.3 Regional assets and environment

The previous chapter addressed arguments that in the current era of globalisation, strategic coupling of local actors to GPNs determines industrial development. The framework of Coe et al. (2004) emphasises the role of 'regional' institutions, as they are required for "*the process of 'fitting' the regional assets with strategic needs of GPNs and simultaneously promote regional advantages and enhance the region's articulation into GPNs"* (Coe et al., 2004, p. 474). To create an economic environment that provides certain regional advantages which are attractive for MNCs to carry out their economic activities, institutions can transform the regional assets (Coe et al., 2004, 2008; Yeung, 2014b). The dynamic strategic coupling process can only take place if the relational advantages of regions interact with the strategic needs of actors in these global production networks (Coe et al., 2004). Other scholars emphasise the importance of favourable regional characteristics as well, and that these are the main reason for MNCs to establish economic activities in a certain region (Felker, 2009; Yeung, 2009, 2015). Van Grunsven & Hutchinson (2014) argue that the regional institutional context in the form of government agencies, research institutions, and business associations is a key driver in promoting evolution through effective generation and circulation of knowledge.

Figure 2.4 conceptualises the local actors in specific regions (e.g. government institutions and labour) and non-local actors in GPNs (e.g. MNCs and financial capital), which are differentiated by the degree of 'territorial embeddedness', which in turn has significant implications for industrial development (Coe et al., 2004, p. 471). The organisational strength and flexibility of labour is an important key actor in the framework. In regions, labour interacts with the strategic needs of GPNs. Institutions can strongly influence the development and skill-level of the local workforce, however the degree of successful transformation of local labour markets is divers. Also, regions may increase the number, flexibility and skill-level of the workforce through immigration. Financial capital institutions are another important non-local actor. Venture capital may support the development of new firms, crucial in raising the local new technological development and the emergence of supporting industries that supply the GPNs. The technological level can also be raised by setting up (public and private) R&D centres. Research institutions can perform R&D activities, in which MNC subsidiaries and local firms can tap into. And, institutions can promote R&D activities among MNC subsidiaries and local firms, raising the industry's technological level. Thus, in the model of Coe et al., (2004), the interaction and collaboration between institutions, firms, labour market and technology activities is determinant for the strategic coupling process dynamics.

Figure 2.4: Local and non-local dimensions of regional development.

Dimensions	*Local manifestations*	*Non-local forms*
Firms	Indigenous SMEs	Global corporations
	Industrial clusters	Entrepreneurial subsidiaries
	Intra-regional markets	Distant global markets
	Venture capitalists	Decentralized business and financial networks
		Global production networks
Labour	Skilled and unskilled workers	Skilled experts and technologists
	Permanent migrants	Transient migrants
		Transnational business elites
Technology	Spillover effects	Global standards and practices
	Tacit knowledge	Intra-firm R&D activities
	Infrastructure and assets	Technological licensing
		Strategic alliances
Institutions	Conventions and norms	Labour and trade unions
	Growth coalitions	Business associations
	Local authorities	National agencies and authorities
	Development agencies	Inter-institutional alliances
		Supranational and international organizations

Source: Coe et al., 2014.

Regions with strong institutions and a high-skilled labour market are expected to better exploit economies of *scale*, through sophistically technologies and skill-specific production networks. In regions with a more flexible labour market, economies of *scope* are expected to be achieved through the presence of a (large) variety of industries. When state institutions can achieve a strong organisation and regulation of labour, by increasing the skill levels and flexibility of the local labour market, this region would experience a higher degree of development. State and regional institutions can increase the conditions of the regional assets and of the institutions themselves, which in turn can lead to the strategic coupling of higher value added activities (Coe et al., 2004, p. 472). So, the influence of government institutions is significant: institutions may promote specific regional assets that are

conducive to high value added production activities, because these activities bring high and sunk costs with them, and are difficult to relocate within a short period of time. Additionally, institutions can stimulate value enhancement activities of MNCs.

The previous subparagraph elaborated on the fragmentation and internationalisation of GPNs, and how these are spatially dispersed over a variety of regions. According to Coe et al. (2004), a region with a highly competitive labour market, a pro-growth coalition of institutions, and an active pole of venture capitalists will likely be engaged in the creation of value through industries that require rapid flows of knowledge embodied in the local workforce, a stable institutional environment and high risk-taking financing. On the other hand, a region with a weakly organised and abundant supply of labour, an unstable institutional structure and an absence of venture and banking capital is more likely to create value through performing highly labour-intensive work for MNCs. These regions perform different roles, due to their difference compositions of regional assets, in terms of value creation vis-à-vis GPNs (Coe et al., 2004, p. 473).

2.3.1 Local innovation systems and business ecosystems

The previous subparagraph elaborated on the role of regional assets and institutions on regional development. Institutions can transform the regional assets so that these fit the strategic needs of MNCs, in which successful strategic coupling can take place. Besides transforming the regional assets, institutions attempt to anchor the activities of MNCs in order to realise industrial growth for a sustainable period. In the literature, the network of surrounding local actors that interact with and have a duplex dependency with firms are described as an 'ecosystem' or 'innovation system', which are built up around a niche of an industry, also referred to as branches. Institutions can influence the surrounding conditions and actors around these branches. Besides institutions, the MNCs are important actors as they search for an attractive economic environment and can influence the local conditions as well. Especially highly sophisticated branches are dependent on their surrounding environment. The availability of research institutions, technologies, skilled labour and supplier firms are determinants for the survival and development of the particular branch. Although there has not been consensus in the literature, several perspectives have been introduced on ecosystems and innovation systems (Ferretti & Parmentola, 2015).

The concept on how innovation occurs has shifted from an essentially linear conception of the development of innovation towards ideas of interactive and systematic processes, in which the firm collaborate with actors. The theory surrounding the local innovation system (LIS) aims to identify a network of technically specialised and locally situated firms, research agencies and institutions that are involved in a process of collectively learning (Ferretti & Parmentola, 2015).

A LIS does not implicate that innovation is limited to the local geographical borders. Ernst (2002, 2003) states that global innovation networks (GIN) have indicated that transnational firms and local firms are intertwined in innovation networks. These GINs integrate dispersed engineering, product development, and research activities across geographic borders. Lead MNCs have the dominant position in the GIN, globally dispersing their innovation activities over specialised local clusters, controlling and steering the diffusion of knowledge across firm boundaries and national borders (Ernst, 2009). To attract

knowledge activities of MNCs, policies and institutions need to adjust to the unpredictable dynamics in technology and markets. Institutions have to shape the regional conditions, such as engineers and R&D facilities, in order to attract activities of MNCs (Ernst, 2002). In recent decades, Asia's role in GINs have increased with more locations involved in innovation, mostly due to strong government institutions and effective policies (Ernst 2009).

Ferretti & Parmentola (2015) analysed literature regarding different levels (transnational, national, regional, local) of innovation systems and which factors are determined to identify a theoretical model for the local innovation system. Because there are multiple definitions of the LIS, some better than others, Ferretti & Parmentola (2015) identify four elements as defining the existence of a LIS:

- A network of innovative firms, localised in the same area and bound by horizontal and vertical relationships;
- A set of research and educational institutions, such as universities and research centres, which generate scientific knowledge that contributes to innovative processes;
- A series of infrastructure provisions that incentivise the localisation of innovative firms within the given area;
- The presence of cooperation mechanisms among all these actors, capable of stimulating reciprocal learning and thereby processes of innovation.

The last aspect is particularly important, because the cooperation between firms and research institutions favour not only the exploration and development of the existing knowledge base, but also is more likely to favour experimentation in new knowledge through interaction. Actors in close cultural and geographic proximity will develop social interaction mechanisms, that stimulate the interactive learning process. Thus, the social embeddedness of actors are important elements for the development of an LIS.

Besides the identified four elements that define the existence of a LIS, the types of actors have also been identified. Ferretti & Parmentola (2015) identify macro-actors (firms, local institutions and non-profit research organisations), that in collaboration can succeed in orientating synergy production of knowledge. The firm moves forward on its own path of value creation through processes of product innovation and of seeking sustainable competitive advantage. The innovation path of a firm is linked with other actors in the system, in which the degree of the 'decision' to share knowledge with other actors is fluctuating. The non-profit organisations (universities and research institutions) are mostly devoted to basic research, often carried out independently from other actors. Universities can contribute directly to the LIS via the attraction of new knowledge resources from elsewhere and share the obtained and developed knowledge with other actors. The co-development of innovation of universities with other actors in the network, which are mostly firms, is an increasingly appearing phenomenon. In developed countries, universities have shifted to a central role as innovators, incubators and promotors of ideas, transforming pure invention knowledge into innovation. Finally, the local institutions can facilitate and steer the innovation process.

2.3.4 Local innovation systems for emerging economies

Ferretti & Parmentola (2015) identified that the characteristics observed in LISs of developed countries, such as Japan and the USA, significantly differentiate from those in emerging countries, such as the Asian Tigers. In developing countries, FDIs by foreign MNCs play a more crucial role, because innovation networks of developing countries are much more globalised (Ernst, 2009; Ferretti & Parmentola, 2015). New knowledge and technologies flows into the region through direct investments or technology licensing. The three actors (firms, research centres, and local institutions) that facilitate the process of innovation development only appear in the last phase of the innovation process, in which the developing country has left the phase of low value added activities, such as assembly behind and has engaged in higher value added activities such as R&D; and firms have evolved into OBMs. Therefore, especially in the emerging economies, the role of MNCs are vital in the innovation process throughout multiple phases. In this way, Viotti (2002 in Ferretti & Parmentola, 2015) describes innovation system in developing countries rather as learning systems, because the acquisition of pre-existing knowledge and supporting processes for learning is rather favoured over stimulating the creation of new knowledge.

Also, governments have been playing a significant role in the development of successful innovation systems in developing countries and have provided the basic investments in the innovation infrastructure. In developing countries, these include investments in human capital, technology transfers, academic capacity building and the promotion of industrial innovation. Finally, developing countries LISs are characterised by actors that are incapable of or missing contribution innovation activities, resulting in rather fragmented innovation systems. Among the actors, the levels of embeddedness and trust are still insignificant to develop strong inter-linkages.

In a lot of developed countries, the university has a central role in the economic upgrading and technology process, in which spin-offs, entrepreneurial universities, and strong relations with science-based industries are significant pillars. A lot of emerging countries have a lack of contribution of universities, which are largely limited to education. The motor of creation of a LIS in an emerging economy can be the university, shifting their activities from research and training towards guiding entrepreneurial development. Besides the above mentioned functions of universities in developed economies, the university can contribute to the birth of an industry through individual cooperation agreements, in which it supports local firms in development and research. Thus, Ferretti & Parmentola (2015) identify three different configurations of LISs in emerging economies: government-driven LIS; the firm-driven LIS; and the university-driven LIS.

2.4 Industrial upgrading

The concepts addressed throughout this chapter are factors influencing the changing composition of an industry. These changes have two possible outcomes: upgrading and downgrading. Upgrading can be understood at multiple analytical levels, among others industry and branch. Upgrading at the industry level involves the increase in productivity, expansion of functions, or the movement to higher-technology categories of branches (Ernst, 2003). An industry experiences upgrading when the sophistication-level of a branch or multiple branches increases. If the opposite occurs, the industry has experienced

downgrading (Van Grunsven & Hutchinson, 2014). According to Van Grunsven & Hutchinson, upgrading at the firm level can be conceptualised as local branching. In this case a technologically unsophisticated variety of products is augmented (initially) and/or gradually replaced by more sophisticated variety that may be related or unrelated (Van Grunsven & Hutchinson, 2014, p. 7).

According to Van Grunsven & Hutchinson (2014) upgrading at the industry level can be *measured* in two ways: the relatively shift to a higher degree of higher-technology products segments (or sub-sectors in industries, *including a long-run possibility of specialisation in specific products and/or processes and/or technologies*); and a shift in the hierarchical network in inter-firm relations, in which a firm can develop into a original brand manufacturer (OBM) that captures the highest value added activities. However, this research is performed mostly on the shift of branches in order to analyse the evolution of the E&E industry. Developments at the micro-level are less relevant and therefore confined to a number of individual cases of firm evolution, helping to better understand and map the industrial evolution.

Although there is not a clear hierarchy of branches in terms of sophistication, certain assumptions can be made about differences in sophistication based on several researches that have focused on the evolution of industries. The United Nations (UN) published a number of articles analysing the sophistication level of countries, in which an increase of technological sophistication from simple manufacturing activities towards more complex production processes is considered as 'moving up the ladder'. Increasing technological sophistication in manufacturing is a major source of dynamic comparative advantage (UN, 2009). Another way to measure the 'sophistication-level' of a branch is analysing the composition of the workforce. A branch with a high degree of engineers employed in the workforce may be considered to be more sophisticated. A shift towards higher-sophistication products requires innovation, research, design and testing activities, and technical education and a skilled workforce (UN, 2009).

Other assumptions can be made based on industry indicators, referring to value added rates, output and export data. Lall et al. (2006), stated that the value added rates of an export product increases as it reaches a higher level of sophistication. Timmer & Szirmai (2000) concluded that the shift towards more productive branches is the most effective indicator for industrial development. In which the relative increase of manufacturing of high value added products results in industrial upgrading.

3. Context

The theoretical framework outlined that through the processes of globalisation and internationalisation, the value chains have been increasingly dispersed. MNCs strategically relocated their economic activities in their production networks on a global scale towards the regions that offer the best advantages. The regional conditions, such as the local skill base, infrastructure and strong legislation, are determinants in the dynamic strategic coupling process. The 'type' of economic activities that are relocated to a certain region are linked to these local conditions.

Through the process of strategic coupling, the government has an important role, as the path of an industry, or even a region, can be changed by active government intervention (Hutchinson et al., 2013). Singapore has increasingly been connected onto the flows of the GPN/GVC by attracting MNC activities. Instead of nurturing the local enterprises to develop high-tech manufacturing like most East Asian countries did, Singapore developed the industries by attracting MNCs into the city-state.

This chapter provides a background on the early and late industrialisation of Singapore and furthermore elaborates on the relevant regional characteristics, as outlined in the theoretical framework. The first paragraph adduces the developmental stages of Singapore. The subsequently second to sixth paragraph address the locational assets which are important for the development of Singapore. The chapter concludes with the seventh paragraph, which includes the a conceptual model and expectations that guide this research.

3.1 Industrial development of Singapore: a brief history

Until the 1950s, Singapore functioned as an *entrepôt*, profiting from the natural advantages of a deep port and a strategic location on the shipping route between Asia and Europe (Perkins, 2013). This role was affected by the efforts of neighbouring countries to develop their ports and resulted in the direct marketing of their products and in import-substituting industrialisation, resulting in a significant decline of the export volume per capita during the later 1950s. Singapore needed to shift towards industries, and the required services, as it desired a more diversified economy (Huff, 1995; IBP, 2008).

During the 1960s, the foundation of Singapore's success story was laid, as a result of the major government interventions that originated under the regime of the PAP (People's Action Party) that took power in 1959. (IBP, 2008; Perkins, 2013). After the independence from Malaysia in 1965, the import-substitution based economic policies were replaced with export-orientated policies. The city-state economic policies distinguished itself from the other Asian Tigers through the strong influence of foreign MNCs in industrial development (Huff, 1995). This policy was possible and logical because of the former free trade regulations it had functioning as an *entrepôt*, the present investments and labour, and the large English-speaking population. This formed an environment conducive for subsidiaries of MNCs to operate in. Simultaneously, the relationships with its neighbours were unfriendly, making the decision to realise economic growth through relatedness with the 'First World' a more logic one than to be dependent of its unstable neighbours. As well as a small domestic market has been an important factor to focus on export-industries (Chu & Hill, 2006). The choice of export-orientated industrial development was also a political choice, as the party's

regime tried to avoid pro-communistic and pro-Chinese attitudes. The leading economic Chinese entrepreneurial class was deliberately neglected (Yeung, 2002).

The industrialisation process that emerged in the 1960s with the arrival of the first MNCs that established labour-intensive manufacturing and assembly activities, has been summarised in table 3.1, and consists of multiple stages. These stages illustrate the industrial development from simple low-value manufacturing and assembly activities in the 1960s towards an increase in capital-intensive and high value-adding activities, such as R&D and RHQ functions.

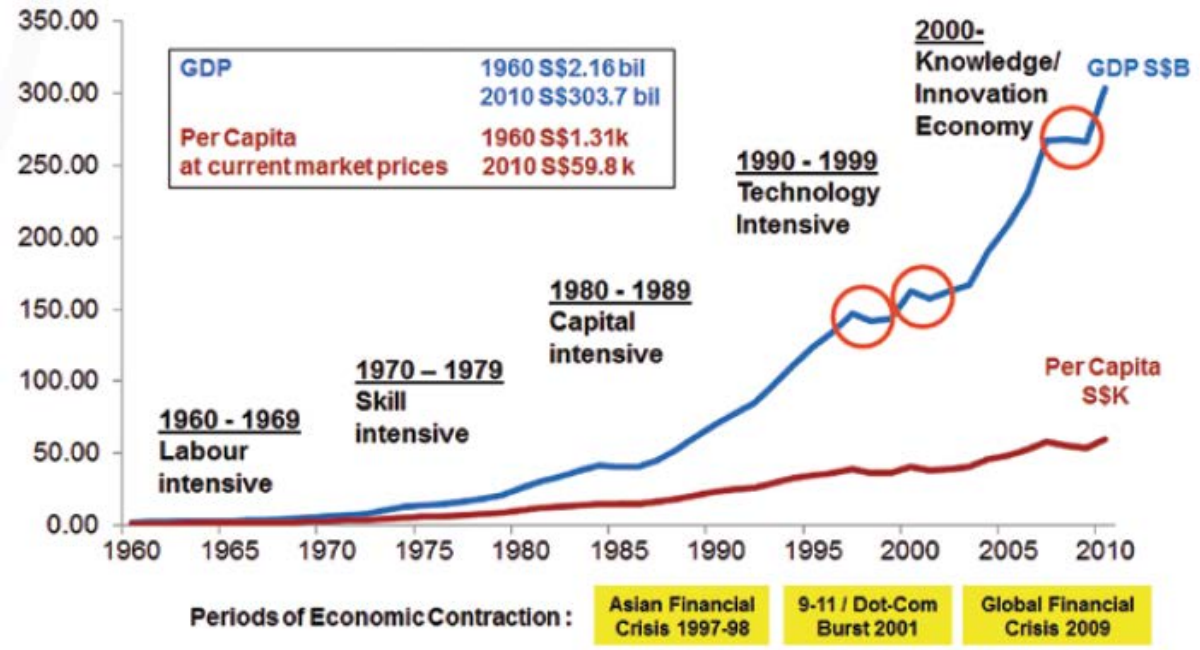
Table 3.1: Six stages of development in Singapore.

I: 1960s-1970s	II: 1970s-late 1980s	III: late 1980-1990s	IV:1990s-2000s	V: 2000s-2010	VI: 2010-present
MNCs invited to provide employment opportunities.	Local technological deepening, characterised by rapid growth of local process technological development within MNCs and the development of local supporting industries.	Rapid expansion of applied R&D by MNCs, public R&D institutions and later local firms.	Emerged emphasis on high-tech start-ups and the shift towards technology-creation capabilities. Regionalisation policies. Further investments in R&D-facilities promoted by A*STAR	Focus on innovation through Science & Technology Plan 2010. Focus on 'putting science to use'.	Expansion of research Institutions. Promoting R&D in biomedical sciences, life sciences by EDB and A*STAR Singapore as a global innovative city

Source: Wong, 2004; STEP, 2015; Van Grunsven, 2013;

Figure 3.1 visualises the first five stages of development, adding GDP levels (total and per capita).

Figure 3.1: Stages of development of Singapore, 1960-2010.



Source: STEP, 2011.

In the 1960s, the focus was centralised on the attraction of low-value labour-intensive manufacturing and assembly activities. The Economic Development Board, which was established in 1951, played a major role in this attraction and in further economic developments in the city-state (Huff, 1995).

By the 1970s, providing a conducive business environment for potential foreign investors was vital for economic development (Toh, 2013). The Development Bank of Singapore (DBS) was established in 1968 to provide long-term financing to the industrial sector, supporting the establishments of MNCs. During this decade, international competition, labour scarcity, protectionism, and unpredictable energy costs threatened Singapore's labour-intensive industries, which caused the launch of various policies to promote industrial restructuring towards high-tech manufacturing and high value added services (Lee et al., 2016). In 1979, the government started with investing in education and infrastructure, and provided fiscal incentives and increasing wages. The development of industries such as electronics was favoured over heavy industries, like shipbuilding and chemicals. A new Ministry of Trade and Industry (MTI) was formed to take charge of the process and devise relief programs for the industries, while the EDB maintained its target on promoting industries (Mathews & Cho, 2000).

The 1985 recession abruptly ended the implementation process set up in the 1970s and early 1980s (IBP, 2008). A new strategy was outlined by the MTI in 1986, to overcome its first major economic setback since the industrialisation process took off. The crisis had revealed the weakness in the previous high-wage policy, which was implemented to help the general upgrading of the economy and improving working welfare, but hardened the struggle for smaller firms to survive and affected the competitive position of export products due to rising production costs. At the same time the city-state experienced intensified international competition and a global economic slowdown (Lee et al., 2016).

Since the early 1990s, the Singapore government took steps to prepare the city-state with the status of an 'advanced country', which meant accelerating the shift towards knowledge-intensive industries (Mathews & Cho, 2000). The city-state focussed on increasing their competitiveness through intellectual capital and capabilities to absorb, process and apply knowledge and innovation, regarded crucial to face the processes of globalisation and rapid technological change and diffusion (Smakman, 2004). In 1991, the concept of 'the next lap' in the development trajectory was introduced by the MTI. The plan aimed to realise ambitious industrialisation policies to take the economy to a qualitatively higher stage of technological and commercial activities (Mathews & Cho, 2000). The Strategic Economic Plan, as a post-recession economy strategy, was outlined in a report of the Singapore Economic Committee and consisted of two important elements: upgrading the low-productivity activities and developing highly specialised niches. The goal was to transform the industrial structure of Singapore to the changing external and domestic economic environments, by promoting and developing Singapore, with the twin engine of growth: a total business centre of the high-tech manufacturing and high value added services (IBP, 2008). The small and declining labour pool initiated policies to increase attracting foreign labour and promoting human capital. The investments in a strong (communication)-infrastructure, a skilled workforce, and information technologies had to enable the city-state to shift its focus towards high value added activities. Especially co-founded R&D activities

between government institutions and MNCs were promoted, to tap into the knowledge flows of the MNCs. Furthermore, regionalisation policies were developed to relocate labour intensive low value added activities abroad (addressed in more detail in paragraph 3.7); and the city-state aimed to become an expert on services, especially business and financial services: Singapore had to become a global hub in the Asia-Pacific region (Lee et al., 2016).

At present date the city-state continues to invest in R&D activities and research institutions, both by public and private parties, in which the EDB and A*STAR take up an important navigating role. The chosen path to develop Singapore into a global innovative city has only increased in recent decades. During the last two decades, other sectors, such as the biomedical science and life sciences, have increasingly enjoyed the support of the government and its institutions. Programmes are implemented to increase the research scientist and engineers in the targeted sectors in order to increase their competitiveness. Sustaining Singapore's economy through innovation is the central theme in the government's strategic plans (STEP, 2015).

3.1.1 The role of the government and its institutions

Throughout the industrial development process of Singapore, the government had a central and dominant role through active interventions. Singapore's political system officially is a 'parliamentary republic', with the PAP (People's Action Party) in power since 1959 (Weiss, 2014). Lee Kuan Yew has led the party from 1959 to 1990, and his son Lee Hsien Long has succeeded him in 2004. The endurance of the political situation can be attributed to the impressive economic growth under the party's regime, in which Lee is seen as its creator. The years of political turmoil after the independence of Malaysia have been replaced by an extraordinary de-politicisation of public life.

The pro-activeness, determination and focus of the government have resulted in the favoured position of the island over other regions in Southeast Asia during the industrialisation process. The government has actively promoted the local assets, providing and increasing the high-quality environment in which MNCs' activities have strategic been coupled. Singapore's high level of transparency regarding government procedures and effective enforcement of corruption control provides a safe business environment for businesses and investments. The stable political environment, cooperative labour unions, together with the present pro-market and pro-business legislations, engendered an existing economy that can absorb technologies, investments and managerial competencies to produce products (Toh, 2013). Hamilton-Hart (2000) ascribes the stable political environment and an effective economy to the work of the elite of government and non-state actors, who have become intertwined in terms of their roles, interests and career paths. Although pervasive ties between government and businesses have an increased risk for corruption and distortion of public policies, these abuses have largely been avoided by the Singapore government (Hamilton-Hart, 2000, p. 197). The successful control of the corruption levels has resulted in one of the least corrupt nations in the world (TI, 2015).

When the role of the government is discussed in the literature, often this refers to the government institutions. Hamilton-Hart (2003) highlighted the role of strong institutions in Singapore that constrain the mixed public-private sphere. Probably the most important institution in the industrialisation process has been the EDB, which has addressed the

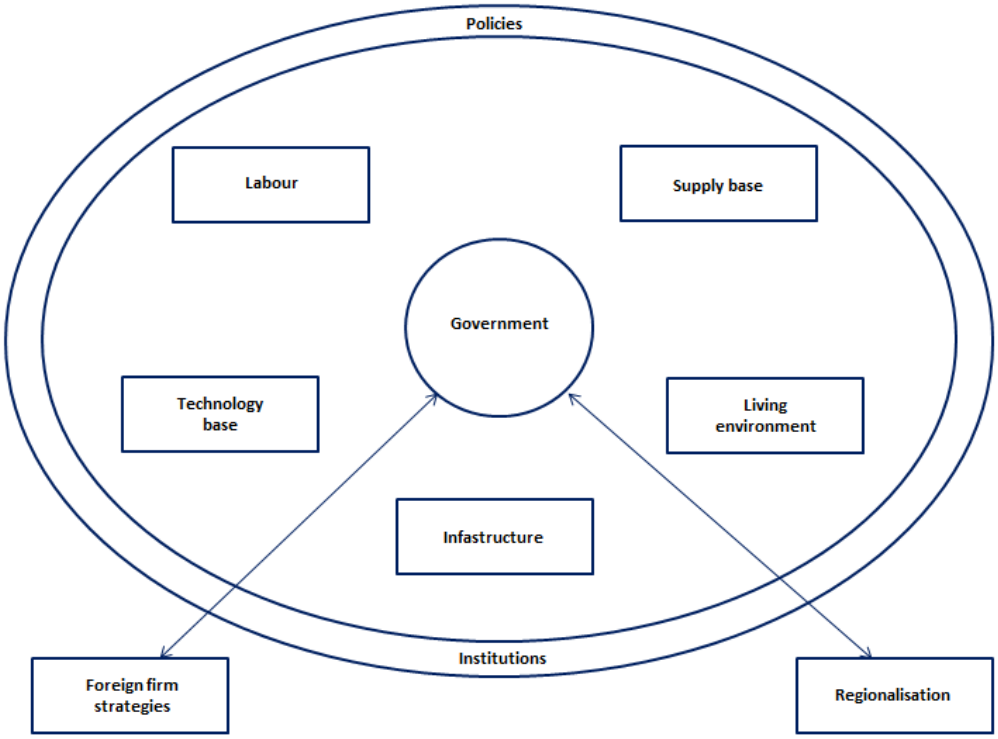
challenge of attracting FDIs and has actively promoted the upgrading process. Other important institutions in the upgrading process have been the Singapore Housing Board (SHB), Agency for Science, Technology and Research (A*STAR) (formally operating as the National Science and Technology Board), and the Ministry of Manpower (MoM), Ministry of Trade and Industry (MTI), National University of Singapore (NUS), and the DBS. The role of each of these institutions will be further addressed in the following paragraphs.

The Singapore government and its institutions have performed pro-actively, attracting and facilitating the favoured activities and industries. To stimulate the development of particular industries, the government pro-actively targeted certain MNCs to relocate their economic activities, in which investment and tax incentives were granted. The further facilitating of these MNCs has been a rather complex endeavour, which demands efficient and effective implementation of multiple government institutions and agencies. At the same time, industries that were considered less profitable and/or outdated have been forced to leave through certain policies, of which the raised wages by the EDB in the mid-1980s has been one of the most decisive measurements (Hamilton-Hart, 2003).

3.2 Locational assets and drivers of evolution

The previous paragraph briefly summarised the evolution of Singapore from a low-value added labour-intensive region towards a high-tech capital-intensive region and increased services activities, functioning as a regional hub in Southeast Asia. The pro-active role of the government and key institutions have been highlighted, as these have formed the local assets for the upgrading process in Singapore.

Figure 3.2: Local assets and 'drivers of evolution'.



Source: own draft, 2016.

Figure 3.1 provides a framework which includes an overview of all relevant local assets, which are influenced by the government, institutions and their policies. These assets are addressed in more detail in the next paragraphs.

3.2.1 Local supply base

The theory emphasised the importance of the supplier base for attracting MNC's economic activities (Coe et al., 2004). In Singapore this has initially not been the case, as the relocation of MNC's activities initiated the development of supplier firms. In the early phases of development, the capacity of Singaporean local firms to become incorporated in the GPN of MNCs was important for the overall performance of these local firms (Smakman, 2004). FDIs can introduce new processes to the domestic market, learning-by-observing, networks, training, labour force training, and other spill-over effects and externalities. Local firms can profit from spill-overs and technologies transferred by foreign MNCs (Alfaro et al., 2004), which has been the case in the city-state. The MNCs provided economic activities for a large supporting industry in Singapore and induced the development of technological capabilities among a substantial amount of subcontractors and contract manufacturer firms (CEMS), which increasingly occurred in Singapore after the 1990s due to globalisation and the fragmentation of production. Some of these CEMs have developed into global contractors that command dozens of factories and supply networks in Southeast and East Asia (Hutchinson, 2013).

The crisis of 1985 had revealed that the economy had become too dependent on MNCs, which encouraged the government to revalue the position of domestic firms. From the late 1980s the government started focussing more on promoting local firm activities, strengthening the base of Small and Medium local enterprises (SME). The Report of Committee on Singapore's Competitiveness in 1998 emphasised the importance of the local firm's development for the economies global competitiveness (Smakman, 2004).

3.3 Labour, skills, wages and availability

The increased skill level of the local workforce was considered vital for the promotion and enabling of MNCs to upgrade towards high value added activities. Important factors that have changed the labour force of Singapore have been a number of education system reforms, labour skill programmes and labour migration policies.

3.3.1 Educational levels

Singapore has had three functions as a city: a port city, an industrial city and recently has shifted towards a global city. These transitions have ordered the human capital of the city to evolve and adapt through education, immigration, and labour policies (Ho & Ge, 2011).

In 2014, 51.5 per cent of the Singapore labour force had a tertiary degree in education (32%) or a diploma/professional qualification (19.5%) (table 3.3.). This is an increase of 15 per cent compared to a decade ago. Tertiary degree-holders increased with 21.6 to 32 and diploma & professional qualification-holders increased with 14.9 to 19.5 per cent (MoM, 2015a). Noteworthy is that 40 per cent of the tertiary degree holders in the resident labour force are from non-Singaporean descent, representing the necessity of the needed skilled labour immigration for the higher value added activities in the city-state (MoM, 2015a).

A skilled workforce is needed to perform capital-intensive and high-tech activities in the city-state, such as R&D. In the recent decade the government has invested massively in labour skill programmes and the improvement of the educational system.

Table 3.2: Labour force and education level compared between 2004 and 2014.

(x 1000)	**2004**	**2014**
Total labour force	2,315.9	3,530.8
Resident labour force	1,733.4	2,185.2
Labour force participation (%)	63.3	67.0
Educational composition (%)	100	100
Primary & Below	16.2	11.5
Lower secondary	13.7	7.7
Secondary	24.8	17.9
Post-Secondary (non-tertiary)	8.8	11.5
Diploma & professional qualification	14.9	19.5
Tertiary Degree	21.6	32.0

Source: MoM, 2015.

3.3.2 Labour migration & foreign talent

Singapore has known low birth-rates and has identified immigrants and temporary workers to compensate the limited domestic labour pool which could not keep up with the economic growth (Ho & Ge, 2011, p. 268). In 1991, the EDB set up the International Manpower Division, which had the task to attract foreign skilled manpower. Multiple programmes, such as company grant schemes to ease costs of employing skilled workers and permanent resident schemes, were implemented to boost the high-skilled workforce (Yeoh, 2006, p. 31). Initially the focus was on attracting a wider range of professionals and foreign students, but later also on attracting foreign workers with lower education levels to take up the menial work (Ho & Ge, 2011, p. 268).

As a result, the foreign workers have significantly increased in the last two decades, with the share of foreign workers in the total labour force increasing from 16.1 per cent in 1990 to 34.7 per cent in 2010 (see table 3.4). The most rapid growth occurred in the 2000s, when Singapore's non-residential workforce increased with 76.8 per cent, from 615,700 in 2000 to 1,088,600 in 2010 (Ho & Ge, 2011; MPI, 2012).

Table 3.3: Labour force: foreign workers in Singapore.

Year	**Total labour force**	**Number of foreign workers**	**Percentage of total labour force**
1970	650,892	20,828	3.2
1980	1,077,090	119,483	7.4
1990	1,537,000	248,200	16.1
2000	2,192,300	615,700	28.1
2010	3,135,900	1,088,600	34.7

Source: MPI, 2012.

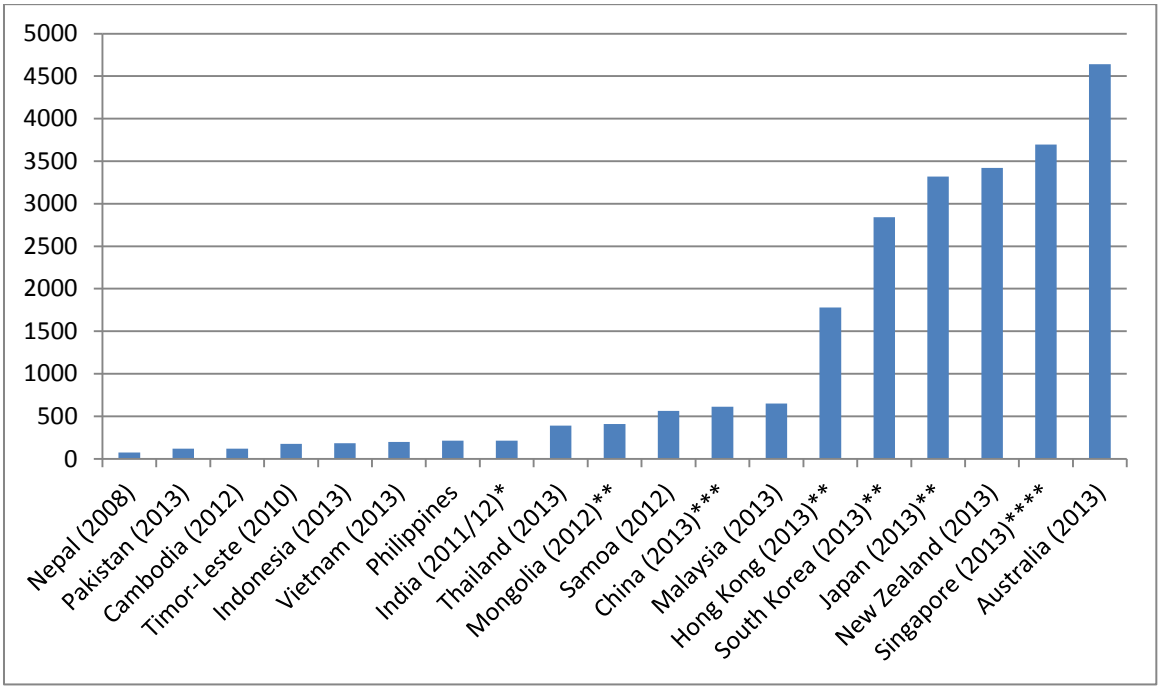
Around 240,000 of the immigrants that have arrived in Singapore since 1970 were so-called skilled workers, with higher education degrees, together with a small number of

entrepreneurs. This group has subsequently increased rapidly due to recruitment by the government and liberalised immigration equability criteria, needed to meet the demands of the newly increased high value-adding activities. An even larger number of immigrants were so-called unskilled and low-skilled workers, making op for a total of 870,000 people (MPI, 2012). The increasing immigration led to a strikingly population growth, from 3.05 million in 1990 to 5.08 million in 2010, and is predicted to grow to 6 million in 2010 and to 6.5 million in 2030 (Hui, 2013; Short & Harris, 2014). However, the increased immigration has been opposed by especially the well-educated middle-class. The immigrants are accused of 'taking away ' jobs, and the immigration has led to increased crime-rates. Public initiatives to restrain immigration have increasingly emerged in the city-state (Hui, 2013; Weiss, 2014).

3.3.3 Wages

The Singaporean wages account for the highest in the Southeast Asian region, with an average monthly wage of US$ 3694 in 2013 (figure 3.4). The period during the 1960s and 1970s that Singapore was a low-wage country are no longer the case. Singapore average wages are multiple times higher than other countries in the Southeast Asian region, even higher than Japan (ILO, 2015).

Figure 3.3: Average monthly wages in countries from Asia and the Pacific in 2013 (in US$).



*Average daily wage or salary earnings of regular wage and salaried employees aged 15 to 59 years, multiplied by 313/12. The exchange rate is from the Statistical Yearbook, India 2014.

**Based on an establishment survey with broad coverage; Hong Kong (China) and Japan refer to full-time employees.

***Based on establishment surveys; calculated as employment-weighted average of urban units and private enterprises.

****Based on administrative records from the Central Provident Fund Board.

Source: ILO, 2015.

Besides the increase of average wages that are a result of economic growth, labour productivity and high value added activities; the relatively high Singaporean wages are also affected by policies implemented by the government, which aimed at transforming the economy towards higher value added activities. Before the 1985 recession, the wage policy was controlled by the government through the National Wages Council, which set annual wage guidelines based on agreements of representatives of trade unions and the government. A central element of these guidelines was that these could be applied to all sectors of the economy and were in the line of macroeconomic projections (IBP, 2008). In the early 1980s, the Singaporean government was determined to transform the labour-intensive manufacturing to more capital- and technology-intensive manufacturing activities. The wage rates were recommended, through the National Wage Council, to be increased by 20 per cent annually for two consecutive years prior to 1981. At the same time, it was determined to reduce the dependence on imported labour from non-traditional sources (Toh, 2013).

This policy was judged to be inefficient after discussions grew about the shortcomings of the economy following the 1985 recession. The increase of wages that had to effectuate the upgrading-process, affected the competitiveness of the industries in a negative matter: the increase in wages outgrew the increase of productivity. The government put forward a revised policy, the National Wages Council report of December 1986, in which greater flexibility was admitted to stimulate competiveness. This meant that bonuses became more common and wage increases were linked to increases in productivity, although it was unclear how this should be measured. Because of the diminishing role of the government, these adjustments led to increasing negotiations about wages between workers and employers (IBP, 2008).

Despite the average high wages in Singapore, the Ministry of Manpower does currently not have a national policy for prescribing minimum wages for all workers, whether local or foreign, arguing that: *"Whether wages should increase or decrease is best determined by market demand and supply for labour, skills, capabilities and competency to perform the task"* (MoM, 2015a). The National Wages Council annually performs wage guidelines based on economic indicators such as employment growth, inflation, consumer price index, overall productivity growth, and the economic development of the global economy. The main goal is to be sustainable and not erode the competitiveness of the economy, aiming to keep the real wages increases in line with the productivity growth over the long term (MoM, 2015a).

Scholars argue that the absent of a minimum wage has resulted in increasing wage inequalities, of which especially the elderly, less adaptable and low-skilled immigrants have suffered. Furthermore, income and ethnicity are strongly related, as the average income of ethnical Chinese and 'Western migrants' is substantially higher than the Malayan and Indian ethnical groups (Yeoh, 2006; Hui, 2013; Weiss, 2014). Skilled workers, both foreign and domestic, have profited most from the economic growth and policies like minimum qualifying salaries, which have been relatively successful in order to attract foreign skilled professionals into Singapore's skilled workforce (Hui, 2013). At the other end, quotas and levies have been used to discourage the employment of low-skilled foreign workers. Despite subsidised job upgrading and training schemes since the 1990s for the labour force, depressed wages have plagued those at the lower-end of the wages distribution (Hui, 2013). The average labour income of household of high-educated and skilled workers have

increased opposed to the average income of households of low-educated and low-skilled workers (SingStat, 2010).

3.3.4 Singapore's regional headquarters strategy

The promotion of regional headquarters establishment by foreign MNCs was part of the upgrading process to realise high value added activities. The previous paragraphs addressed how the government and its institutions promoted the labour intensive low value added activities to relocate abroad and to attract and increase the capital intensive high value added activities, in which the annual increase of wages in the 1980s have been the most important policy.

As part of the 'Regionalisation 2000 Plan', Singapore introduced the 'Regional headquarter Scheme', in which MNCs are persuaded to establish their RHQs in Singapore, controlling and steering their economic activities in the ASEAN region, profiting from the economic growth of the member countries. Singapore conducts tax incentives to attract these RHQs to set up their activities in Singapore. In the recent decades, the largest companies in the financial, business, and manufacturing sector have set up RHQs in Singapore. Following a survey on 130 RHQ's in Singapore, the main strategic decision by global corporations to establish a RHQ were: geographical proximity, strategic necessity and the availability of business services (Yeung et al., 2001).

The main competitors in the Asian-Pacific region as RHQ location are Hong Kong, followed by Shanghai, in which Singapore is favoured as RHQ-location by MNCs in the Asian-Pacific, as it provides regional advantages and capabilities (Purnama, 2013). RHQs that tend to locate in Hong Kong are in control over the firm's activities in East Asia (mostly China), while RHQ that tend to locate in Singapore are merely focussed on the Southeast Asian region. Another distinction is made in the preference of RHQs: RHQs that are focussed on services prefer Hong Kong, while RHQs controlling manufacturing activities prefer to locate in Singapore. A relative new competitor in the Southeast Asian region is Kuala Lumper, that enjoys attracting more RHQs, especially those in control of manufacturing activities. In the recent decades the share of RHQs coordinating manufacturing services has relatively decreased compared to RHQs with financial and business services, which is according to Ho & Ge (2011) a result of the shift of Singapore into a global city (p. 267).

3.4 Technology, R&D and innovation

The promotion of knowledge, research and design (R&D) activities, research institutions, and innovation are in line with the government's effort to upgrade the economy, from labour-intensive low value added activities towards capital-intensive high-value added activities. In the late 1980s, the Singapore government wanted to transform the nation-state into a knowledge-driven economy, with a focus on knowledge-driven activities in manufacturing and services. As emphasised in previous paragraphs, certain policies have been implemented to achieve this transformation: the Strategic Plan of 1991 focussed on building clusters in high value added manufacturing branches and promoting R&D functions; the 1998 Report of the Committee on Singapore's Competitiveness further stressed the importance of moving towards a knowledge-driven economy, accentuating the need for R&D and innovation even more (Van Grunsven, 2013). The Agency for Science, Technology and Research (A*STAR) was formed in 1991 (as NSTB), to raise the level of science and

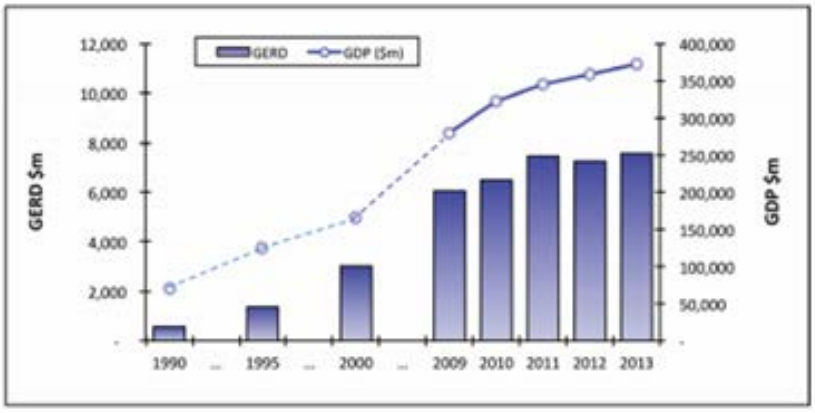
technology in Singapore. The institution took an important role in fostering scientific research and talents to commercialise technologies. In addition, the EDB attracted foreign start-up technology companies that used Singapore as a launch path for the Asian market (STEP, 2015).

3.4.1 R&D and innovation

The Singaporean government realised that knowledge-driven industries needed to be supported by investments in R&D, and by capable researchers, scientists and engineers. Close partnerships between universities, (research) institutions and R&D facilities were stimulated. Capable researchers, scientists and engineers were needed to develop new products and implement innovative research (Ho & Ge, 2011).

Since 1991, the National Science and Technology Board (NSTB) launched 5-years Nation Technology plans, setting aside funds to strengthen manpower training and establishing research institutions, providing support for industrial R&D and indigenous R&D-capability (Toh, 2013). The NSTB established a number of new R&D institutes and promoted collective public-sector development of technological capabilities, and collaborations with universities were established to set up research centres (Mathews & Cho, 2000). Besides collaborations between the government and universities, a substantial account of MNCs have set up R&D facilities in Singapore, stimulated by the government through various incentives schemes and drawn by the strong local research level, high level of skilled engineers and tertiary educational institutions (Hu, 2003; Kumar & Siddique, 2010, p. 38). Another way of stimulating R&D activities was the realisation of the Science Parks by the EDB, which base more than 350 MNCs, local firms (SMEs & start-ups) and national institutes (Lee et al., 2009; Scienceparks, 2011). The success of the science parks remains unclear, as a majority of the MNCs seem not, or only partially involved in R&D activities, and separately operating own private R&D-facilities in Singapore (Hu, 2003; Phillips & Yeung, 2003).

Figure 3.4: Gross Expenditure on R&D and GDP growth (1990-2013).



Source: A*STAR, 2014.

In 2013, the level of public expenditure in R&D was S$3.1 billion and the level of business expenditure in R&D was S$4.5 billion, adding to a total of S$7.6 billion (figure 3.5). Over the 1- year period of 2003-2013, the annual growth rate of gross expenditures in R&D was 8 per cent, outperforming the annual growth rate of the GDP (A*STAR, 2014). Also the

growth of local firms in R&D expenditure has increased significantly in the recent years, to S$1,306 million in 2013. Of the total number of 812 companies involved in R&D activities in 2013, 480 (65%) were local companies (A*STAR, 2014). The total number of researchers, scientists and engineers reached a new height of 31,900 jobs. This growth has been largely realised due to the private sector, with realised a 6 per cent growth in the year 2013 (A*STAR, 2014). In the period 1990-2013, the share of foreign researchers, scientists and engineers increased annually to a share of 29.6 in 2013, of the total 31.943 employed in Singapore (A*STAR, 2014). The total number of primary patent applications as a result of R&D conducted in Singapore, stood at 2144, which represents a robust growth of 24.5% from 1722 patents filled in 2012 and a CAGR (compound annual growth rate) of 7.9% from 1001 patents filled in 2003. The total number of patents awarded as a result of R&D was 934, which represents an increase of 13.9% from 820 patents awarded in 2012 and a CAGR of 7.3% from 460 patents awarded in 2003 (A*STAR, 2014).

Business expenditure on R&D in Singapore are high, but still lag behind the levels of other R&D intensive nations, such as the Organisation for Economic Co-operation and Development (OECD) member countries, like the US and Japan. If the innovation climate of Singapore will transform in line with the trend of other OECD countries, the innovation culture becomes more pervasive leading to an increasingly larger role of SMEs and MNCs in R&D and innovation activities. In the coming years, the Singapore government has announced to increase the gross expenditure on R&D to 3.5 per cent of the GDP, a level similar of other R&D-intensive nations (OECD, 2013).

3.5 Infrastructure, connectivity and quality of life

Throughout the 1970s and 1980s, Singapore's telecommunication and transportation infrastructure was superior over competing countries in Southeast Asia, thereby consolidating their superior position as regional production hub in the region for American, Japanese and European MNC's manufacturing activities (Wong et al., 2005, p. 3). Since the late 1980s, Singapore focussed on transforming into a global hub for financial and business services and a global hub for high value added activities, in which a superior tele- and data-infrastructure is considered vital (Van Grunsven, 2013).

Besides the infrastructures as electricity, water, and telecommunication networks needed for business operations, Singapore has a strong sea- and airport connection. Changi Airport is a hub in the region as well as globally providing linkages to more than 200 destinations in over 60 countries, where the seaport provides excellent connectivity to more than 600 ports in over 120 countries. In the yields for competition and innovation, the upgraded of digital connectivity is expected to generate new business opportunities in the digital-related field, as well as synergistic linkages to the industries (Toh, 2013). Policies implemented regarding the development of strong IT and telecommunication infrastructure can been considered successful, as Singapore tops the rank in 'The Global Information Technology Report' (We Forum, 2015).

3.5.1 Quality of life

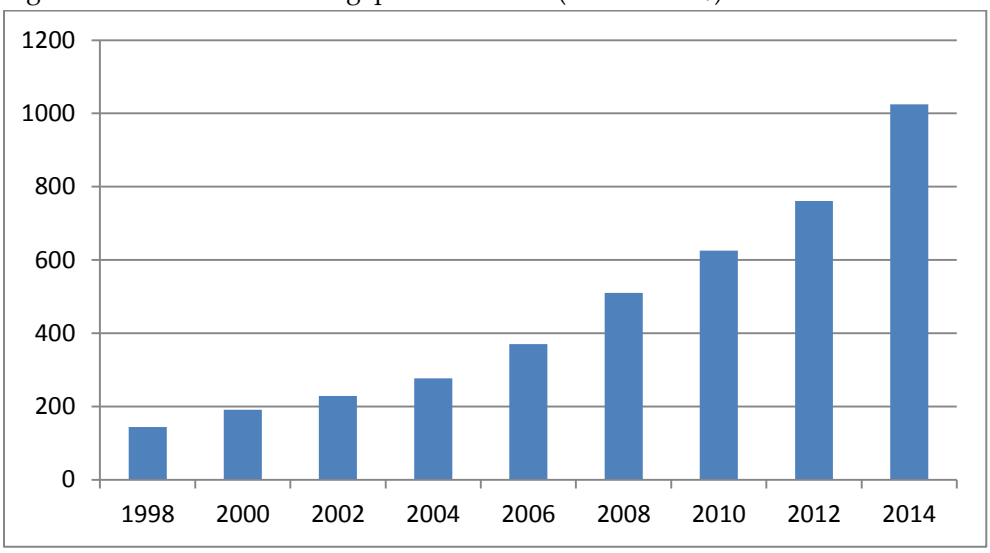
The Singapore government considers the quality of life of its citizens to be an integral part of economic performance of the economy, especially to attract foreign talent who are used to a high living standard (Mahizhnan, 1999). Singapore ranked as 26th city worldwide in the

'Quality of life index' of Mercer, evaluated on 39 indicators including economy, environment, personal safety, health, education, transportation, and other public service factors. Remarkable is the position of Singapore as only Asian city in the top 50, which further only consists of cities from Western countries and Japan. The city-state especially scores well on safety, rule of law (corruption), education healthcare and transportation infrastructure (Mercer, 2015). According to the Mercer, Singapore ranks as the most expensive city for expatriates to live, but at the same ranks first as best city in Asia for expatriates to live in. Additionally, the population of Singapore ranks 24th in the World Happiness Report 2015 (SDSN, 2015).

3.6 Foreign direct investment

The improvement of the local assets as discussed in the previous paragraphs, in order to enhance the dynamic strategic coupling processes, have resulted in an increased amount of foreign direct investments (FDI) into the city-state. After the industrial emergence of Singapore in the 1960s, the amount of FDIs has increased significantly over the decades to $68 billion FDI inflows in 2014 (figure 3.2), ranking 6th in the top FDI inflows economies worldwide (The World Bank, 2015). In 1990, the inward FDI stock in Singapore was US$30 billion, 110 billion in 2000, and 912 billion in 2014. The high FDI penetration reflects the role of Singapore as a manufacturing base for foreign MNCs and as a transportation, logistics, financial, and trading hub in the region. Singapore is likely to maintain its position as a top location for foreign investments, ending 5th in the list of 'MNCs prospective host economies in 2017', finishing behind the USA, China, Brazil and India (Unctad, 2015).

Figure 3.5: Inward FDI in Singapore 1998-2014 (in million S$).



Source: SingStat, 2016.

The foreign MNCs have played a vital role in the post-independence economic history of the country, in which policies on promoting FDI are rooted in the country (Lee et al., 2016). The major FDI investors in Singapore are MNCs from the USA and Japan followed by the European countries UK, Netherlands and Switzerland (Statistics Singapore Newsletter, 2013). Over the recent decades, the 'types' of FDIs have changed. The investments have shifted from lower-value and labour-intensive manufacturing and

assembly activities towards higher-value investments in R&D, RHQ functions and testing. This had led to an increase in the amount of FDIs. Besides, a large shift per sector has taken place, leading to an increased amount of investments towards the services sector. In 1996, 'Financial & Insurances Services' and 'Manufacturing' accounted for over 75 per cent of all FDI (figure 3.6). The shift of Singapore towards a global hub city is reflected in the increasing share of investments made in 'Financial and Insurances services' (40% to 50%). The share of 'Manufacturing' decreased to 14 per cent (SingStat, 2014).

Figure 3.6: Industrial distribution of FDIs in Singapore in 1996 & 2014.

Source: SingStat, 2014.

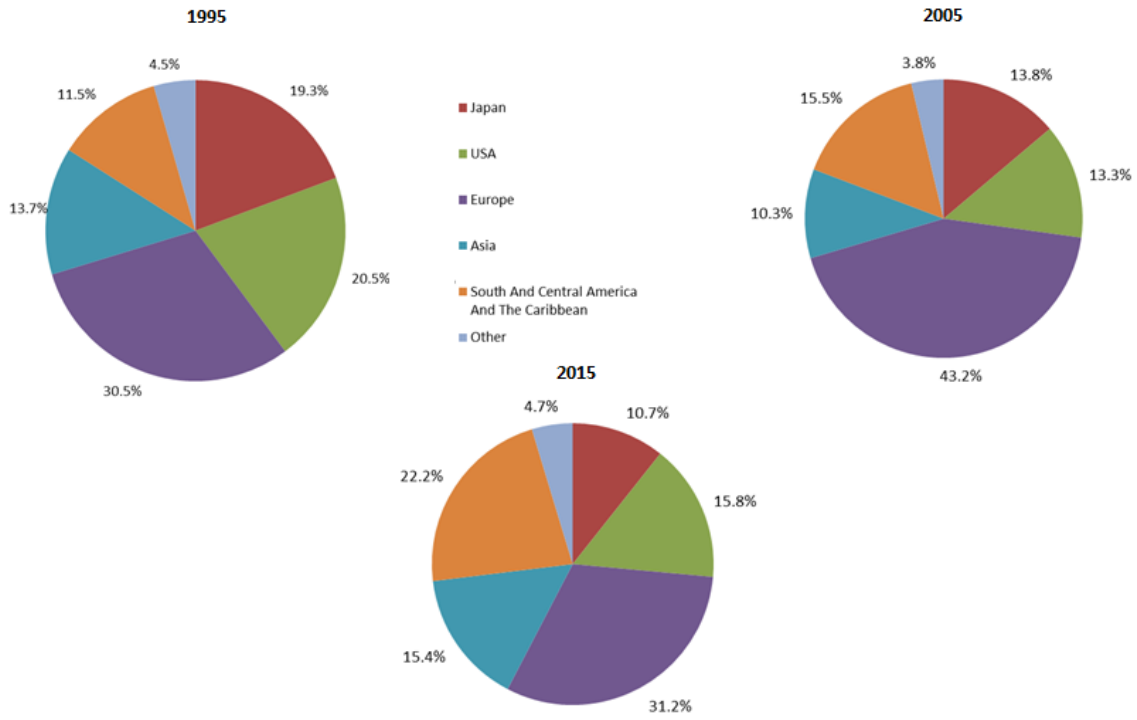
The distribution of FDIs in the 'Manufacturing sector' in 1996 (figure 3.7) presents that the 'E&E related products' (64%) received the largest amount of FDIs, followed by 'Pharmaceutical products (19%), 'Refined petroleum' (7%), 'Machinery and Equipment (10.4%)' and 'Others' (4%). In 2014, the share of 'E&E related products' significantly decreased to 37 per cent. 'Refined petroleum', 'Machinery and Equipment' and 'Others' experienced an increase in the share of FDI (SingStat, 2014).

Figure 3.7: FDIs in the manufacturing industry in Singapore in 1996 & 2014. Source: Singstat, 2014.

In the early 1990s, after the recession of 1985 and the decades of increased shortages of labour and land, the outward FDI of Singapore towards other countries in the region became a focus of the government, leading to a significant increase of outflow FDIs, ranking 12th worldwide in 2014 with a FDI outflow of US$41 billion. The outward FDI stock has increased from 8 billion in 1990, towards 57 billion in 2000, and 573 billion in 2014 (Lee et al., 2016; Unctad, 2015).

Singapore is the main investor in the Southeast Asian region, the majority of the investment outflows in 2014 were to Malaysia, Indonesia, Philippines and Thailand, of which especially the former three show a high degree of dependence from Singapore's FDIs in their economies (Unctad, 2015). The amount of FDIs in Southeast Asia has increased absolutely, but decreased relatively compared to the total amount of outward FDIs. Especially China, the USA and Europe have been increasingly important directions for Singapore outward FDI over the recent decades (Blomqvist, 2002; Lee et al., 2016). Noteworthy is that the distribution of outward FDI from Singapore into other countries shows resemblance with the distribution of inward FDI. The dominant share of FDIs is in the 'Financial and Insurance services', followed by the 'Manufacturing' and 'Wholesale and Retail' sector (Lee et al., 2016).

Figure 3.8: the share FDIs in Singapore by country/region (1995, 2005, 2015).



Source: SingStat, 2016.

3.7 Regionalisation

The small domestic market, high labour costs and limited land opportunities in Singapore were reasons for the government to shift FDI outward the city-state (Yeoh et al., 2004). Singapore government's policy on FDI is strongly related to the effort to secure the international competitive position and intertwined with the increased wages and attempts to realise industrial upgrading. In order to stay competitive, the labour-intensive low value

added activities had to relocate to other regions with lower land and labour costs in order to survive (Blomqvist, 2002; Yeoh et al., 2004). These policies were outlined in the 'Regionalisation 2000' programme, which included the 'Second Wing' strategy. The policy existed of four main regional initiatives: regionalisation of local firms, regional headquartering, regional investments and regional industrialisation (Yeoh et al., 2004).

Initial regionalisation policies focussed on the creation of Overseas Industrial Parks, which were set up by the government to encourage MNCs and local firms to expend their economic activities in the region (Shaw & Yeoh, 2000; Yeung, 1999). The success of the Overseas Industrial Parks has mostly been questioned in the literature, probably because they never realised their main objective of generating profits that could supplement Singapore's domestic economy (Pereira, 2005).

Although the effectivity of the regionalisation plan have been discussed, the plans did show that the outward look of the city-state increased and additionally also the influence on the development of the Southeast Asian region. The outward FDI have increased significantly in the last decades, a development that has strongly contributed to a deeper integration of the country's economy with that of other countries in the region (Blomqvist, 2002).

3.6.1 SIJORI region

As part of the Second Wing, the development of the SIJORI region received additional attention from the government. The concept of the 'Growth-Triangle' between Singapore-Johor-Riau islands as transnational economic synergy region was formed in 1989, and formalised in 1994 (Chen, 2009).

Figure 3.9: The 'Growth-Triangle' in the SIJORI region.

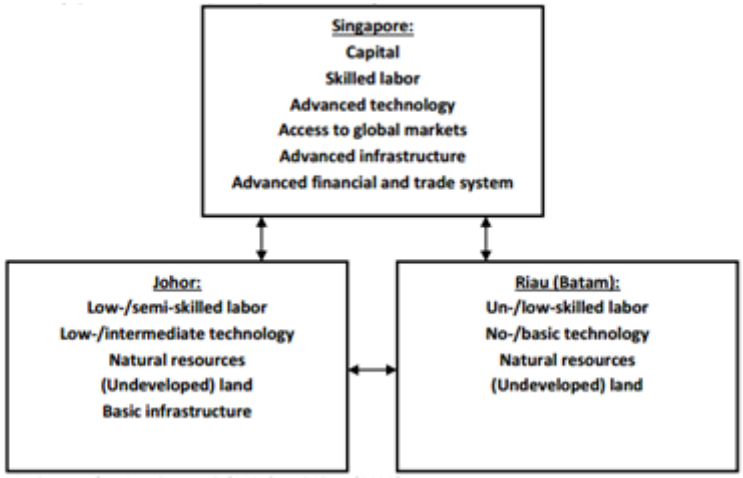
Source: Sparke et al., 2004.

Through relocating its cheaper labour activities to Johor and Riau, Singapore could focus its resources on developing higher value added activities (Chen, 2009). The aim was that the regions with close proximity and their comparative advantages and characteristics would enable economic development through the rise and flourishing of cross-border networks

(Yeoh et al., 2004). According to Van Grunsven & Hutchinson (2014a, p. 33), most Singaporean MNCs have a less extended RPN, as their network is still mostly governed by geographic proximity, with Malaysia and Indonesia as most frequent location for their subsidiaries. Singaporean MNCs do not have a lot of location options to relocate their activities, it appears that the role of the RPN *"is less important than the environmental attributes of a specific location in determining upgrading potential"* (p. 33).

The driving forces of integration of the SIJORI-triangle are economic complementary, the geographical proximity and a policy framework (Vind, 2003). Although using the term 'triangle' is somewhat misleading, because the link between Johor and the Riau region is underdeveloped (Vind, 2003; Chen, 2009). The bilateral cooperation between Singapore-Johor and Singapore-Riau are intense, while the interaction between Johor and Riau is extremely poor and largely absent. There is yet no formal trilateral agreement between all three parties (Chen, 2009, p. 147). The Johor-Singapore connection is historically, economically and culturally stronger than Riau-Singapore. After the independence of Singapore, the division happened almost overnight, and the synergy have since then remained tight (Vind, 2003), in which the Malaysian government is afraid that Johor Bahru will become economically and socially part of 'Greater-Singapore' (Rizzo & Kahn, 2013). The Riau-Singapore relation initiated with the establishment of the Batamindo Industrial Park, but after the Asian Financial crisis has lost momentum (Chen, 2009). In the relationship of the SIJORI Region, Singapore provides capital, knowledge and technology, against the provision of land and labour by Riau and Johor. The business networks are mostly dominated by Singapore, acting as the role of provider, infusing financial capital, knowledge and technology into Johor and the Riau Islands (Chen, 2009).

Figure 3.10: SIJORI Growth Triangle.



Source: Van Campenhout, M. & J. De Graaf (2013), adapted from Sparke et al, 2004; Chen, 2009.

3.6.2 Chinese-Singaporean relations

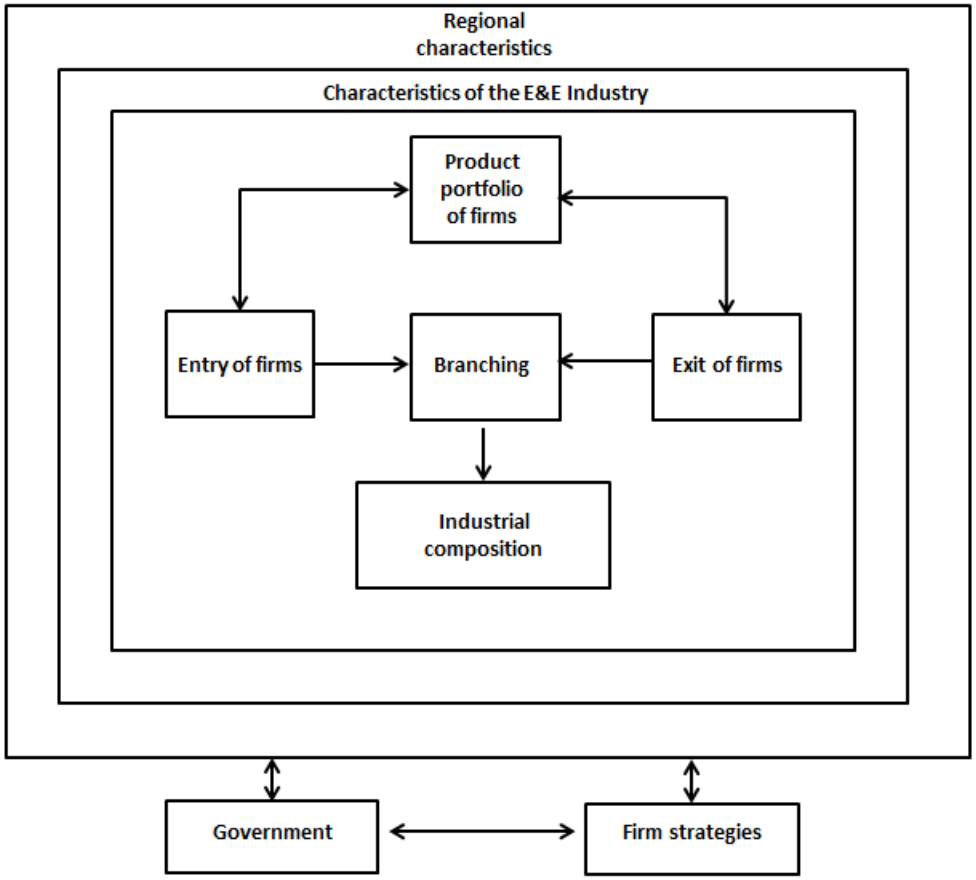
Since the Chinese economy opened up in the 1990s, the economic ties between Singapore and China gradually developed. Since 1990, the bilateral trade increased from around S$5.2 billion to S$95.3 billion in 2010, with China becoming Singapore's third-biggest trade partner, behind Malaysia and the European Union. In order to deepen the bilateral trade and create trade benefits, Singapore and China signed a bilateral FTA, the China-Singapore Free Trade

Agreement (CSFTA) in 2009, being the first comprehensive bilateral FTA that China signed with another Asian country (Wong & Chong, 2014). Both Singapore and China have invested in each other to strengthen their economic resilience and financial stability. On the one hand, China's FDIs rapidly expanded since its strategy of 'going global' in 2000. Singapore is one of the favourite destinations of China, as FDIs grew from S$360 million in 2004 to S$11.5 billion in 2010. Although these figures grew rapidly, it remains small relative to other big investor countries, like the USA (S$65.4 billion) and Japan (S$53.9 billion) (Yao, 2014). On the other hand, the size of Singapore's investments in China grew rapidly as well, with an increase from around S$11.0 billion in 1990 to S$70.6 billion in 2010. The Singaporean government and enterprises have invested increasingly in China, as the cultural proximity and its strategic position in the production network in Asia contribute to advantages in accessing the Chinese market. The investments in China have been very diverse, covering a large span of important sectors, and distributed over all provinces. Besides investing in industries, areas like education, healthcare and clean energy are sectors in which frequently is invested. In the initial phase after 1990, major investment projects mark the type of investments. For instance, the Suzhou Industrial Park is a collaborative project between the Chinese and Singaporean governments and enterprises. After a significant drop in investments as a result of the Asian crisis in 1997-98, the investments increased again, and currently focus on quality and returns. Since the Chinese government became more transparent due to the rules and demands that came with the entrance to the WTO, investors have become more confident. The future stages of investments are, due to rising labour costs, expected to shift to higher-end activities (Fan & Huang, 2014).

3.7 Conceptual model

The developments in the regional context of Singapore might have implications for the way the E&E industry evolved. The policies implemented by the government – some as a result of external developments - influence future developments of the industry substantially, as this is influenced by path dependency, outlined in the theoretical framework. Besides, the current regional characteristics influence the (possible) establishments of new firms, as favourable characteristics are attractive for firms. These regional assets can be transformed by institutions in order to fit the strategic needs of MNCs activities (Coe et al., 2004, 2008; Yeung, 2014b). These relations are visualised in the conceptual model, which includes the factors that are of influence on the composition of the industry (figure 3.11).

Figure 3.11: Conceptualisation of the relevant theoretical aspects of industry evolution.



Source: own draft, 2016.

3.7.1 Expectations

From all these factors that have been addressed throughout this chapter, some expectations have been formulated that will guide this research. Since the 1990s, the Singaporean government focussed its policies on promoting the upgrading of the industries and the development of highly specialised niches; and played a vital role in the industrial development by creating, improving and promoting an environment which is attractive for MNCs. The government tried to achieve this by actively investing in human capital and the development of research centres and universities; stimulating MNCs to invest in R&D activities and research centres as well, in order to generate innovativeness; optimising infrastructure and connectivity; attracting foreign talent through labour migration; increasing wages in order to stimulate productivity growth; and investing in the development of technologies. Besides the role of the local institutional context as a driver of evolution, the relocation of MNCs has been a driver of evolution. The amount of FDI in Singapore increased significantly over the last decades, in which especially the USA and Japan played a major role. These developments led to the following expectations about the E&E industry:

1. The evolution of the E&E industry has been characterised by a high degree of industrial upgrading, as high-sophisticated branches have increased relatively compared to less sophisticated branches.

2. The number of firms has decreased between 1990 and 2014, as the profile of the E&E industry became more narrow, specialised and sophisticated.

3. The American and Japanese MNCs have been the dominant nationalities in the evolution of the E&E industry between 1990 and 2014.

4. Active government intervention and policy implementation have resulted in the development of strong innovation systems around dominant branches.

The Singapore government promoted the development of Singapore into a regional hub for foreign MNCs. The 'Regionalisation 2000' programme outlined this ambition, which promoted the upgrading of activities of existing MNCs and aimed to attract high value added activities from new foreign MNCs. Besides the favourable regional characteristics, tax schemes were developed to attract these activities, such as RHQs and R&D. From the point of view of foreign firms, strategic decisions to establish high value added activities were: geographical proximity, strategic necessity and the availability of business services (Yeung et al, 2001). The development of foreign MNCs gave the opportunity to local firms to emerge as local suppliers in a variety of industries. Another major component of the 'Regionalisation 2000' programme was the relocation of low value added activities of Singaporean MNCs, subsequently contributing to the deepening of Singapore's economy in other regions of Southeast Asia. The main focus of regionalisation by the government has been the neighbouring SIJORI region. This led to the next three expectations about the E&E industry.

5. The number of high value added activities of foreign firm establishments has increased between 1990 and 2014.

6. The role and position of local firm establishments in the E&E industry has increased between 1990 and 2014.

7. Local firms have increasingly regionalised their operations, with the SIJORI region as the most frequent location due to geographical proximity.

4. Methodology

This chapter presents an overview of the methodological decisions regarding the modes of data collection and analysis. As mentioned before, the aim of the research is to map the evolution of the E&E industry from 1990 to 2014 in Singapore. During this period, firms enter, exit or remain in the E&E industry, thereby altering the industrial composition.

This chapter is divided in five paragraphs. The first paragraph addresses the used research design in this thesis. Subsequently, the definition of the E&E industry which is used in this research is given in the second paragraph. Paragraph three makes clear which aspects need to be analysed and which methods are used to collect data for these aspects. The modes which are used to analyse the data are given in paragraph four. Finally, the fifth chapter concludes with a discussion on any problems that have occurred during the research.

4.1 Research design

This research is in essence deductive, as it is derived from existing theoretical insights. These insights are included in the theoretical framework, analysing the concepts related to explain the changes in the E&E industry. The findings are reported in four analysis chapters: the evolution of the E&E industry, the evolution of branches, the evolution of foreign firms and the evolution of local firms. The research is confined to the industry level, in order to observe and map the changes of the E&E industry as a whole in Singapore. The research method is explained in more detail in the next paragraphs.

4.2 Definition of the E&E industry

In order to properly conduct an analysis at the industry level, a definition of the E&E industry is mandatory. According to the Times Directories - Singapore Electronics Industry Directory (SEID), which is annually published by Marshall Cavendish, the E&E industry comprises of four sections: electronics manufacturers; electronic distributors, agents & suppliers; electronics production equipment & automation; and electronics supporting industries. Each of these sections is responsible for an amount of products and services, which change over the years. These products and services are not further classified in a more detailed way (EDB, 2014). Although the sub-sections and products of the E&E industry provided by the SEID give insight into the activities deployed within the E&E industry, the taxonomy does not give a workable definition in order to measure the evolution of the product activities. Since 1948, the UN publishes a classification that can be used as guidance for the development of their product activities (UNSD, 2008). This is called the International Standard Industrial Classification of All Economic Activities (ISIC), which is widely used by national governments to classify their economy over the years.

The Department of Statistics of the Ministry of Trade & Industry composed a Singapore Standard Industrial Classification (SSIC), which is a classification of economic activities undertaken by economic units. This classification is used to reflect significant changes in the structure of the Singapore economy and the emergence of new activities, as well to align with changes in the international standard. The eleventh and latest version was published in 2015, and is included in this research as it incorporates small changes from the previous edition of 2010 (MTI, 2015). The SSIC used the ISIC by the UN to derive their national classification.

The SSIC is a classification with a 5 digit-aggregation structure: section, division, group, class, and item. The highest levels of aggregation, known as "sections", are 22 broad categories, each representing one or more "divisions", which are broken down in "groups", "classes" and "items". The items are at the most detailed level and include 1.097 different cases. According to the SSIC, the E&E-industry is included in the C-section "manufacturing", which comprises 33 divisions. Out of these divisions, 2 divisions can be distinguished that enclose the activities in the E&E industry based on the classification of sub-sectors provided by the Times Directory: manufacture of computer, electronic and optical products; and manufacture of electrical equipment. These relevant subdivisions at the division level, as well as the corresponding groups, are presented in table 4.1 (MTI, 2015).

Table 4.1: SSIC 2015.

Divisions:	**Groups:**
26. Manufacture of Computer, Electronic and Optical Products	261. Manufacture of Electronic Components and Boards
	262. Manufacture of Computers and Peripheral Equipment
	263. Manufacture of Communications Equipment
	264. Manufacture of Consumer Electronics
	265. Manufacture of Measuring, Testing, Navigating, and Control Equipment; Watches and Clocks
	266. Manufacture of Irradiation, Electromedical, and Electrotherapeutic Equipment
	267. Manufacture of Optical Instruments and Photographic Equipment
	268. Manufacture of Magnetic and Optical Media
27. Manufacture of Electrical Equipment	271. Manufacture of Electric Motors, Generators, Transformers, Electricity Distribution and Control Apparatus
	272. Manufacture of Batteries and Accumulators
	273. Manufacture of Wiring and Wiring Devices
	274. Manufacture of Electric Lighting Equipment
	275. Manufacture of Domestic Appliances
	279. Manufacture of Other Electrical Equipment

Source: MTI, 2015.

In this research, the E&E industry is defined as the industry that involves all products presented in table 4.1. The classification used by the SSIC was the foundation on which our own classification in branches is constructed, containing all products of the E&E industry.

This composition does not include several types of establishments, although these fall under the definition of the E&E industry in this research as well. These groups are relevant for the Singaporean E&E industry and are: establishments that don't have production

(anymore), but focus on either R&D/innovation, management (RHQ) or procurement only; and contract electronic manufacturing (CEM). Sales offices without a history of production in Singapore are left out of the research.

4.2.1 Historical evolution of the SSIC related to the E&E industry from 1990 to 2014

The SSIC taxonomy of 2015 substantially differs on some points from the SSIC used in 1990. Therefore, while creating the branches to map the E&E industry, the development of the intermediate editions of the SSIC have been analysed. In that way, a more representative group of branches is created that enables to represent the development of the E&E industry from 1990 to 2014. The evolution of the SSICs can provide the first insights on the dynamics of the E&E industry and offers lines of approach regarding the development of branch taxonomy. Hereby, 'small' assumptions can be made regarding the evolution of the E&E industry. When an item transformed into a group over a 10 year period, the assumption can be made that the importance towards the Singaporean economy increased. While the other way around, when a section disappears or diminishes largely over a certain period, the assumption can be made that the presence of this product group in Singapore has decreased.

While analysing the evolution of the E&E industrial categories of the SSICs, some divisions, groups, classes, and items related to the E&E industry have emerged and disappeared. To provide a clearer overview of the development, an indication has been given by using the editions of 1990, 2000 and 2015. The 2015 edition is analysed, as the editions of 2010 and 2015 are very similar to each other. The edition of 2000 is used an intermediate of the SSICs of 1990 and 2015, as it would be too complex to directly describe the transformation between these two editions (also see appendix 4). To clarify the following paragraph about transformations that have occurred in the SSIC classification, an example is given of the 2015 edition (table 4.2).

Table 4.2: SSIC 2015 section C (manufacturing).

Section:	**Divisions:**	**Groups:**	**Classes:**	**Items:**
Section C: manufacturing	26. Manufacture of computer, electronic and optical products	261. Manufacture of electronic components and boards	2611. Manufacture of Semiconductor devices	26111. Manufacture of discrete devices 26112. Semiconductor wafer fabrication 26113. Assembly and testing of semiconductors 26114. Manufacture of solar wafers 26115. Manufacture of solar cells 26119. Manufacture of semiconductor devices n.e.c.

		262. Manufacture of Computers and Peripheral equipment	2620.Manufacture of Computer and Peripheral equipment	26201. Manufacture of computers and data processing equipment 26202. Manufacturing of disk drives Etc.

Source: MTI, 2015.

Where the 2015 SSIC has two divisions representing the E&E industry (26. Manufacturing of Computer, Electronic and Optical Products and 27. Manufacturing of Electric Equipment) (table 4.1), the 1990 SSIC shows a more scattered classification, falling under the 'Major Division 3': manufacturing. Still, when analysing chronological backwards from 2015 to 1990, the changes in the SSIC classification over the last 25 years can be mapped (see appendix 4). When comparing the 1990 with the 2000-edition, new SSIC items were introduced: *Electronic tubes; Disk media; Tape drives; Storage subsystems*; *Industrial process control equipment; Networking products;* and *Wireless communication equipment*. An item that disappeared from the SSIC classification was: *Manufacture and repair of welding equipment (incl. Arc welding electrodes)*. The item *Manufacture and repair of computer and data processing equipment* except *Computer peripheral equipment* would transform from item into a group, highlighting its increase in importance. This also applies for the item *Manufacture and repair of communication equipment.* The item *Manufacture and repair of semiconductor manufacturing equipment* would evolve into a SSIC-group from 1990 to 2015.

The two product groups *Manufacture and repair of electrical industrial apparatus* (excluding *Electric instruments)* and *Manufacture of electrical machinery, apparatus, appliances and supplies* would convert to the group *Manufacture of other electrical equipment n.e.c.* in 2000. Also the groups *Manufacture of Electrical Households Appliances* and *Manufacture of fabricated metal products* (excluding *Machinery and equipment)* have combined into *Manufacture of domestic appliances.* Noteworthy is that *Communication equipment* did not exist in 2000, and developed from a single item into a group with multiple items. This indicates an increase in importance of this industry. Also the computer and data related industries increased in number of items and classes from 1990 to 2000, but decreased again in 2015, possibly showing the previous importance of the industry that declined over the last decade. The class *Electronic Components* increased over the period 1990-2015, showing a possible increase in diversification of this industry.

Comparing the editions of 2000 and 2015, some divisions, groups, classes and items diversified, some disappeared and others emerged. The classification class for the *Semiconductor industry* has diversified into more items. This diversification also applies for the class *Communication equipment*, indicating that the importance of these industries for the Singaporean economy has increased. Some classes have decreased in number of items, such as the classes *Consumer electronics; Optical instruments & Photographic equipment*; and *Batteries and Accumulators*. There are also some cases where classes were combined to form one group, like the groups *Electric Motors & Generators* and *Electricity Distribution and Control Apparatus,* combined into the group *Electric Motors, Generators, Transformers, electricity distributors and control apparatus;* and the *Computing and data processing equipment and accessories* and the *Other electronic equipment* recombined into the *Computer and peripheral equipment*. New items that were added into the SSIC of 2015, compared with the 2000 edition, are: *Manufacture solar*

wafers; *Manufacture of solar cells; Manufacture and repair of irradiation and electro-medical equipment and instruments*; *Electronic security systems;* and *Manufacture of fuel cells.* Also the *Magnetic and optical media* was established as a class in 2015. The complete development of the SSIC editions from 1990 to 2015 are given in the appendix.

4.3 Information sources

New technological developments, changing consumer behaviour, and economic developments are factors that affect the dynamics in the composition of an industry, which can to a large extent explain the evolution at the industry level. The process of branching, the emergence of new branches and the decline of old branches, characterises the evolution of an industry (Boschma & Frenken, 2009; Neffke et al., 2011). Every economic industry consists of a group of related branches, as where the branch consists of a group of firms producing strongly related products. Based on the taxonomy, electronic related products can be linked to a particular branch. When some new products enter and other products exit, the economic landscape of the path of branches is affected. This affects the composition of the industry as a whole due to the emergence and decline of these branches.

Analysing the current industrial composition of the E&E industry is necessary to explain a dynamic process as evolution. In order to explain this, an inventory is required of all established firms and their product portfolios, firm exits and entries from year to year – covering the time span of this research ranging from 1990 to 2014 – and their relevant characteristics. All lifespans of the products produced by firms within a branch combined together show the development of that branch. The evolution of the E&E industry from 1990-2014 as a whole is shown by the change of the composition of all branches together.

Potential sources for the required data of this research are company directories, like the Kompass directory. This directory comprises product groups with corresponding firms. However, this directory includes manufacturers, suppliers and even electronic shops without making clear distinctions between these groups (Kompass, 2014). Other directories contain limited data, confined to firm size (e.g. Ernst & Young) or nationality, like the Japanese (e.g. Ernst & Young, 2011; Wesleynet.Com, 2009). The source that ultimately arose is the Times Directories: Singapore Electronics Industry Directory. This comprehensive directory for the electronics and supporting industries in Singapore is annually published by Marshall Cavendish Business Information and supported by among others the Economic Development Board of Singapore. The first edition used in this research is the 1990/91 edition, as it was published in a fiscal year, running from 1st of April to 31st of March. The editions of 1992, 1993, 1995 and 1998 were published at the beginning of the year. Ever since 1998, the directory is again published for every fiscal year, with the directory of 2013/14 being the 17th edition.

The SEID consists of lists of electronic manufacturers; electronics distributors (1), agents & suppliers (2); electronics production equipment & automation (3); and electronics supporting industries (4). The lists provide information about the contact details, the type of products the firm is making and services the firm is providing. This information makes it possible to determine if a firm was active in a certain year, which products it makes and to a lesser extent what their year of establishment and country of origin is. The firms are linked to one of these four columns based on their product activities. In this fashion, the directory has

a classification that is inconsistent with the SSIC (table 4.1). The marketing department of the Times Directories has an active policy for collecting data, calling firms to collect information about their activities to list them in the directory, where an extra fee has to be paid by the firms if they want additional information about the establishment shown in the directory (Dora Woo, personal communication, 5 May 2015).

With the collected information, a database has been constructed of in total 1196 E&E firms establishments that are of have been located in Singapore between 1990 and 2014, representing the total population of this research. With respect to terminology, the research units are addressed as firm establishments, while the parent companies are addressed as firms. Firms can have multiple firm establishments (e.g. Sony operates Sony Precision Engineering). Foreign firm establishments, as well as the establishments of Singaporean firms abroad, are alternatively addressed as subsidiaries.

Information about the type of product makes it possible to link the firms to branches. So to map the E&E industry of Singapore between 1990 and 2014, and to determine whether the industry has experienced any upgrading or not, the items included in table 4.3 has been extracted and included in a database.

Table 4.3: Indicators per firm establishment.

Indicator	**Description**
Company name	Full name of firm establishment in Singapore
Country Origin	Country of origin of the (parent) company
Year established	Year of establishment of the firm establishment in Singapore
Address	Last known address of the firm establishment in Singapore
Telephone	Last known telephone number of the firm establishment in Singapore
Name Parent	In case the establishment is a subsidiary, the name of the parent company is noted down
NOTES	Additional notes on: the function of the firm establishment (GHQ, RHQ, representative office, production/manufacturing plant); subsidiary of the firms establishment (Batam, Johor, or elsewhere in Asia); name changing; acquirements; fusions; and bankruptcy.
Website company	The website of the (parent) company
Email address	The email address of the firm establishment in Singapore
Active years	These 19 columns, representing each period from 1990 to 2014, contain whether the firm establishment was present in Singapore in that particular year (based on the Times Directory).
No Pd (product)	These 19 columns state in how many and which electronic sectors the firm establishment was active over the period 1990-2014.
Type Pd (product)	

The SEIDs do not provide all the required information for the database as some firm establishments are covered in less detail than others. Besides, 'gap' years may occur, when the firms are not registered in the directory of a certain year, but are in those of the previous and subsequent years.

4.3.1 Additional data sources

In order to resolve the flaws of the directories and add the information required for the database, additional sources have been used to obtain data regarding: country of origin, year of establishment, function, website, email address and active years. These additional sources are shown in table 4.4. The company directories and official government records are seen as the most reliable sources of data. After consulting the industry directories and the official government data, missing data is elaborated with company information and newspaper articles. Data collected in the initial two steps are controlled and verified by company information and newspaper articles.

Table 4.4: List of information sources.

Type of source	**List of sources**
1. Industry directories (guides, yearbooks, etc.) *Used for:* - Country of origin - Year of establishment - Active years	- Singapore Electronics Industry Directory 1998-2014 (Times Directories) - Japanese Business in Singapore 1995 & 2005 (Kompass Directory) - Foreign companies in Singapore yearbook 1998 and 2009 (Commercial Intelligence Service) - Singapore top 3000 companies and small & medium enterprises 2010 (Ernst & Young) - Singapore top companies and Small and Medium enterprises directory 2011 (Ernst & Young) - Singapore 1000 & SME 1000 (Ernst & Young)
2. Official government data (chamber of commerce, bankruptcy files, etc.) *Used for:* - Country of origin - Year of establishment - Active years	- EuroCham: Singapore 2008/2009 (European Chamber of Commerce) - Japanese Companies in Singapore (JETRO) - Japanese Singapore Trade Directory (Wesleynet.Com) - Directory of British Business in Singapore 2004 (British Chamber of Commerce) - Directory of Netherlands Companies in Singapore 2003 (Dutch Chamber of Commerce) - Norway in Singapore 2001 (Norwegian Business Association) - SGC Membership Directory 2006-2007 (Singaporean-German Chamber of Industry and Commerce) - Singapore Business Pages 2009 (Yellow Pages)
3. Company information (websites) *Used for:* - Country of origin - Year of establishment - Function - Website - Email address - Active years	- Company websites - Brochures
4. Newspaper article *Used for:* - Country of origin - Year of establishment - Function - Active years	Newspaper articles providing background information of companies. - The Straits Times - The Business Times Singapore

The Kompass Directories of Japanese business are used as an additional data source for the analysis on the development of firms with multiple establishments. These directories include the number of Japanese firms in Singapore, including lists of all their establishments in Singapore. The type of products and the activities in which they are engaged in are given for each establishment. Unfortunately, the coverage proved to be limited, as the only two available editions are from 1995 and 2005. The Kompass directories for the American and European firms proved to be less helpful than the Japanese editions, as the amount of information is less detailed.

Furthermore, additional secondary information is collected for specific aspects that are included in the analysis, like business ecosystems, and regional production networks. Regarding the identification of business ecosystems or local innovative systems around branches, crucial factors are defined, as the interaction of firms with the business and societal environment, mutually beneficial relationships with each other (e.g. collaborations between local firms and MNCs or between firms in a branch and providers of complementary products) and the involvement of other actors like, products, processes, organisations, and the government/institutions. All these actors work together around a central platform, the core business, in this research the branch. Examples of involvement of the government are the investments in facilities which are meant for shared utilisation of firms, stimulation of MNCs to establish R&D facilities, or strategic coupling processes, in which the government attracts foreign MNCs to improve the regional economic development. Secondary source material, like governmental publications and reports, and news articles, will be used to collect the data. The RPNs of foreign firm establishments are mapped by looking at their subsidiaries and their activities in the region. Their activities are divided into: global headquarters, regional headquarters, R&D facility, sales & marketing, and manufacturing. Kompass and company websites are used to retrieve this information.

The analysis on the regionalisation of local firms consists of mapping the network of Singaporean MNCs, with a focus on the SIJORI region, and on anatomising the functions of establishments of non-Singaporean MNCs in Singapore. This information is compiled from the websites of the companies included in the database. While mapping the network of Singaporean MNCs, a taxonomy of the locations of the subsidiaries is made, divided into the following locations: SIJORI (Batam and/or Johor), China, and Penang. Locations outside Southeast Asia are not taken into account. Company websites and news articles are used to provide data about these aspects.

4.3.2 Taxonomy of branches

Both the classifications used in the SEID and the SSIC are not suitable for mapping the evolution of the E&E industry. Even more, because the two classifications are so fundamentally different, an inconsistency problem occurs. The SEID taxonomy is problematically unclear because the demarcations of the groups/sub-groups/product categories result into an accumulation of different overlapping product groups, and even overlap that occurs on different levels. The taxonomy of the SSIC is more clear and has a better 5-digit ramification systems of products being linked to divisions, sub-group, groups and items. Still, the problem is presented that the aggregation-level is either too high or too low, making it impossible to map the E&E industry in a clear manner.

In order to map the development of the E&E industry, a taxonomy is 'created' on the 'right' aggregation level. The SSIC classification was used as a format on how to construct the relevant branches. Therefore, it formed the basis to identify 16 branches, which are structurally given in table 4.5. Following the theoretical framework, a group of firms that (more or less) have similar product activities can be related to a branch. For all the firms in the SEID, the product activity (or multiple product activities) are given. The taxonomy links these product activities of the firms to one of the 16 branches, enabling us to map the E&E industry.

Table 4.5: Taxonomy of branches.

Index branches in the E&E industry		**Products**
Consumers	**1**	Audio & Video equipment//Video cassette recorder//compact disk players//microphones//remote control//television tuner//TV-receiver//Cassette mechanisms & cassette recorder//Portable audio//speakers//Tuners//Hi-Fi//VCR mechanism//Amplifiers//magnetic tape heads//TV & monitor tubes//picture tubes // Radio cassette recorders // Display devices// Household appliances//Fans //thermostat//Cooling Fans//weighing scales// VHF/UHF/Microwave devices
Semiconductors & Wafers	**2**	Semiconductor etc.//Diodes//IC assembly & test//IC burn-in service//IC design//IC leadframes//Light Emitting Diodes//Embossed carrier tapes// Semiconductor materials//substrative organic//Standard Ics//solar cells//solar products//Standard Linear Ics//Standard logic Ics//substrates// Semiconductor Testing Services// Wafer//Wafer foundries//Epiwafer//Integrated Circuit//Integrated Circuit assembly & Test
Hard Disk Drives & Disk Media	**3**	Disk media//Data storage device //Other Data storage// Winchester Disk Drives//Disk Drives
Computers & Computers Peripherals (incl. Office Equipment)	**4**	Computer etc.//CD-rom drives//computer aided design//Keyboards//tape drivers//thermal printers// office equipment//office machinery//Fax machines//Computer monitors//Computer keyboards//Computer multimedia//Printers//Computer systems//CAD//Electronic typewriter//typewriting//Copiers//DVD//CD-ROM//CD-r//Compact disk player//CD replication//
Printed Circuit Boards	**5**	Printed circuit boards etc. //hybrid circuits//burn-in boards// flexible PCBs//Rigid PCBs//PCB assemblies//PCB design//PCB fabrication materials//PCB Test & Diagnostic equipment// PCB et related etc.//memories
Other Electronics Components and Boards	**6**	Electric Components//Electric Materials//Quartz crystal products //capacitors //Connectors, Sockets & Pins //electromagnetic interference protection//electronic ballast//design automation//linear actuators//magnetic heads //resistors//carbon film resistors//chip resistors//metal film resistors//metal oxide resistors//printed resistors circuits//resistors networks//trimmer resistors// silicon rubber //Coils etc//Inductors//Aluminium Electrolytic Capacitors//Film capacitors

		//Crystal filters & oscillators//electronic paste//tubes////Electronic design automation//Automotive components parts//Liquid Crystal Display (LCD)//Modems (or interface cards)//Multilayer ceramic capacitors// Ceramic packages, filters, resonators//Ceramic components// ceramic
Communication, Networking and Security Equipment; Telecommunication	**7**	Broadcasting equipment//Networking products//Radio Frequency Identification (RFID)// Smart Cards, RFID & Readers //Alarm monitor systems//Burger Alarm system//Data Communication Systems//Pagers//Parking systems //Security alarm systems//sensors//smoke detector//speed warning devices//antennas systems//Rack & Consoles//Communication Equipment//Detectors Telecommunication//Telecommunication equipment//Telecommunication Equipment & products
Measuring, Testing, Navigation & Control Equipment; Watches & Clocks; Electromedical and Electrotherapeutic Equipment	**8**	Control systems//controllers//electronic instruments, calculators, measuring, test// Test jigs & fixtures//potentiometers//instrumentation & control systems//micro controllers// Analogue meter//clocks assemblies and radios//Clocks //timers & time pieces//Instrumentation systems//Barcode equipment// voltage regulation// High voltage capacitors// Filters//compressors
Optical Instruments & Photographic Equipment	**9**	Lasers//lasers processing systems//Photomasks//Projectors//phosphor
Wires & Cable Devises	**10**	Cable//Wire & Cable Harnesses// Wire bonders// Wires & Cables//bonding wires//Cable cords & plugs//Cable ties//jumper wires
Other Electric Equipment	**11**	Bobbins//electronic equipment & suppliers//electronic materials// glass-to-metal seals//speed drives//surge arresters //variable speed drives// thermoelectric modules//
Electric Motors, Generators, Transformers & Electric Distribution and Control Apparatus	**12**	Direct Drive Systems//Ferrite Core//Ferrite// ferrite etc//Transformers //Motors//DC converter// Relays// switchboards// Switches// switchgear// switching power supplies//electric fuses//Membrane switches//Power distribution transformers
Batteries & Accumulators	**13**	Batteries//accumulators//electronic power packs//power supplies //Battery chargers//Uninterruptible power supplies//AC Adapter
Other (incl. Toys & Games)	**14**	Prototyping services//training & educational equipment//Digital Signage//Toys & Games
Contract Manufacturing	**15**	Contract Manufacturing//PCB Sub-assemblies & Contract Manufacturing

Source: adapted by Times Directories, 2014.

4.4 Data analysis

The structured database is used to execute an analysis on all relevant branches, in order to provide the needed information to display the evolution of the E&E industry as a whole in Singapore. In this way, the evolution of branches and the E&E industry in total was derived by analysing the evolution of the industrial composition, together with a description on the trends within these branches in the 1990-2014 period.

While analysing the database, clear considerations are made about what share of firms belongs to which branch per year. With regard to this calculation, two alternatives should be considered, as the possibility occurs that firm establishments are involved in more than one branch. First, when firm establishments are involved in more than one branch, it could be counted as present in all these branches which it is involved in. For instance, Hitachi Cable Asia Pacific (HCAP) Pte Ltd is involved in two different branches: Semiconductors & Wafers and Wire & Cable Devices. In this case, they would be counted as adding one firm establishment to the total number of firm establishments active in each of these branches in a certain year and thereby counted double/dually. Second, whenever a firm establishment was involved in more than one branch, an extra modification is applied, as their presence in the total number of firms establishments active in each of these branches in that year was calculated as a share of the total number of branches they were active in. In this way, it was possible to calculate the share of each branch per year.

For practical reasons, option 1 is opted as the method of calculation in this research, as option 2 leaves several uncertainties. As some firm establishments are involved in up to 14 different branches, the calculations would become very detailed and indistinct. Option 2 could also result in a wrong premise, as in reality the core business of a firm establishment lies in one certain branch, but in the calculations the share of each branch would remain equal. By counting all the branches which a firm establishment is involved in as present, the total number of active firm establishments in a branch in a certain year could be calculated. In order to calculate the relative weight of each branch, it was necessary to include the number of firm establishments listed under the products index instead of the number of firm establishments listed under the manufacturers index. In this way, the irregularity of counting firm establishments double is clarified.

Besides the analysis on the evolution and composition of branches, an analysis is done on firm entries and exits. The amount of exits is determined by looking at the amount of firm establishments present in a given year, but not anymore in the next year. The other way around, the amount of entries is determined by looking at the amount of firm establishments that entered the industry in that year and were not present in the year before. Besides this, there is also the possibility that a firm establishment doesn't enter or exit the industry, but enters or exits a certain branch. In these cases, the firm establishments is counted as an entry or exit in a certain branch. Finally, the origin of the firm establishments are analysed by the share of nationalities.

The data for the cases of firm establishments are not confined to the 1990-2014 period, but include information before 1990, and after 2014.

4.4.1 Upgrading

Upgrading at the industry level involves the increase in productivity, expansion of functions, or the movement to higher-technology categories of product segments (or sub-sectors) in industries. Here, the increase in technological sophistication indicates the industrial upgrading (Van Grunsven & Hutchinson, 2014). Although there is not an universal accepted definition of technology, technological progress may be regarded as a *'better way of doing things'* or as *'producing more from less, by employing new technologies and generating new products and processes'*. Where high-tech refers to *'activities that employ or embody inputs (which) in some*

sense are technology intensive' (Chu & Hill, 2006, p. 6). An industry experiences upgrading if the development of branches shows a shift towards a more sophisticated stage relative to the previous stage. If the opposite occurs, the industry has experienced downgrading.

According to Shin et al. (2012), active components, like integrated circuits (semiconductors) and hard drives, generate more value added than passive components, like capacitors and resistors (other components). These components are more specialised and capable of higher degrees of differentiation (Shin et al., 2012). In a case study of Thailand's E&E industry, the increased activities in IC design and hard disk drives development are valuated as an increase in the sophistication level (UN, 2005). The increase of sophistication level in Penang has been considered the result of intensified semiconductor manufacturing (UN, 2009). Another way to measure the 'sophistication-level' of a branch is analysing the composition of the workforce. A branch with a high degree of engineers employed in the workforce may be considered to be more sophisticated. A shift towards higher-sophistication products requires innovation, research, design and testing activities, and technical education and a skilled workforce (UN, 2009). Lall et al. (2006), stated that the value added rates of an export product increases as it reaches a higher level of sophistication. Lall et al. consider semiconductors, telecom equipment, electrical measuring products and automatic data processing equipment to be high-sophisticated, because they have complex manufacturing processes and have a high value added share per export product. With these criteria, components do not match the previous product groups and are considered less-sophisticated (Lall et al., 2006, p. 227). According to Lall et al., the overall export sophistication level of the economy was a result of substantial semiconductor and disk drive activities (p.233).

4.5 Methodological limitations

While collecting and analysing the data, some limitations occurred. The next paragraph identifies these limitations and defines how these limitations were handled.

At the macro level, some issues arise with the collection of data. Data of the years 1994, 1996, 1997, 1999 and 2001 is missing, and therefore data about entry, exit and presence of establishments is unknown for these years. In these cases, if establishments were active in the years surrounding missing years, it was assumed these establishments did not leave the industry. In other cases, establishments were absent in one edition, but present in the previous and following edition. In these cases, the assumptions were made that the establishment had remain active in the industry. Besides, there is evidence that the listed data in the Times Directories is not 100 per cent correct. In some cases, company websites showed that certain establishments are not active in the E&E industry or they produce different products than which are included in the Times Directories. In some cases, it takes a couple of years before an establishment is included in a database, after it is established in Singapore. If clear evidence on contrary information was found on the website of firms, adjustments were made in the database.

The years which are used as measuring points might result in limitations, as not all the editions are used for detailed information. In this way, the evolution of the industry and branches is available, but not the detailed information about the composition for every year. The chosen method for calculations also results in a limitation, as in this way the relative share of establishments in a branch could not be calculated. This limitation was dealt with by

including the number of companies listed under the products index instead of companies listed under the manufacturers index.

Most data on the firm level had to be retrieved from company websites. The only available information describe the current state and developments of the firms. In this way, it is impossible to analyse the evolution of the RPNs from the point of view of MNCs and local firms.

5. Evolution of the E&E industry

The introduction, theoretical framework and the context chapters have elaborated on the industrial process of Singapore and the development of the E&E industry in Southeast Asia. This chapter zooms in on the evolution of the E&E industry in Singapore, which has been a major pillar in the industrialisation process of the city-state. This first paragraph of this chapter briefly discusses the evolution of the E&E industry in Singapore until 1990, in which some key policies that affected the process have been addressed. The following subparagraphs will provide a more detailed description of the evolution of the E&E industry between 1990 and 2014, providing and analysing data regarding the number of firms, entry and exit rates, the share of nationalities and other indicators of the E&E industry.

5.1 Evolution of the E&E industry until 1990

The E&E industry in Singapore originated in the late 1960s, when the city-state desired a more diversified economy away from being dependent on a port alone. Singapore needed to shift towards industrialisation (Huff, 1995). The PAP that had taken office in 1959, and still is in office today, introduced the idea of strong government intervention to stimulate economic growth (IBP, 2008). The government established the EDB to attract FDI and MNCs' activities (Mathews & Cho, 2000). From that aspect, the highest priority was shifted to the attraction and development of the E&E industry, particularly on manufacturing and assembly activities (Huff, 1995). Since the E&E industry embarked in Singapore, it experienced four phases of development (Van Grunsven , 2013).

The first phase emerged in the late 1960s and can be characterised as the first wave of foreign firms coming to establish offshore production, mostly focussing on assembly for products as transistors and low-end consumer product electronics. The foreign firms were attracted by low labour costs, good infrastructure, tax incentives and the central location of Singapore in Southeast Asia. The most important task of the established EDB was to attract foreign MNCs' economic activities. These MNCs provided large employment opportunities, as almost one-third of the Singaporean labour force was active in the E&E industry (Van Grunsven, 2013). To avoid labour strikes and secure competitiveness, the 'Labour employment act' was passed in 1969 (Mathews & Cho, 2000). The focus on attracting foreign MNCs to stimulate economic growth was also geopolitical, as the city-state wished to become independent of its unstable and unfriendly neighbours, as well as the fear of the government that the local Chinese business elite potentially favoured to establish (business) relationships with communist China, which could potentially affect the recently obtained sovereign status (Yeung, 2002).

The second phase, the late 1970s to the late 1980s, marks the diversification in more and diverse product groups, like disk drives, computer systems, other computer peripherals and integrated circuits, as well as supporting sectors, such as PCB assembly and precision engineering (Van Grunsven, 2013). This period was also characterised by industrial restructuring, in order to deal with the economic growth and the subsequent labour shortage and rising costs that eroded Singapore's position as a low-manufacturing base. This necessitated restructuring towards high-tech manufacturing and high value added lines of business (IBP, 2008). The first, less successful attempts at upgrading activities in the E&E industry also mark this phase (Mathews & Cho, 2000; Van Grunsven, 2013).

During the third phase, which started in the late 1980s, the focus shifted towards knowledge-intensive activities and new attempts at upgrading (Mathews & Cho, 2000). The wages had been annually raised with 20% by the EDB in the early 1980s. Low value-adding, labour-intensive operations regarding relatively mature products were stimulated to relocate out of the city-state (Van Grunsven, 2013). The previous high-wage policy, which was implemented to help the general upgrading of the economy and improving working welfare, had hardened the struggle to survive for the smaller firms. The annually raised wage policy stimulated the upgrading process of the E&E industry, but also affected the competitiveness of firms. The government and its institutions embarked an intense effort to stimulate knowledge-intensive activities to reassure the economic growth and upgrading of the city-state (Mathews & Cho, 2000). Government institutions and MNCs co-founded initiatives to stimulate R&D activities (Mathews & Cho, 2000). Various programmes were implemented to stimulate human capital, improve skilled workers and train engineers. To attract new investments, the government implemented lower operation and wage costs, and increased flexibility in the labour market. A new wave of investment in the late 1980s resulted in the growth of the computer and related industries, particularly the disk drives, personal computer, computer monitor and printer industries, which resulted in new economic growth (Wong et al., 2005, p. 3).

Table 5.1: Developmental phases in the E&E industry, 1970-2014.

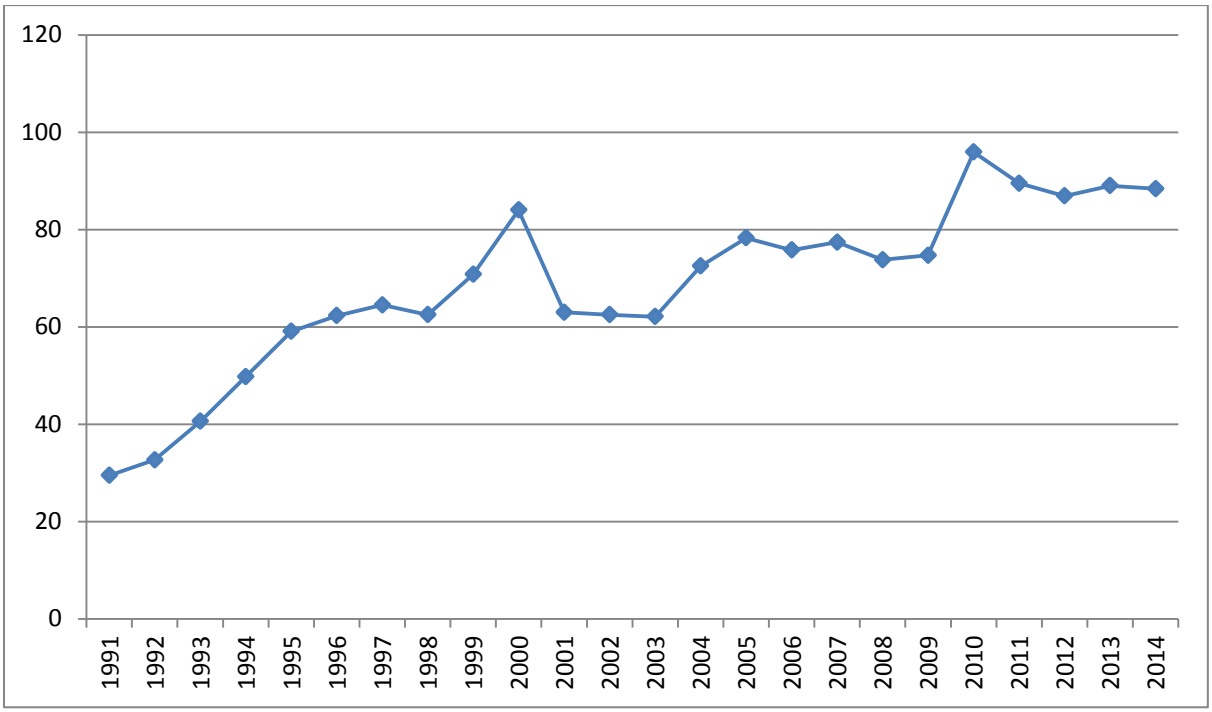
I Phase – 1970s	**II Phase – late 1970s to late 1980s**	**III Phase – 1990s**	**IV Phase – early 2000s**
- First establishments of offshore production by foreign MNCs. - Attracted due to infrastructure, low labour costs, English-speaking population and central location.	- Further growth of the E&E industry. - Initiation upgrading process. - Diversification E&E industry. - Originating supporting activities.	- Further upgrading of the E&E industry. - Increasing efforts of the government to stimulate upgrading. - Relocation labour-intensive manufacturing activities abroad. - Stimulating R&D and RHQ activities.	- Industry 21 Master Plan targeted high value added and high precision products and processes. - Gain productivity and loss employment. - Increased role other industries.

Source: Van Grunsven, 2013.

5.2 Evolution of the E&E industry 1990-2014

The early upgrading policies of the late 1980s developed further in the 1990s, still focussing on promoting high value added activities to increase the competitiveness of the city-state's economy. In the early 2000s, the fourth phase emerged with the government launching the 'Industry 21 Masterplan', which pointed out the E&E industry as a key component of the future of the economy and targeted high value added and high precision products and processes, with increasing input from computer science, engineering and artificial intelligence research. The fourth phase is characterised by an increase in productivity and a decrease in employment, and further offshoring of labour-intensive manufacturing and assembly activities into Southeast Asia (Van Grunsven, 2013, p. 50).

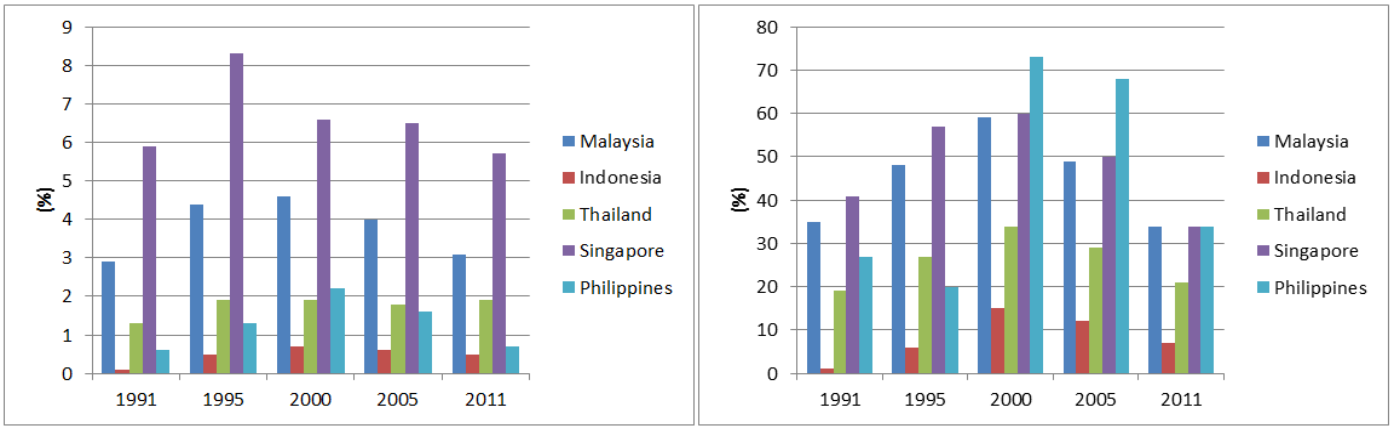
Figure 5.1: Annual output of the E&E industry, 1990-2014 (in billion S$).



Source: SingStat, 2016.

The E&E industry's output has significantly increased between 1990 and 2014 (figure 5.1). Between the 1990 to 2014 period the manufacturing output of the E&E industry has increased significantly, from 28 billion dollars in 1990 towards 84 billion dollars in 2014. In 2014, the industry accounted for 5.3% of Singapore's GDP, contributed to 29% of Singapore's manufacturing output (EDB, 2014). Especially in the 1990-1995 period and 2006-2010 period the average annual growth was high. In Table 5.1 indicates the key indicators of the development of the E&E industry. Between 2010 and 2014 the output of the E&E industry has decreased, with an average annual decline of 2.3 per cent (table 5.1).

Figure 5.2: Share in world electronics exports (left) and share of electronics in national exports (right), 1990-2014.



Source: Rasiah et al., 2014.

The increase of output and domestic export in the 1998-200 period could have been the result of the Asian Financial Crisis (AFC) in the year 1997. This assumption is supported by the

export rates of Singapore from 1991 until 2011 (figure 5.2 & 5.3), which are strongly related to the demand from the United States. During the crisis, the American economy was booming and had a growing demand of E&E products. This helped to expand the export of E&E goods from Southeast Asia (figure 5.2.) - as the production prices had dropped significantly as a result of the crisis - favouring Singapore as an export-oriented economy. The assumption that the significant increase of output in the year 2010 (with 27.2 per cent) can be linked to the Global Financial Crisis (GFC) of 2009 is less probable, as the crisis had struck the American and European market, two of the most important export-markets of Singapore, leading to a decrease in worldwide demand (Rasiah et al., 2014).

Table 5.2: Indicators of the Singaporean E&E industry 1990-2010, absolute and relative.

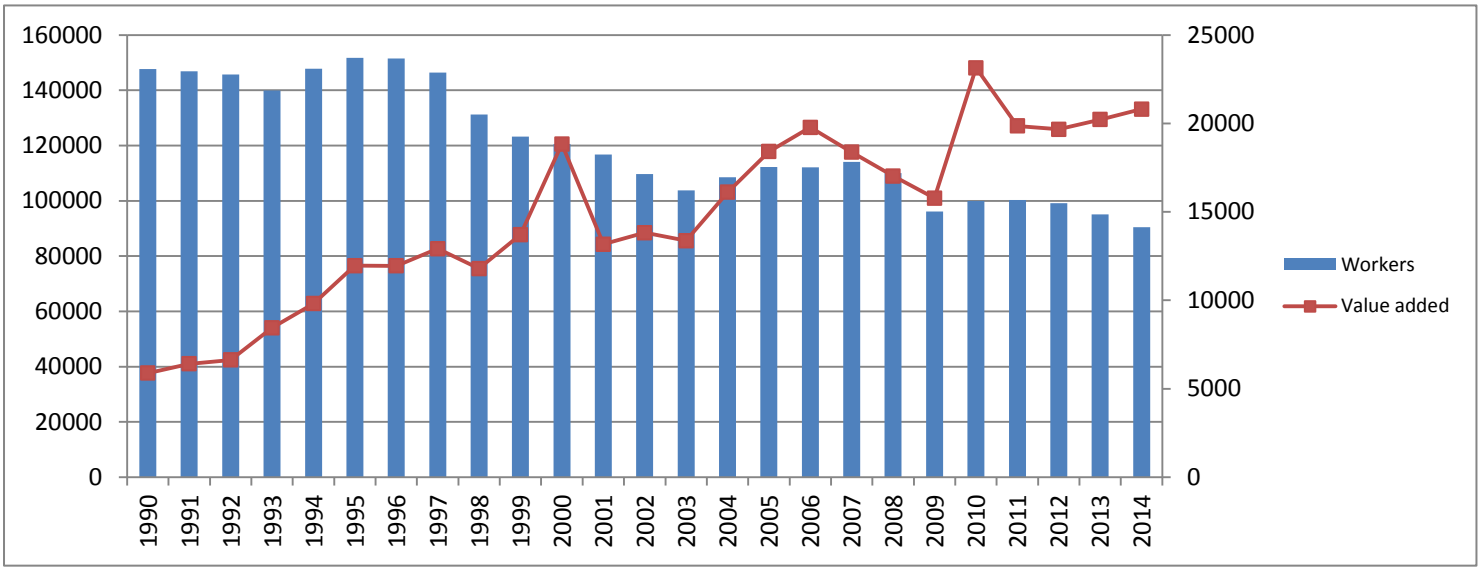
	Average annual value				
	1991/95	*1996/00*	*2001/05*	*2006/10*	*2010/14*
Output (S$m)	45,008.8	71,456.5	69,806.4	81,761.5	89,906.3
Annual growth (%)	15.6	6.9	-0.3	4.6	-2,3
Value added (S$m)	8,650.1	13,842.3	14,974.4	18,817.1	20,138.6
Annual growth (%)	15.5	10.6	1.3	6.5	-2.4
Employment	146,395	134,576	110,193	106,464	96,253
Annual growth (%)	0.6	-4.4	-1.3	-2.1	-2.5
Fixed asset investment (S$m)	-	3,617	4,483	4,629	4,691
Domestic export at end period (S$m)	59,342	74,393	75,386	65,000	56,014
Annual growth (%)	-	4.5	0.3	-3.0	-8.2
Productivity			Average annual value		
Real VA per worker (S$ 000)	58.9	104.9	136	177.5	167.8
	% share of total manufacturing				
	1991/95	*1996/00*	*2001/05*	*2006/10*	*2011/2014*
Output (S$m)	48.6	53.8	43.1	40	31.4
Value added (S$m)	39.5	44.6	37.5	34.5	32.6
Employment (000)	40.5	37.9	31	26	22.9
Fixed asset investment (S$m)	-	43.5	52.8	37.7	43.6
Domestic export at end period (S$m)	60.3	54.7	36.3	26.1	32.9

Source: SingStat, 2016

At the end of the year 2000, in terms of output and domestic exports, the industry contributed around 50% of the entire manufacturing sector (table 5.1). Between 2000 and 2014, the absolute indicators illustrate an ongoing growth, while the relative indicators indicate a decreasing share of the industry. Although the E&E industry has increase in terms of output, the share of the E&E industry as share of the manufacturing industries has decreased. Measured over the 2011-2014 period, the E&E industry share of the total output has dropped to 31.4 per cent, illustrating a strong relative decline between 1990 and 2014. According to Van Grunsven (2013) this decline has been the result of the growth of other industries that have become increasingly important in the profile of Singapore's economy (Van Grunsven, 2013).

The number of workers in the E&E industry has significantly decreased during the 1990-2014 period, from 148 thousand workers to 90 thousand workers (figure 5.4). Although the number of workers had increased slightly between 1990 and 1996, the decline in number of workers initiated in 1997. The value added of the E&E industry has increased significantly over the 1990-2014 period, from 5,888 in 1990 towards 20,807 in 2014, covering an increase of nearly 400 per cent. The productivity per worker in the E&E industry has therefore increased significantly (table 5.2). This is in line with the statement of van Grunsven (2013), that the absolute loss in employment has been the result productivity gains and the changing internal structure of the industry, in which the E&E industry has experienced upgrading (Van Grunsven, 2013). The workforce has been increasingly involved in high-tech production process. The share of skilled workers has increased to 63 per cent in 2014. The significant increased share of skilled workers in the E&E industry are the result of numerous training programmes, and reforms and investments in education that enabled companies to engage in more sophisticated and high value added activities (EDB, 2015). Also, the increase productivity per worker can be linked to the increased R&D activities in the E&E industry, especially due to the increase of private R&D activities, between 1990 and 2014 (A*STAR, 2014). Together with the wage policies, firms were forced to upgrade their worker's productivity. *BH Technologies (S) Pte Ltd*, a PCB manufacturer, argued that the productivity has compensated the increase in wages, in which the availability of engineers and skilled workers has been important (Lin Xi, personal communication, 2015).

Figure 5.3: Annual number of workers in the E&E industry and total value added, 1990-2014.



Source: SingStat, 2016.

Table 5.3: Productivity per worker in the E&E industry (x1000), 1990-2014.

	1990	**1994**	**1998**	**2002**	**2006**	**2010**	**2014**
Value added per worker	39.9	66.4	89.8	125.9	176.4	231.4	230.1

Source: SingStat, 2016.

The successful government policies have been characterised by the focus on and consistency towards the promotion of economic growth, and responsiveness toward changing business

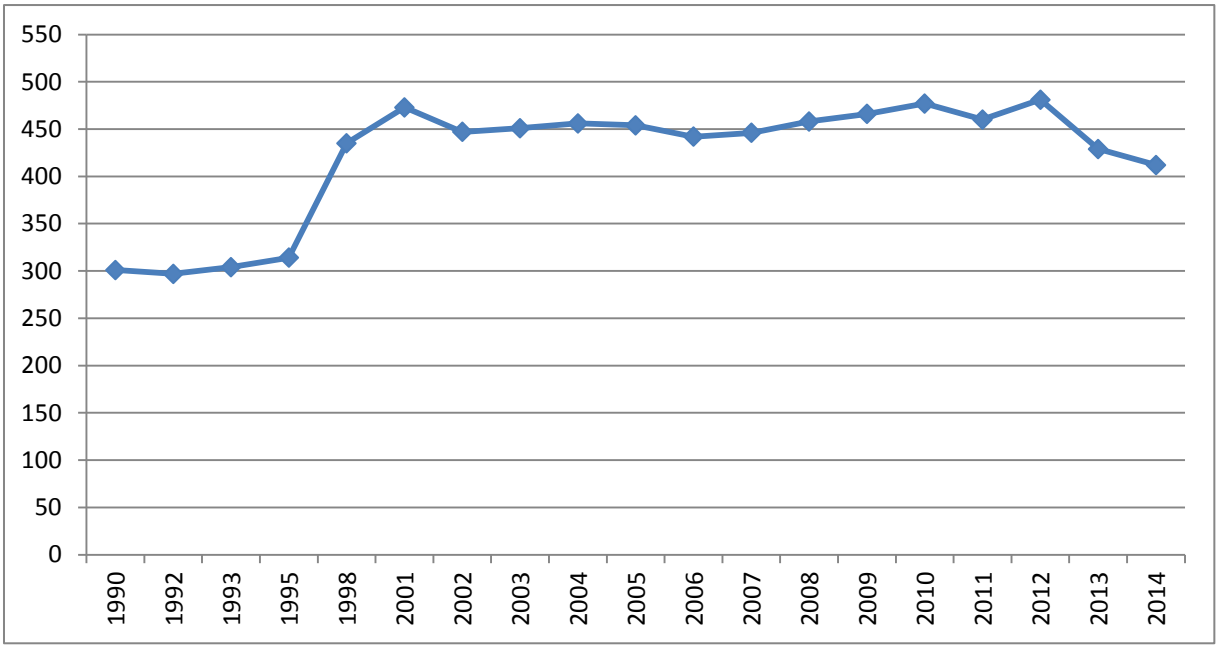
conditions. Recently, the government policies tend to transform the industry into an innovation-driven electronics hub. Where new growth paths derive from the innovative developments in technology, manufacturing and business climate (Toh, 2013). Since the development of the E&E industry embarked, Singapore has developed from a modest beginning as an assembly location into a vital node in the GPNs of MNC's. The E&E industry has been a major pillar of Singapore's economy, but its share in the total economy has decreased significantly over the years.

According to Toh (2013), it is common for small domestic markets, such as Singapore, that most goods are exported. Therefore, the export data has to be valuated from a different perspective. The export of E&E products was 26% in 2014, in comparison with 15 years ago this was 60 %. The decline of the share of E&E products in the export numbers is due to the increase of other sectors in the recent decades, like the pharmaceuticals, industrial equipment, biotechnology and life sciences. According to Toh (2013) this diversification of exports reflects the growing maturity of the economy.

5.2.1 Number of firms

Between 1990 and 2014, a total of 1198 establishments were in operation in the E&E industry. Some of the world's lead MNCs have performed economic activities in Singapore, including Philips, Siemens, Sony, Western Digital, Toshiba, Fairchild and Panasonic.

Figure 5.4: Number of E&E firm establishments in Singapore in 1990-2014.



Source: own data.

With regard to the evolution of number of firms in the E&E industry in the 1990-2014 period, the development reveals a stable initial phase (figure 5.3). From 1995 to 2001, the number of firms experienced a rapid growth, as the amount of firms increased from 314 to 472. After a small drop to 445 firms in 2002, the number of firms increased steadily - with the exception of small decreases in 2006 and 2011 – until 2011, when a peak was reached of 480 firms. However, after this small peak, the number of firms dropped to 428 in 2013, and finally to

408 in 2014 (figure 5.1) The promotion of upgrading in the E&E industry by the government and its institutions has not resulted in a decrease of firms between 1990 and 2011. In the 2011-2014 period the number of firms have gradually decreased. This decline of number of firms is possibly linked to the decreased of output, export and employment in the 2010-2014 period (table 5.1). The decline of these indicators could be the beginning of a trend, in which the share of the E&E industry in the total economy will decrease further.

Table 5.4: Development of E&E firm establishments in Singapore, 1990-2014.

Year	1991	1992	1993	1995	1998	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total firms	**301**	**297**	**304**	**314**	**435**	**473**	**447**	**451**	**456**	**454**	**442**	**446**	**458**	**466**	**477**	**460**	**481**	**429**	**412**
Annual growth(%)	N.A.	-1,3	2,4	3,3	38,5	8,7	-5,5	0,9	1,1	-0,4	-2,6	0,9	2,7	1,7	2,4	-3,6	4,6	-10,8	-4,0
Entries	N.A.	45	28	32	188	155	39	47	60	28	24	37	53	39	49	24	39	16	6
Exits	N.A.	49	21	22	67	117	65	43	55	30	36	33	41	31	38	41	18	68	23
Balance	N.A.	-4	7	10	121	38	-26	4	5	-2	-12	4	12	8	11	-17	21	-52	-17

Source: own data.

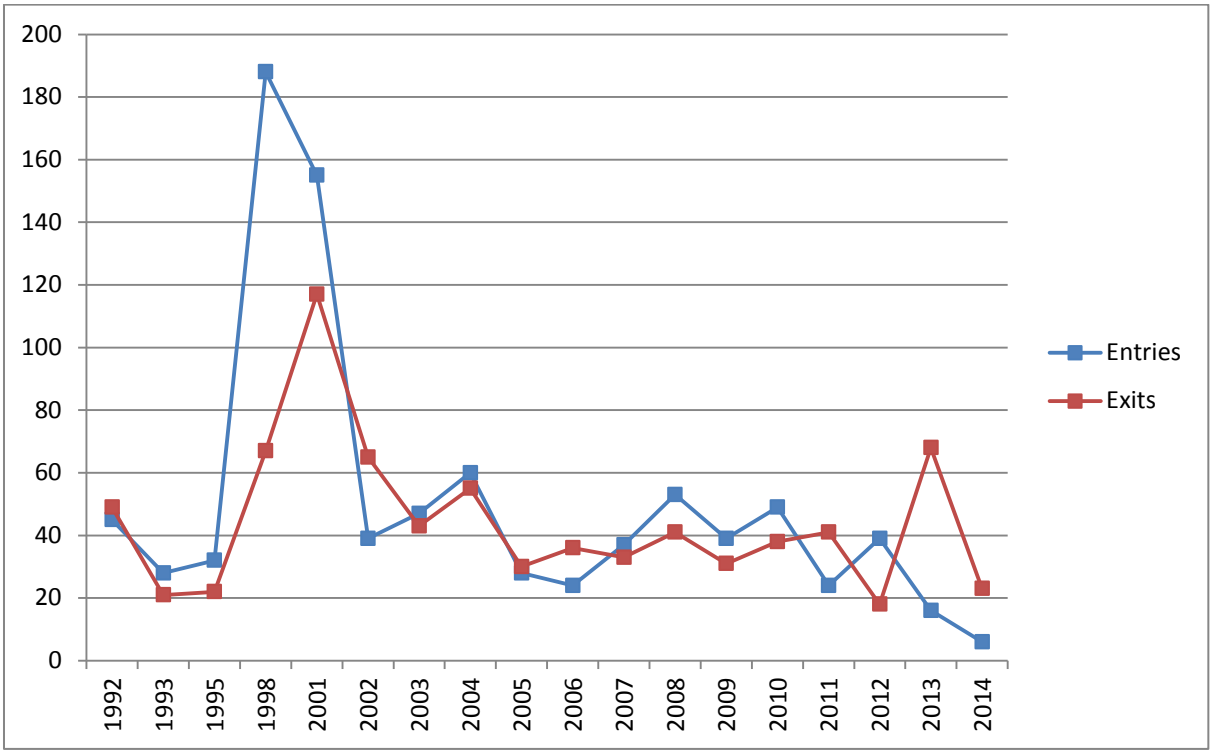
The increase in the number of firms in the 1998-2001 period might be a result of the impact of the Asian financial crisis, which struck Southeast Asia in 1997. In this period the output and value added of the E&E industry increased significantly. As mentioned earlier, the increase of this economic indicator can be linked to the AFC of 1997, that lead to the increase of export rates in Singapore (figure 5.2 & 5.3). During the crisis the American economy was booming, leading to an increased demand of E&E products from SEA. In contrast to the 1997-98 Asian crisis, the 2008-09 Global Financial Crisis (GFC) had more negative effects on the export rates as the crisis had severely affected Singapore's export markets, leading to a decrease in of the export rates (figures 5.2 and 5.3) The American economy was affected by this crisis and the US dollar devaluated, thereby crashing the export demand in Singapore (Rasiah et al., 2014). This decrease in export and the (temporally) worldwide economic crisis could have disturbed, delayed and prevented local entrepreneurs and foreign MNCs to carry out any investments. The slight increase in number of firms in the 2009-2012 period is therefore difficult to explain.

5.2.2 Entry & exit

A total of 1198 firms had a presence in Singapore at some point during the 1990-2014 period, of which 408 are currently in operation – indicating a survival rate of just above 33 per cent. Of the 301 firms that were active in 1990, 52 were still in operation in 2014. The average tenure of firms is 6.7 years. From 1990 to 2001, the level of firm entries was characterised by a high number of entries, leading to a positive balance of 121 firms in 1998 and 38 firms in 2001 (table 5.3 & figure 5.5). Here must be noted that the amount of firm entries and exits in 1998 includes all entries and exits from 1996 to 1998, and the amount of firm entries and exits in 2001 includes all entries and exits from the years 1999, 2000 and 2001. Still, if the 1998 and 2001 entry rates are divided by the number of years represented, the number of entry firms is still relatively high. As the years 1996, 1997 and 1998 would have realised an entry rate of 63 firms per year respectively. The high entry rate of firms in 1998 is possibly a result of the Asian Financial Crisis in 1997. The manufacturing costs in the city-state dropped leading to

an increase of export. The relatively high exit rates in the following years of 2001 and 2002, 117 and 65, could be linked to the high entry rates in 1998, in which the increase in number of firms increased the competition of firms in the industry. The high exit rates in the 2001- 2004 period could have been the possible result of the initiation of the fourth stage as described by Van Grunsven (2013) (table 5.1). As the government and its institutions targeted firms performing high value added and high precision products and processes, and further promoting other firms' activities in 'less sophisticated product activities' to relocate abroad.

Figure 5.5: Firm entries and exits in Singapore, 1990-2014.



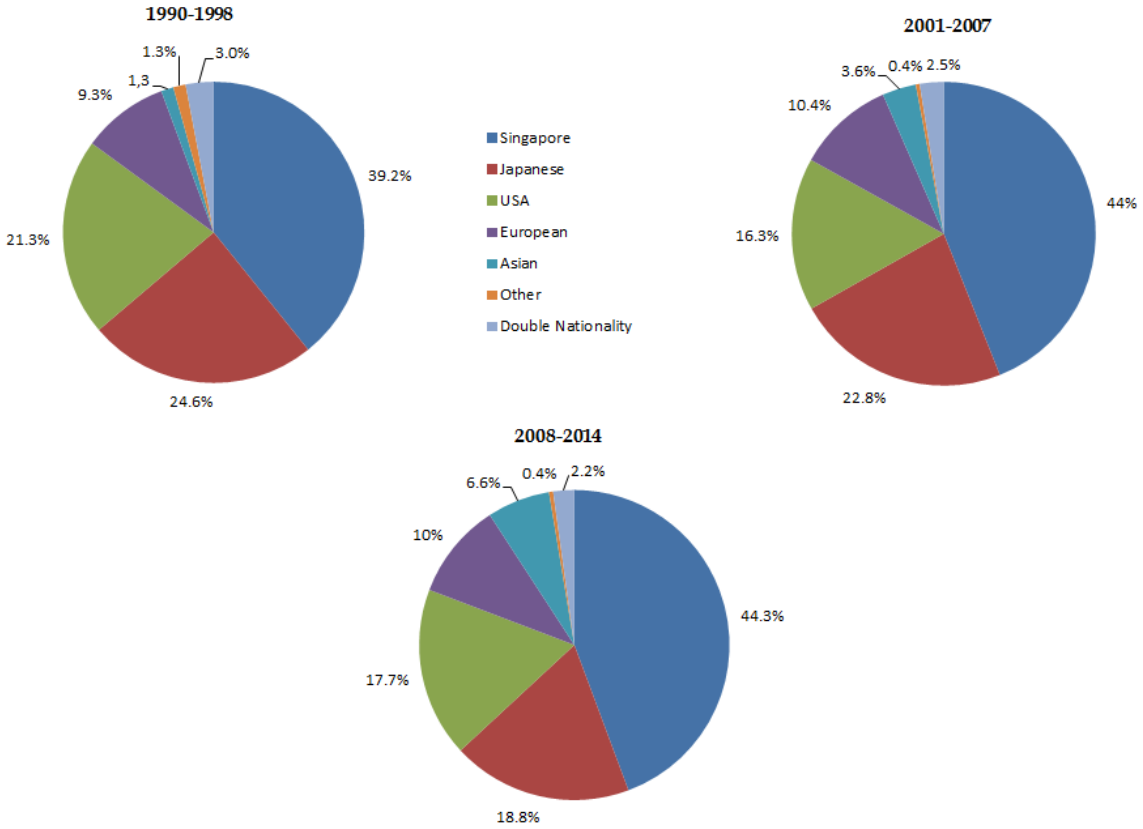
Source: own data.

The overall firm exit rates show resemblance with the entry rates, as it experienced a peak towards 2001. After 2001, the level of firm entries fluctuated, with slight increases in 2004, 2008 and 2010. The level of firm exits also fluctuated, while staying relatively small, with the notable exception of 2013, when 68 firm establishments ceased their presence in Singapore (figure 5.4). The high entry rates of firms measured in the years 1998 and 2001 is most likely due to the Asian crisis of 1997/98, as the firm exits stabilised again in the year 2002 and onwards. The year 2013 had a high number of firm exits (68), leading to a strong decline of 52 in the total number of firm establishments. Also the number of entries declined significantly in the years 2013 and 2014.. The low entry rate could have been a result of companies withholding or ceasing their investments. The high exit rate is linked to the decrease of output and share of GDP of the E&E industry since 2010. The year 2013 could be the beginning of a trend, leading a high exit rate of firm establishments in the following years.

5.2.3 Nationalities

The attraction of MNC investments active in the in the E&E industry to realise economic development in the city-state, has resulted in a large share of foreign firm. The Singaporean firms have remained to be the most dominant group of firms between 1990 and 2014, followed by the Japanese and American firms. The fourth and fifth group nationalities are the European and Asian firms (figure 5.7).

Figure 5.6: Share of nationalities of firms in the E&E industry in 1990, 2002 and 2014.



Source: own data

The Singaporean, American and Japanese firms together constitute over 75% of all firms over the years 1990, 2002 and 2014. The large share of Japanese and American subsidiaries is in line with the literature regarding the important role they have played in the development of Singapore (Huff, 1995; Hutchinson, 2014; Mathew & Cho, 2000; Rasiah et al., 2014; Wong et al., 2005). Especially, the American firms have been pioneers in the development of the city-state. Both the American and Japanese MNC have contribute significantly to the upgrading process of Singapore. The development and differences between Japanese and American MNCs will be further addressed in the following chapters.

The share of Singaporean firms increased from 40% in 1990 to 44% in 2014 respectively, on the contrary the share of American firms decreased from 21% in 1990 to 17% in 2014 and the share of Japanese firms decreased even more from 25% in 1990 to 15% in 2014 respectively. This decline in the share of foreign MNCs is possibly caused by the policies implemented by the Singapore government and its institutions to promote local firms and to reduce the dependency on foreign MNCs. The share of other nationalities presents the

composition of the origin of the remaining firms, which together contribute to around 20% of the total number of firms. The share of double nationalities firms, which are joint-venture establishments, remains around 2 per cent. The joint-ventures between MNCs reflects the role of Singapore as a global hub in the E&E industry. Even joint-venture between Japanese and American MNCs, the two main competing firm nationalities in the world, have established in Singapore. Singapore has been able to become the regional node for the two distinguish production network of Japanese and American firms. According to Boruus et al. (2000) Singapore is unique in its way that American and Japanese operate in the economy, even copying production systems and strategies form each other.

The fourth and fifth largest group are formed by the European and Asian MNCs. In 2014, the German (18), Swiss (8), France (7) and UK (5) firms were the largest nationalities of the European firms, and the Taiwan (17), Hong Kong (10) and South Korea (4) were the largest nationalities of the Asian firms.

5.3 Conclusion

In this chapter, a closer look has been given on the changes of the E&E industry on the level of the industry as a whole. A number of indicators regarding the E&E industry have been analysed, including the policy stages, number of firm establishments, output, value added, employment, exports, and entry and exits. Due to the findings presented in this chapter the following subquestion can be answered:

2. "How can the trajectory of the E&E industry in Singapore from 1990 to 2014 be characterised?"

The government's effort to increase upgrading has not resulted in a strong decrease of firm establishments between 1990 and 2014. Between 1998 and 2012, the E&E industry's trajectory in number of firms was stable. Only between the years 2012 to 2014, the number of firm exits has largely exceeded the number of firm entries, but this period is too short to identify a trend. The significant increase in number of firms in the 1998-2001 can be linked to the AFC in 1997. The booming US economy and decreasing manufacturing costs in Southeast Asia led to an significant export increase (Rasiah et al., 2014).

Between 1990 and 2014, the output and value added has increased significantly. However, this indicators have declined in the 2010-2014 period. In the recent decades, the output and value added per worker has increased, in which the number of workers in the E&E industry has decreased significantly. Over the 1990-2014 period, the share of skilled workers in the E&E industry has increased significantly. The increase wage policy implemented in the late 1980s has affected the productivity and employment development of the firms. These indicators reflect the shift towards a more sophisticated profile of the E&E industry.

Although the output and value added rates have increased, and the number of firms has shown a stable trajectory, the share of the E&E industry has relatively declined in the total economy of Singapore (Toh, 2013). Other industries, such as biosciences, life science and pharmaceutics have absolutely and relatively increased over the recent decade. The focus of the government has shifted towards these industries, as the government and its institutions

promote complex, high-tech and high value activities to enlarge the competitiveness of the economy.

The Singaporean firms formed the largest group in the composition of nationalities in the E&E industry between 1990 and 2014. The relative share of Singaporean firms has increased, possibly due to the increased focus of the government and institutions on the support and development of domestic firms. The two largest groups of foreign firm establishments are from Japan and the US. The relative share of these two nationalities has decreased over the 1990-2014 period. The following fourth and fifth nationalities groups are the European and Asian firm establishments. The share of the Asian firms in the total amount has relatively increased.

In the next chapter the shifts *within* the E&E industries are addressed, by analysing which branches have experienced growth and which branches have experienced decline, enabling to illustrate a more detailed profile of the dynamics of the E&E industry. In chapter 6 and 7, the role and evolution of foreign firms in the evolution of the E&E industry, and in some particular branches, has been addressed.

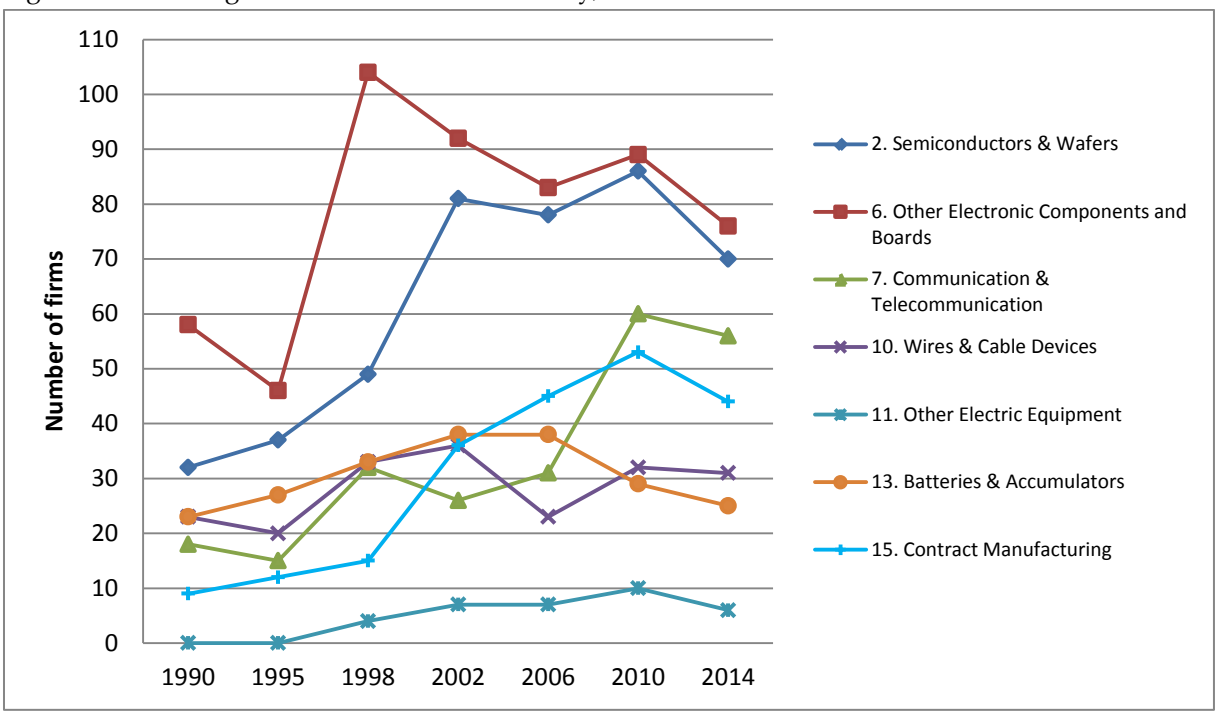
6. Evolution of branches

The previous chapter addressed the overall evolution of the E&E industry. The evolution of the E&E industry can be identified by the evolution of branches, changing the configuration of the industry. This chapter elaborates on the evolution of and within branches. The first paragraph addresses the overall evolution of branches between 1990 and 2014. The next three paragraph each zoom in on a specific branch, respectively the 'Semiconductor & Wafers', 'Hard Disk Drives & Disk Media' and 'Consumer Electronics' branches. In all three paragraph the existence of an innovation system have been analysed. The final paragraph concludes with a brief overview.

6.1 Evolution of branches

With regard to the evolution of branches in terms of number of firm establishments from 1990 to 2014, a division of three groups can be distinguished: growing branches, declining branches, and branches that remained stable in number of firm establishments (figure 6.1; figure 6.2; figure 6.3).

Figure 6.1: Growing branches in the E&E industry, 1990-2014.

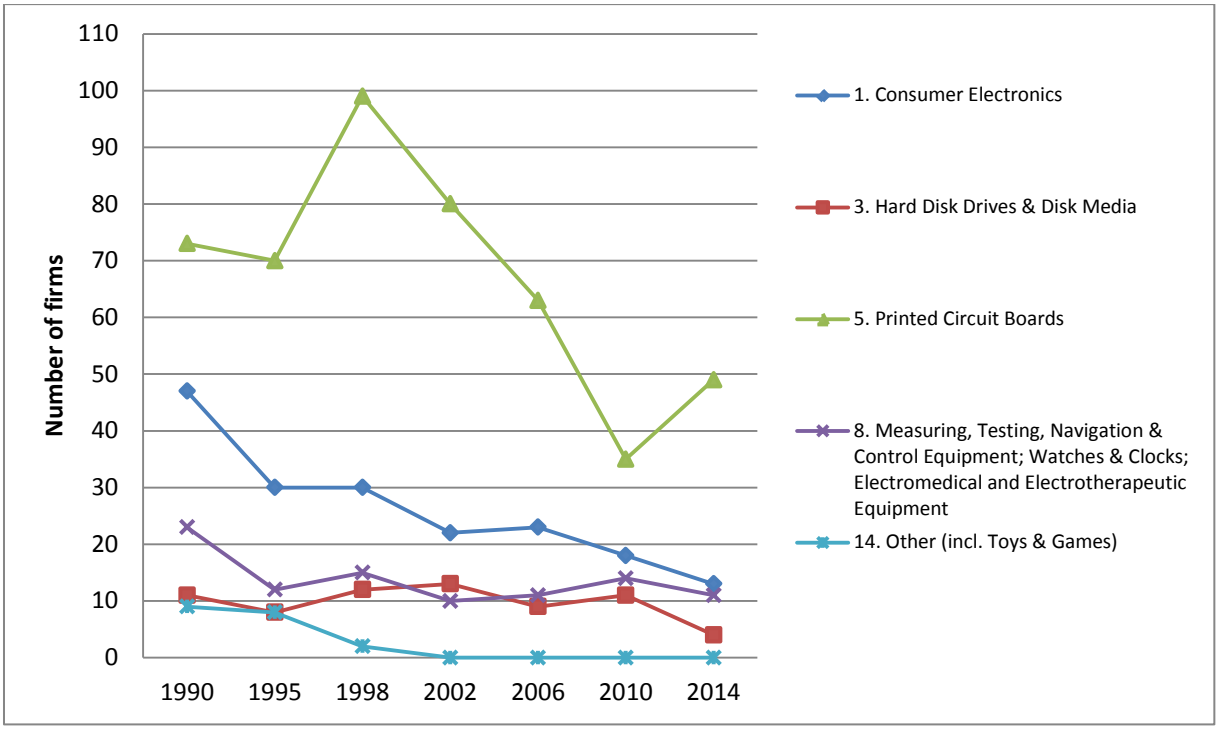


Source: own data.

Branches that experienced the largest increase in number of firm establishments (also referred to as firms) between 1990 and 2014 were the 'Semiconductor & Wafers' (semiconductor) branch (32 to 70); the 'Other Electronic Components and Boards' (components) branch (58 to 76); the 'Communication & Telecommunication' (communication) branch (18 to 56); and the 'Contract Manufacturing' (CEM) branch (9 to 44). Besides these branches, the 'Wires & Cable Devices' branch (23 to 31); 'Batteries & Accumulators' (9 to 25); and 'Other Electric Equipment' (0 to 6) experienced an increase in number of firms. The evolution of these branches present varying degrees of growth, but also similarities: all growing branches reached its maximum number of firms in 2010, with

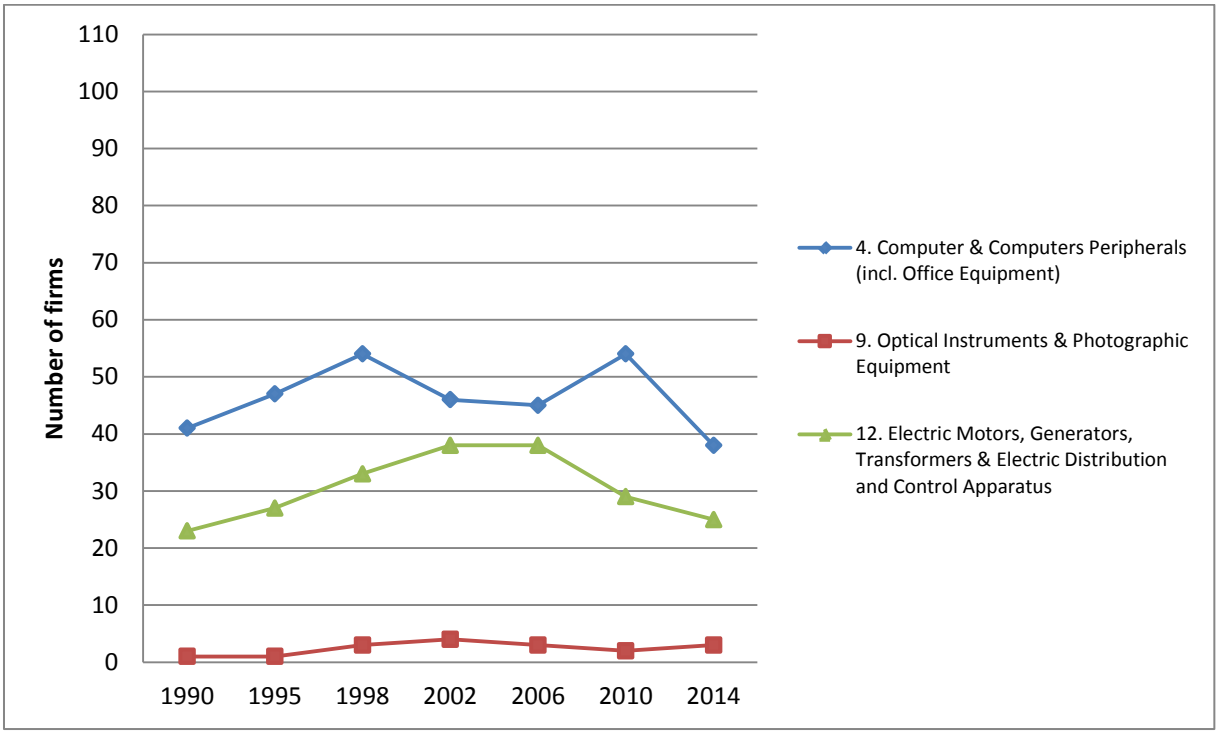
the exception of the components branch, which reached its peak in 1998, and the 'Wire & Cable Devices' branch, which reach its peak in 2002 (figure 6.1).

Figure 6.2: Declining branches in the E&E industry, 1990-2014.



Source: own data.

Figure: 6.3: Stable branches in the E&E industry, 1990-2014.



Source: own data.

The branches that experienced a decline in number of firms were the 'Consumer Electronics' branch (47 to 11); 'Measuring, Testing, Navigation & Control Equipment; Watches & Clocks; Electromedical and Electrotherapeutic Equipment (measuring) branch (23 to 11); 'Hard Disk Drives & Disk Media' (HDD) branch (11 to 4); and 'Other (incl. Toys & games)' branch (9 to 0). The 'Printed Circuit Boards' (PCB) branch initially grew from 73 in 1990 to 99 firms in 1998, but declined significantly towards 35 firms in 2010, after it increased towards 49 firm establishments in 2014 (figure 6.2). Furthermore, three branches remained somewhat constant: 'Computer & Computer Peripherals (incl. Office Equipment)' (computer) branch (41 to 38); the 'Electric Motors, Generators, Transformers & Electric Distribution and Control Apparatus' (electric motors) branch (23 to 25); and the 'Optical Instruments & Photographic Equipment' (optical instruments) branch (1 to 3). These branches had not experienced a significant change in number of firms between 1990 and 2014 (figure 6.3).

6.1.1 Share of branches

Table 6.1 illustrates the evolution of the composition of the E&E industry in share per branch over the 1990-2014 timeframe. The share of branches in number of firms correspond with the evolution of branches in number of firms. In 2014, most firms were active in the components (16.8%), semiconductor (15.9%), communication (12.4%), and PCB branch (10.8%), together accounting for over half of all the firms active in the E&E industry. The share of semiconductor firms increased from 8.2 per cent in 1990 to 15.9 per cent in 2014. Other branches that experienced a steady increase in proportions are communication (4.9% to 12.4%), batteries & accumulators (1.9% to 5.5%) and CEM (0.3% to 9.7%). The share of the HDD branch decreased from 3.3 per cent to 0.9 per cent. Besides this branch, the shares of the consumer electronics (12.6% to 2.9%) and PCB (20.0% to 10.8%) branches experienced a significant decrease.

Table 6.1: Share of branches in the E&E industry, 1990-2014.

	1990	**1995**	**1998**	**2002**	**2006**	**2010**	**2014**
1. Consumer electronics	12.6	8.4	5.9	4.3	5.2	3.7	2.9
2. Semiconductor	8.2	11.1	10.1	13.4	17.0	15.7	15.9
3. HDD	3.3	2.7	2.4	1.7	1.5	1.8	0.9
4. Computer	11.2	14.1	10.7	9.5	10.1	10.5	8.5
5. PCB	20.0	21.0	19.6	16.3	14.3	6.8	10.8
6. Components	15.9	13.8	20.6	18.7	18.8	17.3	16.8
7. Communication	4.9	4.5	6.3	5.3	7.0	11.7	12.4
8. Measuring	6.3	3.7	3.0	2.0	2.5	2.7	2.4
9. Optical instruments	0.3	0.3	0.6	0.8	0.7	0.4	0.6
10. Wires & cable devices	6.3	6.0	6.5	7.3	5.2	6.2	6.8
11. Other electric equipment	0.0	0.0	0.8	1.4	1.6	1.9	1.3
12. Electric motors	6.3	8.1	6.5	7.7	0.7	5.6	5.5
13. Batteries & accumulators	1.9	3.6	3.6	4.3	5.2	5.4	5.5
14. Other (incl. toys & games)	2.5	2.4	0.4	0.0	0.0	0.0	0.0
15. CEM	0.3	0.3	3.0	7.3	10.2	10.3	9.7
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: own data.

However, as mentioned by Martin (2010), the evolution of a branch or industry can be measured in multiple ways. Indicators such as output, value added and employment rates are useful to describe the evolution of the E&E industry and to identify the sophistication-level of branches. Even when the number of firms in a branch has entered a stable state of equilibrium, this does not automatically imply that these firms have stopped evolving. The output of the E&E industry has increased to S$82.7 billion in the year 2014. In this year, the number of workers has declined to around 90 thousand, while the value added per worker has increased (EDB, 2015). The output, value added and employment data of the semiconductor, computer, HDD, consumer electronics and components branches, which have been important branches in the E&E industry, provide better insights on the evolution of the industry between 1990 and 2014 (table 6.2 and 6.3).

The output of semiconductors and computers increased over the 1991-2014 period. However, the output and value added rates of the computer branch have decreased in the 2006-2010 and 2010-2014 period. The output of the HDD and components branches increased in the 1996-2000 period, and the output of both branches further decreased in 2001-2005 and following periods. Furthermore, the value added rates of semiconductors, computer and disk drives increased, while the value added of components decreased (table 6.2). The measured increase of output and value added rates of the consumer electronics branch after 2010, is most likely a result of the increased share of the 'Infocomm' sector in the E&E industry in the recent decade. The Infocomm sector mostly consists out of the application of ICT, but a segment of the industry also includes actual manufacturing and services (Van Grunsven, 2013). The share of the 5 branches in the total manufacturing output has declined, from 45 per cent in the 1991-1995 period to 35 per cent in the 2011-2014 period.

Table 6.2: Indicators of E&E branches, 1991-2014.

	Average annual value				
	1991/95	**1996/00**	**2001/05**	**2006/10**	**2011/14**
	Output (S$M)				
Semiconductor	6,550	14,954	23,645	42,132	46,875
Computer	5,917	11,512	12,172	10,203	7,337
HDD	10,087	18,847	16,124	11,992	5,857
Consumer electronics*	16,262	19,015	13,017	12,015	19,674
Components	2,986	3,582	3,200	2,468	1,876
	Value added (S$M)				
Semiconductor	1,436	3,552	5,740	9,227	9,959
Computer	1,305	1,685	2,468	2,282	2,222
HDD	1,458	2,938	1,836	1,706	1,835
Consumer electronics*	2,491	3,116	2,175	1,555	2,075
Components	859	1,176	1,145	777	420
Total manufacturing output	92,693	135,476	170,609	250,485	295,130
	Electronics % share of total				
	45.1	50.1	40.0	31.5	35.5

Source: Singstat, 2016. *Consumers includes Infocomm products.

Interesting are the rates of the HDD, consumers and components branches. The number of active firms in the HDD branch decreased significantly over the years, while the value added rates increased. This might imply that the remaining firms focus on technologically intensive manufacturing. The number of firms active in the components branch increased, while the output and value added remained somewhat stable. This might be due to the fact that components branch entailed basic components for E&E products and these are always only semi-finished products, which are then inserted into other products in order to produce an end-product (Toh, 2013).

Although the E&E industry experienced a significant decline in number of workers over the 1991-2014 period, the number of workers in the semiconductor branch increased significantly with 150 per cent over the 1991-2014 period (table 6.3). The overall industry, including the other four branches, experienced a decreasing numbers of workers. This reflects the shift towards technologically intensive manufacturing and therefore the decline of labour-intensive manufacturing, as the value added per worker increased significantly (Toh, 2013). The increased number of workers in the semiconductor branch is possibly linked to increased number of firms and output, as the branch output grew over 600 per cent between 1991 and 2014.

Table 6.3. Number of workers per branch, 1991-2014.

	1991/95	**1996/00**	**2001/05**	**2006/10**	**2011/14**
	Number in thousands				
Semiconductors	16,2	23,9	32,5	40,7	40,4
Computer	21,8	20,0	15,0	13,4	8,7
HDD	29,7	31,8	21,4	14,9	9,7
Consumer electronics	39,0	23,4	12,9	10,0	9,6
Components	15,5	15,2	11,3	8,7	6,9
Total manufacturing	361,5	354,1	361,1	411,7	421,0
	Branches % share of total				
	33.8	32.3	26.1	21.3	17.9

Source: Singstat, 2016

The semiconductor, HDD and consumer electronics branches have been important branches for the evolution of the industry in Singapore and are addressed in the following paragraphs in order to retrieve more insights on the evolution of these branches.

6.2 The evolution of the semiconductor branch

The previous paragraph underlined the significance of the semiconductor branch for the industry in terms of number of firms, output, value added and employment. In 2014, the branch employed 37.4 thousand workers and had a total output of S$47 billion, accounting for more than half of the E&E industry's manufacturing output (SingStat, 2014). Between 1990 and 2014, a total of 212 firm establishments were active in the branch, of which 70 are currently in operation – indicating a survival rate of 33 per cent. The number of firms gradually increased from 32 to 49 in the period from 1990 until 1998. From 1998 to 2014, the number of firms increased from 49 to 81 in 2002 and 86 in 2010, and since then decreased to 70 firms in 2014 (figure 6.1; table 6.4). Of the 32 firms that were active in this branch in 1990,

only 2 American firms were still active in 2014, namely Linear Technology and Texas Instruments Singapore. The average tenure of firms active in the semiconductor branch is 5.7 years.

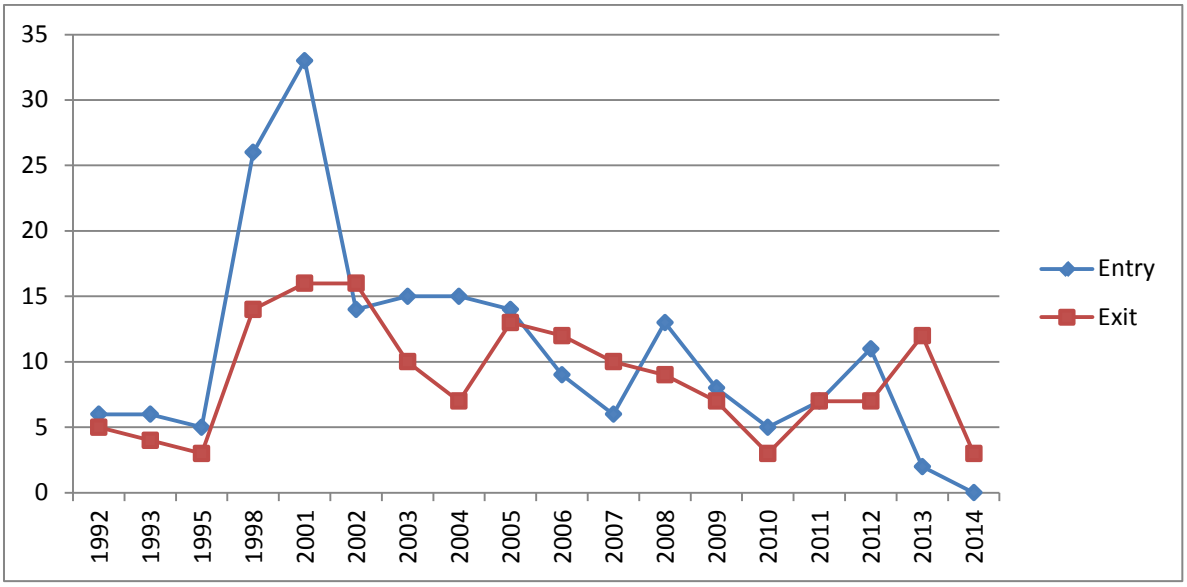
Table 6.4: Semiconductor branch development in numbers of firm establishments, 1990-2014.

Year	1990	1995	1998	2002	2006	2010	2014
Firms	32	37	49	81	78	86	70

Source: own data.

The level of firm entries until 2001 are characterised by major peaks in 1998 and 2001, when respectively 26 and 33 firms entered the branch (figure 6.4). Since 2001, the number of entries gradually decreased, with the exception of two peaks in 2008 and 2012, when respectively 13 and 11 firms entered the branch. The firm exits rates show resemblance with the entry rates, fluctuating after small peaks in 2001 and 2002. The exit rates surpassed the entry rates in 2012, resulting in the decrease of firms between 2010 and 2014 (presented in table 6.4).

Figure 6.4: Firm entries and exits in the semiconductor branch in Singapore, 1990-2014.



Source: own data.

Table 6.5 contains more detailed information regarding nationality and date of arrival of the firms in the semiconductor branch. In 1990, the vast majority of firms originated from the US, Singapore and Japan. This pattern stayed constant between 1991 and 1998. Between 2001 and 2007, the number of Singaporean firm entries increased notably. Singapore remained to outnumber the American and Japanese in the 2008-2014 period, with 18 firms entering the semiconductor branch (table 6.5). Other firm nationalities that had firm entries in the semiconductor branch in Singapore were Germany, Taiwan and the Netherlands. Countries that are known for their global lead MNCs active in the global semiconductor branch. However, in the 2008-2014 these group nationality entries were lacking in the breakdown by nationality.

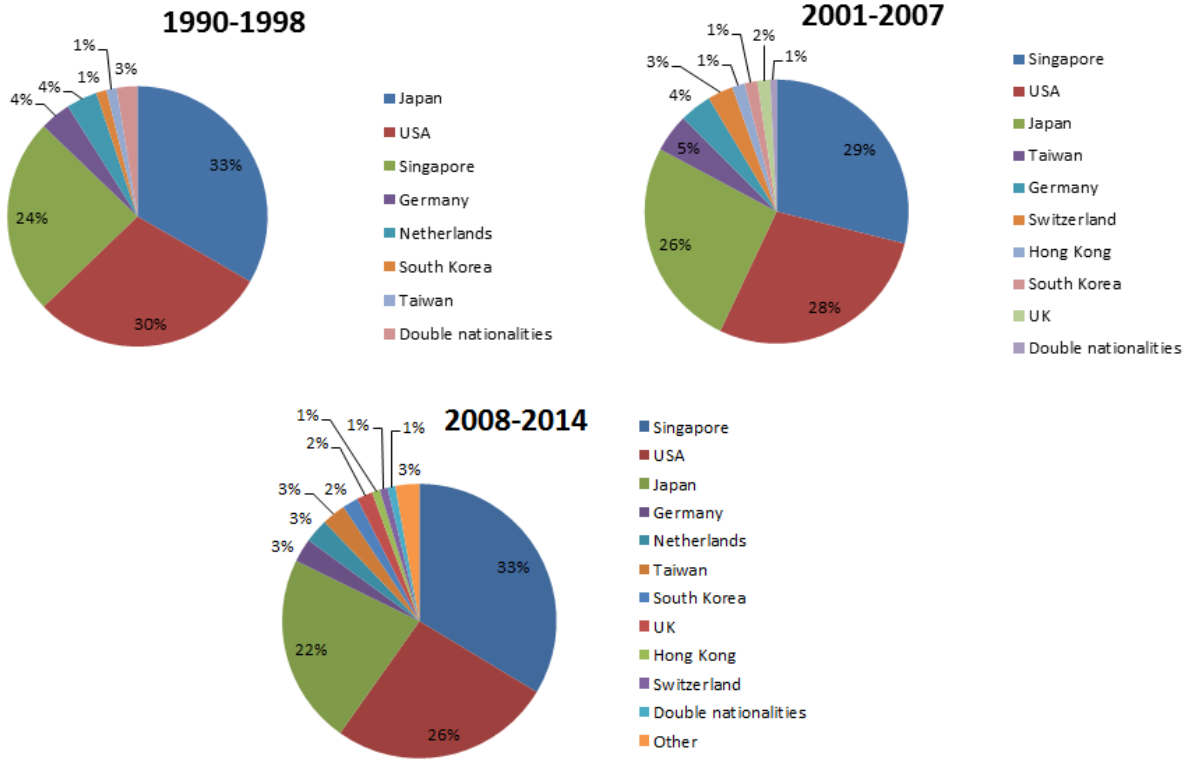
Table 6.5: Breakdown of the semiconductor branch by date of arrival and nationality.

Cohort	Total number	Main nationalities
Present in 1990	32 (15.1%)	USA (11); Singapore (10); Japan (8)
1991-1998	43 (20.3%)	Japan (14); USA (12); Singapore (9); Netherlands (3)
2001-2007	96 (45.3%)	Singapore (30); USA (25); Japan (19); Taiwan (5); Germany (3); Netherlands (3)
2008-2014	41 (19.3%)	Singapore (18); USA (11); Japan (6)
1990-2014	212	Singapore (67); USA (59); Japan (47)

Source: own data.

Between 1990 and 2014, a total of 67 Singaporean firms have been active in the branch, with an average tenure of 5.1 years. The growing amount of Singaporean firm entries reflects in the share of nationalities, which increased from 24 per cent in the 1990-1998 period to 33 per cent in the 2008-2014 period. The total of 59 American firms had an average tenure of 6.2 years, and their share decreased from 30 per cent to 26 per cent. Finally, the Japanese share decreased from 26 per cent to 22 per cent, while the total of 47 firms had an average tenure of 6.2 years (figure 6.5).

Figure 6.5: Share of nationalities in the semiconductor branch in Singapore.



Source: own data.

The large share of American and Japanese firms in the semiconductor branch has a long and influential history, since the establishment of American MNCs such as Texas Instruments, Fairchild and National Semiconductor, and later Hewlett-Packard (HP) and Motorola, initiated the development of the semiconductor branch in Singapore. Another important initiator was the French-Italian MNC SGS-Thomson, which was one of the first firms

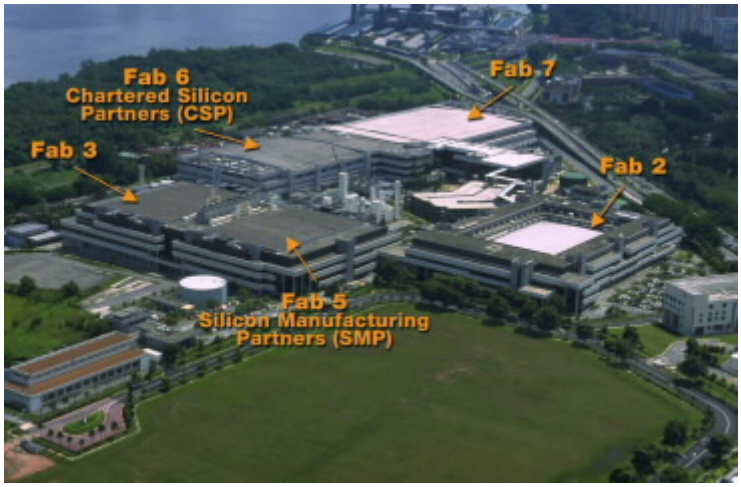
establish an assembly factory in Singapore (Mathews & Cho, 2000; Rasiah & Xiao-Shan, 2016).

The semiconductor MNCs relocated their manufacturing and assembly activities to Singapore to cut down manufacturing costs. The predominantly foreign American MNCs were looking for cheap labour locations overseas that could perform highly labour-intensive semiconductor assembly activities, and favoured Singapore over other locations in the region, because of the presence of an English-speaking population, the restrictions on foreign investments in Taiwan, and the political uncertainties in Hong Kong due to neighbour China. The Japanese MNCs followed later in the 1970s, by establishing their own chip packaging and assembly plants (Wong et al., 2005, p. 2).

During the early 1980s, the government started with active involvement in the development of the branch, as the government implemented policies that promoted the technological level of the semiconductor activities of MNCs. The upgrading of the semiconductor branch was part of the Second Economic Plan, which focused on promoting technologically intensive industries. The government offered incentives, resulting in upgrading of activities of the semiconductor MNCs such as HP, Fairchild and SGS-Thomson (Mathews & Cho, 2000; Rasiah & Xiao-Shan, 2016). The investments made by the government in human capital and a skilled workforce (incl. engineers) enabled the foreign semiconductor MNC subsidiaries to embark in high-technology activities. The capabilities of the MNC subsidiaries increased as R&D, marketing, advanced assembly, and test services activities were realised in Singapore (Rasiah & Xiao-Shan, 2016).

After the crisis of 1985, which was the result of the implemented increase wage policy, the government invested in wafer fabrication facilities to promote upgrading in the semiconductor branch, in order to increase the competitiveness of the economy (Mathews & Cho, 2000). In 1985, SGS-Thomson was the first MNC to establish a wafer fabrication facility in Singapore, illustrating that the upgrading dynamics of branch were strongly firm-driven (Rasiah & Xiao-Shan, 2016). National companies such as Standard Chartered Semiconductor, Tech-Semiconductor and Tri-Tech were established to compete in the global wafer foundry market (Toh, 2013; Wong, 2000). In 1994, the investments in the wafer fabrication parks expanded with the implementation of the Cluster Development Fund of S$1billion, which was expanded to S$2 billion by the late 1990s. By 1998, 11 advanced wafer fabrication facilities were in operation in Singapore, including SGS, SGS-Thomson, Charted Silicon Partners, Charter Fab I and Hitachi/Nippon Steel (Rasiah & Xiao-Shan, 2016). The majority of these wafer fabrication facilities were set up through joint ventures between MNCs and government institutions. In 1999, the wafer plant Systems on Silicon Manufacturing (SSMC) was established through a joint venture between Philips, the Taiwanese Semiconductor Manufacturing Company and the EDB. Another example is the joint venture between Advanced Micro Devices Inc and United Microelectronics Corp, establishing a new 300-mm wafer foundry in 2005. The EDB and JTC have been important government institutions that were strongly involved in establishment of wafer fabrication facilities, of which the latter have been strongly involved in the realisation of 5 wafer fabrication parks in Singapore (JTC, 2016).

Figure 6.6: GLOBALFOUNDRIES' wafer fabrication in Singapore.



Source: GLOBALFOUNDRIES, 2015.

Besides the investments in wafer fabrication activities and propagation from the state-owned enterprises, the government established IC design centres, R&D facilities, and technology and research institutes. For instance, the Institute of Microelectronics (IME) was founded by A*STAR (formally known as NSTB) as a research institute in 1991, undertaking core R&D, developing skilled R&D personnel and collaborating with industry partners and universities, providing training and development for future scientists and engineers. In 2014, the semiconductor branch employs around 3,500 R&D engineers in areas across the value chain, such as IC design, wafer fabrication process development, assembly, package and test development, as well as embedded software development (A*STAR, 2016; AHK, 2013; EDB, 2015; Rasiah & Xiao-Shan, 2016). IC design activities have substantially increased over the recent decades. Government institutions including IME, NUS, Nanyang Technology University, Singapore University of Technology and Design, the EDB and A*STAR actively promoted IC design activities in the city-state. The VIRTUS (Singapore's design centre of excellence) was established to increase the number of IC engineers in the city-sate. In 2010, over 1,100 IC designer were active in Singapore. Successful Singapore-based firms that have set up IC design activities in Singapore are Broadcom, Freesystems, Infineon Technologies, Lantiq, MediaTek and STMicroelectronics (EDB, 2010). In the case of Infineon Tehcnologies, Singapore has become a crucial R&D hub in the GPN, employing 400 R&D engineers of whom 200 were IC designers. MediaTek is Asia's largest fabless IC design company, in which Singapore has become one of its important locations, developing high-tech products such as system-on-a-chip (SOS), high definition DTVs and optical storage (Van Grunsven, 2013). The large group of IC designers in Singapore, of which a large share substantial skilled designers in the analogue, mixed-signal and RF IC, gave Singapore-based firms a competitive advantages (EDB, 2010).

In 2016, Singapore was home to the world's top 3 wafer foundries, and counts fourteen silicon IC wafer fabrication plants. Singapore hosts 9 of the world 15 fabless semiconductor companies, 28 IC design centres, as well as 15 semiconductor assembly and test operations, including 5 of the world's top outsourced assembly and test service companies. In terms of wafer production capacity, this segment competes with countries like Japan, South Korea, Taiwan, US and newcomer China. The wafer fabrication parks in

Singapore facilitate companies which in 2016 collectively produced approximately one million wafers per month, accounting for 6% of the world's wafer production (EDB, 2016).

In order to further stimulate collaborations between semiconductor firms and public research institutes, A*STAR and IME established the 'Singapore Semiconductor Vision 2020 Taskforce' in 2015. This taskforce is spearheaded by the local semiconductor association Singapore Semiconductor Industry Association (SSIA) and the global semiconductor association SEMI, and collaborates with firms as Applied Materials, GLOBALFOUNDRIES, Micron, SSMC and STATS ChipPAC. The taskforce attempts to even further boost the position of Singapore as a global semiconductor manufacturing hub through focussing on innovation, R&D, and talent (Channel NewsAsia, 2015).

6.3 The evolution of the HDD branch

The output and value added rates of the 'Hard Disk Drives & Disk Media branch' (HDD branch) underline its significance for the industry in the 1991-2014 period (table 6.2). Between 1990 and 2014, a total of 37 firm establishments were active in the HDD branch, of which only 4 firms are currently in operation (HGST, Showa Denko, Seagate Technology International and Western Digital) – indicating a survival rate of slightly above 10 per cent. The number of firms remained somewhat stable throughout the 1990-2010 period, but significantly decreased towards 4 firms in 2014 (figure 6.2; table 6.6) Of the 11 firms that were active in this branch in 1990, only 2 are still active in 2014: Seagate and Western Digital. The average tenure of firms active in this branch is 4.7 years.

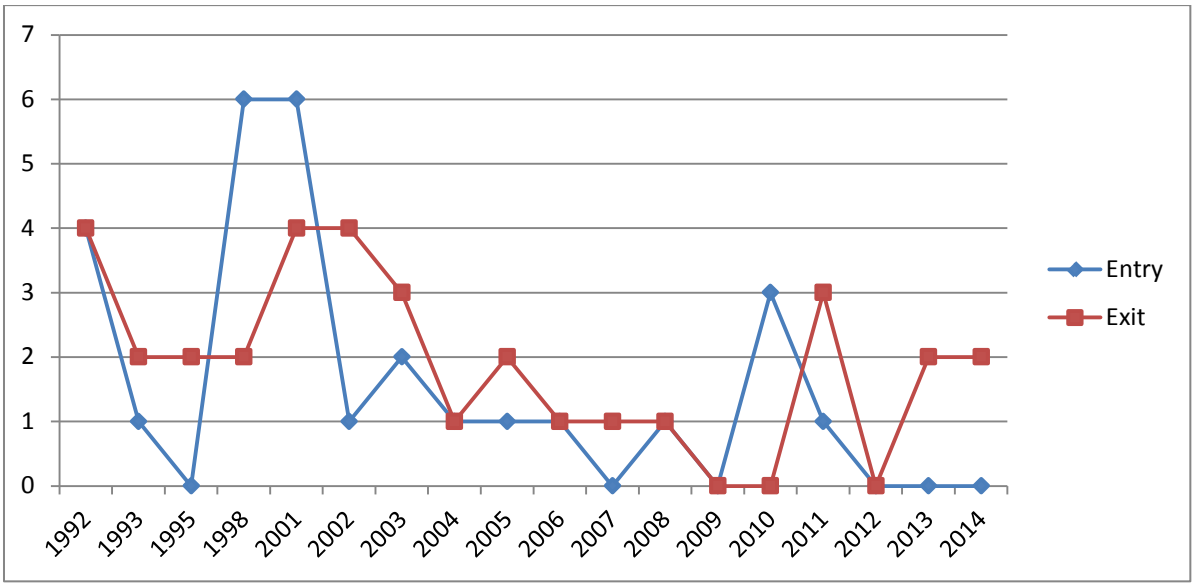
Table 6.6: Number of firm establishments in the disk media branch in 1990-2014.

Year	**1990**	**1995**	**1998**	**2002**	**2006**	**2010**	**2014**
Firms	11	8	12	13	9	11	4

Source: own data.

With regard to the entry and exits in the HDD branch, the level of firm entries experienced an initial small growth in 1998 and 2001, as the number of firm entries exceeded the number of firm exits (figure 6.7). Since 2002, the firms exits have exceeded the firm entries, with an exception in 2010 that experienced 3 firm entries. The high exit rates of firm establishments have logically resulted in a declined number of firm establishments in the HDD branch (table 6.6).

Figure 6.7: Firm entries and exits in the disk media branch in Singapore, 1990-2014.



Source: own data.

Over the 1990-2014 period the majority of the HDD firm establishments in Singapore were of American origin (table 6.7 & 6.8), reflecting the dominant role of the American firms since the emergence of the branch in the 1970s (Van Grunsven, 2013). Since the establishment of the first HDD facility by Seagate in 1982, other small American MNCs made the same move and transformed into large successful firms. By 1990, Singapore was a major hub and the world's largest producer of hard disk drives. While the American firms adopted similar organisational characteristics and focussed on Singapore, the Japanese firms active in the HDD industry maintained to produce in Japan until 1995 (Borrus et al., 2000; McKendrick et al., 2000).

In 1990, 10 out of the 11 firms active in the branch were of American origin, illustrating the dominance since the branch emerged in Singapore. The Japanese and Singaporean firms both accounted for 13.6 per cent of all active firm establishments in the branch between 1990 and 2014. The number of Japanese and Singaporean firm entries increased in the 1991-1998 and 2001-2007 periods, while the American firm entries decreased. Eventually, in the 2008-2014 period, the number of Singaporean and Japanese firm entries outnumbered the American, which was non-existent in that period (table 6.7). Logically, the high entry of Japanese and Singaporean firm establishments compared to American firm establishments increased their share of nationalities in the periods of 2001-2007 and 2008-2014 (table 6.8). Of the 4 firm establishments in 2014, 3 were of American origin.

Table 6.7: Breakdown of the disk media branch in Singapore by date of arrival and nationality.

Cohort	**Total number**	**Main nationalities**
Present in 1990	11 (29.7%)	USA (10); UK (1)
1991-1998	11 (29.7%)	USA (4); Japan (3); Singapore (3)
2001-2007	11 (29.7%)	Singapore (4); Japan (3); USA (3)
2008-2014	4 (10.9%)	USA (3); Japan (1)
1990-2014	37	USA (17); Singapore (10); Japan (7)

Source: own data.

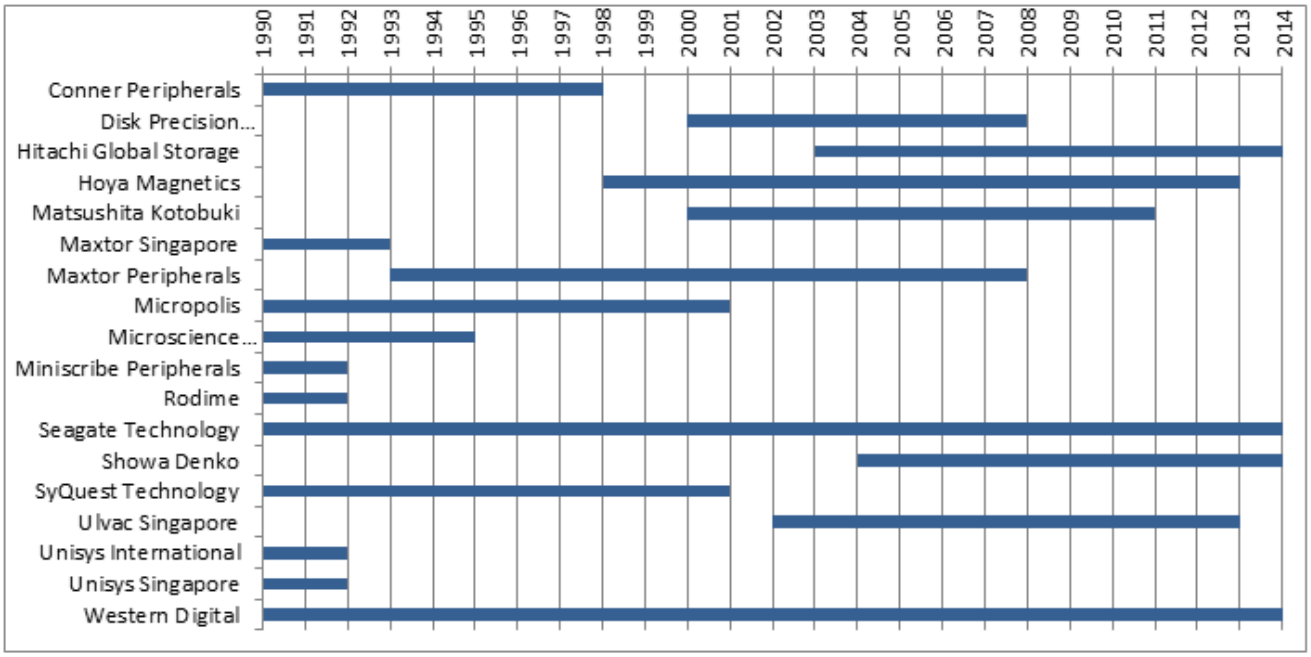
Table 6.8: Share of nationalities of the disk media branch in Singapore.

Cohort	Total number	Nationalities
1990-1998	22	USA (63.6%); Japan (13.6%); Singapore (13.6%); Taiwan (4.6%); UK (4.6%)
2001-2007	23	USA (43.5%); Japan (26.1%); Singapore (26.1%); Hong Kong (4.3%)
2008-2014	11	Japan (36.4%); Singapore (36.4%); USA (27.2%)

Source: own data.

The average tenure of American and Japanese firm establishments is significantly higher than the average tenure of Singaporean firm establishments between 1990 and 2014. The 17 American firms had an average tenure of 6.1 years and the 7 Japanese firms an average tenure of 7.3 years. The average tenure of the 10 Singaporean firm establishments was significantly shorter, with only 2.3 years. The reasons for the low average tenure of Singaporean firm establishments is caused by the acquisition of other firms active in the HDD branch, bankruptcy and firms leaving the branch as a result of transformation in product portfolios (figure 6.8). In 1990, 11 firms were active in the branch, of which 3 (Microscience International, Rodime and SyQuest Technology) ceased their operations before 2001, 4 (Conner Peripherals, Maxtor Singapore, Micropolis and Miniscribe Peripherals) got acquired by other active firms in the branch, and 2 (Unisys International and Unisys Singapore) exited the branch. In 2014, only 4 firms are still active in the branch, to be precise the American firms Hitachi Global Storage Technologies, Seagate Technology and Western Digital; and Showa Denko from Japan. The HDD branch in Singapore is therefore dominated by a small group of large globally operating foreign MNCs and smaller local firms with a bigger circulation rate.

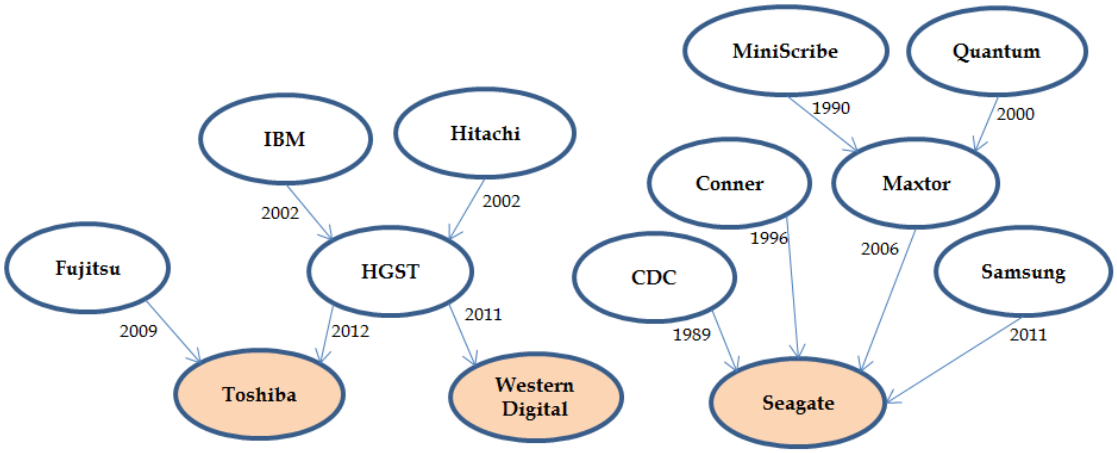
Figure 6.8: Lifespans of important firms in the disk media branch in Singapore.



Source: own data.

In order to better understand the dynamics, position and network of the 4 firms in Singapore, the most important acquisitions in the global HDD branch are presented (figure 6.3). The global HDD branch has a long history of acquisitions and defunct firms, and has been dominated by a small number of (Singapore-based) American and Japanese MNCs. In East Asia, Japanese and American MNCs have contested over the dominance in the HDD branch. In 2014, the manufacturers in the HDD branch have decreased from once 200 globally active firms to only 3 global lead firms: Toshiba, Seagate and Western Digital, of which the latter two are based in Singapore. Show Denko has become one of the largest independent media developer and supplier (Van Grunsven, 2013). HGST has been acquired by Western Digital in 2012, in which the Singaporean-based establishment is now active as a wholly owned subsidiary of Western Digital (figure 6.9). Before the firm was acquired, HGST itself was the result of a merger between IBM (USA) and Hitachi (Japan), and had its operation HQ in San Jose. The American firms Seagate and Western Digital grew by the acquisition of mostly smaller firms, that had developed innovative products and processes (framework 6.1). The acquisition of these smaller firms was the strategy of the two American MNCs to compete with the Japanese market leaders, with a large degree of success (Cooke, 2013).

Figure 6.9: Main acquisition in the HDD branch from 1989 to 2014 worldwide.



Source: adapted from StorageNewsletter, 2013.

Although the share of the branch in number of firms declined, the value added rates remained stable and even increased in the 2010-2014 period. Between 1996 and 2014 the output of the branch declined (figure 6.2; table 6.2). These indicators are most likely linked to the shift of product types between 1990 and 2014. In 1990, the 11 firm establishments active in the HDD branch were involved in the manufacturing of Winchester disk drives. In 2014, the 4 firm establishments active in the HDD branch manufactured disk media products, illustrating the shift towards higher value added and technologically intensified manufacturing. Hence, the technologies to storage data in the city-sate have evolved substantially. The density of data storage increased significantly, introducing psychically smaller products (Van Grunsven, 2013). During the 1990s, firms in the HDD branch started relocating hard disk drive manufacturing activities towards more labour-competitive regions. For example, Seagate and Western Digital have established a number of

manufacturing plants in countries such as China, Malaysia and Thailand. As the firm operations in Singapore shifted focus to the development of disk media products. This shift has caused the number of workers in the industry to drop significantly over the last two decennia (Van Grunsven, 2013). In recent years, the city-state accounts for 40 per cent of disk media manufacturing worldwide (EDB, 2016). Almost half of the world's data is stored on disk media made out of these tiny parts manufactured in Singapore (EDB, 2014).

Government institutions, particularly A*STAR and the EDB, have been actively involved in the attraction and development of the HDD branch. The education and training programmes, skilled workers and the attraction of foreign talent were important local advantages for the upgrading of HDD firms (Cooke, 2013). The relocation of the manufacturing activities of Wester Digital to Singapore in 2010, after an absence of ten year, by acquiring Hoya Magnetics, illustrates the attractive position of Singapore (Cooke, 2013; Van Grunsven, 2013).

Besides investing in the local environment, the foreign MNCs collaborated with a variety of institutions, mostly focused on training programmes for engineers and increasing R&D activities. In 2013, Seagate opened up a R&D facility, in collaboration with A*STAR and the EDB, worth S$100m. The chairman of the EDB described Seagate as 'a valued partner of Singapore for more than 30 years'. Since its establishment in Singapore in 1982, the firm claims that the government institutions have been important factors in the success of the company (Seagate, 2015). Western Digital had established a R&D centre in Singapore in 2011, in which the expertise of A*STAR and the local universities in the development of advanced hard drive technologies were seen as important local advantages. Western Digital announced a partnership with the Data Storage Institute (DSI), established by A*STAR, in 2012 to collaborate on the development of 'advanced head, media and hard drive system design' (Cooke et al., 2013, p. 1805). Both Seagate and Western Digital have mentioned the local talent pool of engineers and skilled workers as crucial assets of the Singaporeans environment to upgrade their activities (Cooke et al, 2013; Seagate, 2015; WD, 2011). The COO of Western Digital, Tim Leyden, describe Singapore as "*a wealth of engineering talent…this is a product of a supportive government, R&D resources from DSI and universities, and a long history of hard drive industry manufacturing and engineering operations in the country. The resulting environment has produced an advanced technology research and human resource culture that makes Singapore an ideal location for WD investments*." (WD, 2011). The firms have also been actively involved in the improvement of the local labour force. For instance, in 2014 Seagate started a collaboration with the NUS and Nanyang Technological University. The announced S$100m bursary programme aimed at growing the pool of graduates with 'science, technology, engineering and math skills'.

According to Cooke (2013) the relocation of the headquarters and R&D center towards Singapore, in combination with the support and collaboration of government institutions, have been main factors in the leading position Seagate and Western Digital have in the HDD branch today. Especially in the recent decade, as the technology to data storage evolved substantially, the contribution of Singaporean institutions, R&D centers and engineers have been crucial. As the amount of digital content made per year by individuals, as well as companies, has been increasing, the demand for mass storage data will continue to drive demand for products such as hard disk drives and disk media. Although just a number

of firms have remained in the industry, the product evolution in the branch is most likely to continue for the next couple of decades (Forbes, 2011).

Framework 6.1: Seagate.

Seagate Technology International **established: 1982**

In 2014 Seagate was one of the largest companies of Singapore employing 7 thousand employees (Seagate, 2015). The company was founded in 1979 in California. In 1982 the first manufacturing activities were relocated to Singapore, as the company was in search of lowering labour costs (Cooke, 2013). The first R&D centre would soon follow and was set up in 1984 (Seagate, 2015). Soon other manufacturing facilities in SEA followed, with Bangkok as second most important location in the region. As the Japanese Yen raised in value enabled Seagate to undercut the prices of its main Japanese competitors (Fujitsu, Hitachi, NEC and Toshiba). Seagate had grown through acquisition: Imprimis was acquired in 1989; DEC storage's division in 1994; followed by Conner Peripherals and Maxtor in 2006. In total 11 smaller firms were acquired in the 1989-2014 period. The most significant acquisition was Samsung in 2011, as Samsung and Seagate combined their HDD branch activities, which lead to Seagate becoming market leader. Western Digital had followed in the footsteps of Seagate, and had been able to catch up to Seagate in 2009. In 2014, Seagate competed with Toshiba and Western Digital for global domination (Cooke, 2013).

6.4 The evolution of the consumer electronics branch

The first paragraph illustrated the share of the consumer electronics branch in the E&E industry has diminished. The output and value added rates declined in the 2000-2010 period, the increase of the indicators in the 2010-2014 is mostly likely due to the Infocomm sector (6.1.1). The number of workers in the consumer electronics branch declined significantly, from 39 thousand in 1990 to less than 10 thousand in 2014 (table 6.2; table 6.3). Between 1990 and 2014, a total of 97 firms were active in the branch, of which 13 are currently in operation – indicating a survival rate of 13 per cent. The number of firms declined gradually from 46 firms in 1990 to 21 firms in 2002 and, after a stable period until 2006, declined further down to 13 firms in 2014 (table 6.9). Of the 46 firms that have been active in this branch in 1990, only 2 were still active in 2014: the Japanese firms JVC Electronics and Toshiba Singapore. The average tenure of firms active in the consumer electronics branch is 4.7 years.

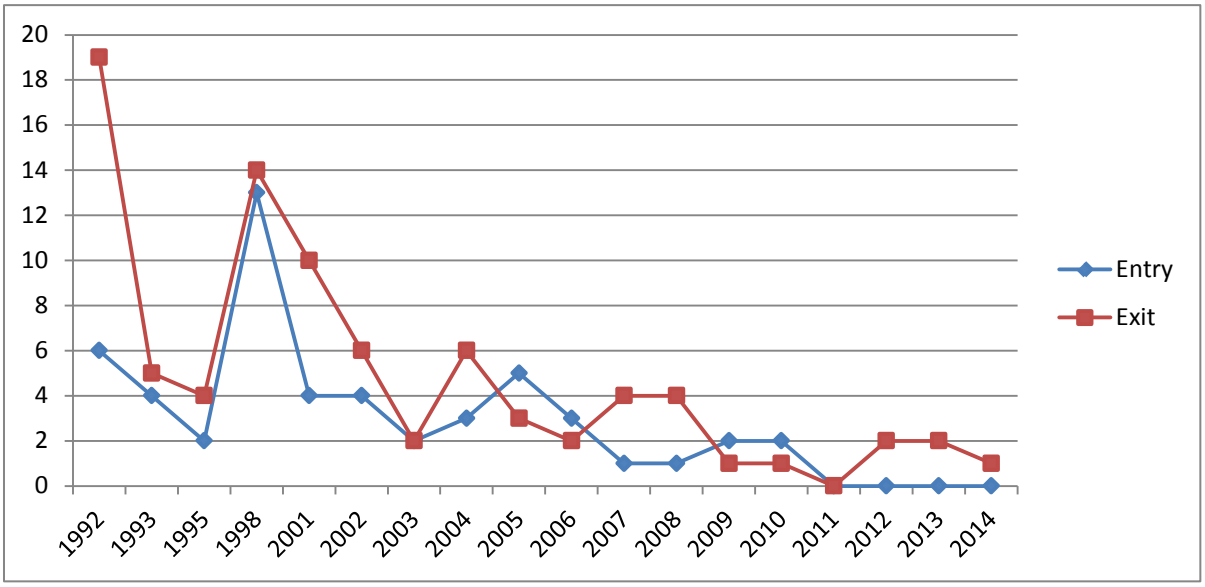
Table 6.9: Consumer electronics branch development in number of firm establishments 1990-2014.

Year	1990	1995	1998	2002	2006	2010	2014
Firms	46	28	30	21	23	19	13

Source: own data.

The decreasing number of firms is reflected in the level of firm entries and exits, which is characterised by a huge amount of firm exits (figure 6.10). Especially in 1992 and 1998, the level of firm exits was high, when respectively 19 and 14 firms exited the branch. After 1998, the amount of firm exits decreased. The level of firm entries stayed relatively small, with the exception of 1998, when 13 firms entered the branch. The absence of firm entries in the 2011-2014 period indicated that the branch is likely to decline further in the subsequent years.

Figure 6.10: Firm entries and exits in the consumer electronics branch in Singapore, 1990-2014.



Source: own data.

The increase wage policy of the government in the late 1980s has had a strong impact on the survival of the consumer electronic branch, which severely affected the competitiveness of E&E consumer product manufacturers. The (low sophisticated) manufacturing of consumer product(groups) in the early 1990s such as microphones, car tuners, radios, speakers, TV tubes, cooling fans and remote controls had all left Singapore in 2014. High value added activities, such as RHQs, S&M and R&D centres, and some high-tech manufacturing activities had reamed in 2014. This trend has been further elaborated on in the next chapter.

NVEC Video Engineering Pte. Ltd. Company is one of the few remaining (local) firms in the consumer branch. The CEO mr. SU emphasised that the increased wage policies have had a severe impact on the competitiveness of his firm. A lot of companies have relocated their manufacturing activities towards China and Thailand, because the domestic labour stock was too small and the wages were too high in Singapore. Over the recent decades, the firm has narrowed down his product portfolio, and decreasing the production volume. Mr. Su shared his concerns regarding the survival of his firm in Singapore as a result of the high wages level that have become too expensive for (video) manufacturing activities. The only reason he has not yet relocated his company to Malaysia was that he could not find a suitable factory (J.C. Su, personal communication, 2015).

Table 6.10: Breakdown of the consumer electronics branch by date of arrival and nationality.

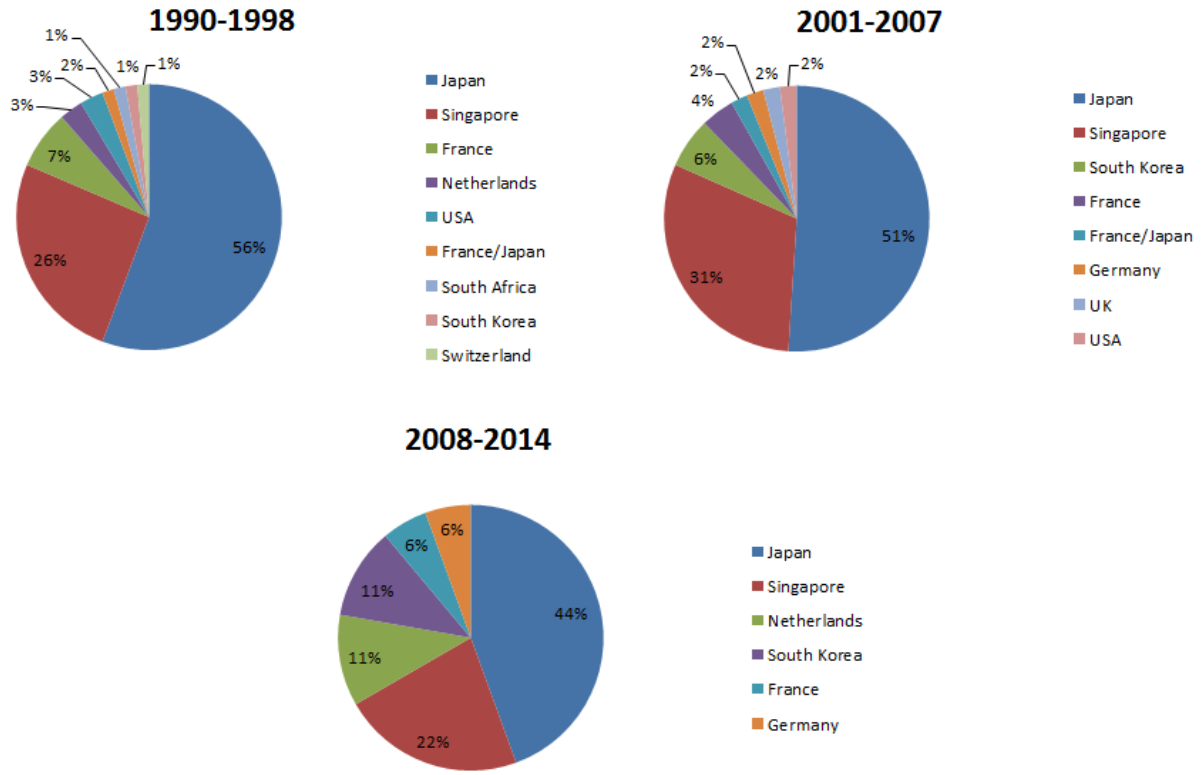
Cohort	**Total number**	**Main nationalities**
Present in 1990	47 (50.0%)	Japan (30); Singapore (10); France (2); USA (2)
1991-1998	23 (24.5%)	Japan (10); Singapore (8); France (3)
2001-2007	20 (21.3%)	Singapore (8); Japan (6); South Korea (2)
2008-2014	4 (4.2%)	Japan (2); Netherlands (1); Singapore (1)
1990-2014	94	Japan (47); Singapore (27); France (7)

Source: own data.

The breakdown of the consumer electronics branch by date of arrival and nationalities presents that majority of firms in 1990 was of Japanese origin. The investment patterns of Japanese firms in the consumer electronics branch gradually decreased after 1990. The entries of Singaporean firms increased in the 1991-1998 period and surpassed the entry level of Japanese firms between 2001 and 2007 (table 6.10). The firm entry nationalities were of France, American, Korean and Dutch origin.

The share of nationalities in the consumer electronics branch presents that the Japanese firms have been the largest group, dominating the branch between 1990 and 2014. The total of 47 Japanese firms had an average tenure of 5.7 years. The share of Singaporean firms increased from 26 per cent in 1990-1998, to 31 per cent in 2001-2007 and eventually decreased to 22 per cent in 2008-2014. The 27 firms of Singaporean origin had an average tenure of only 2.7 years (figure 6.11).

Figure 6.11: Share of nationalities in the consumer electronics branch in Singapore.



Source: own data.

The consumer branch emerge as a result of the predominantly Japanese subsidiaries that shifted their manufacturing activates towards Singapore in the 1970s to late 1980s. The Japanese MNCs, such as Hitachi, JVC, Sony, Panasonic and Toshiba, which al have (had) manufacturing subsidiaries in Singapore, dominated the global consumer electronics product sector for decades. Most of the Japanese MNCs have relocated their (labour-intensive) manufacturing and assembly to more labour-competitive region SEA, such as Indonesia, Thailand and Vietnam. In chapter 7 the dynamics and transformation of Japanese MNC subsidiary establishments in Singapore, in terms of product manufacturing and activities, has been addressed.

6.5 Conclusion

Due to the analysis of the evolution of branches in the E&E industry, and the evolution of the semiconductor, HDD and consumer electronics branches, the fourth subquestion can be answered.

4. "Are there differences between evolutionary trajectories of branches, and which factors explain these differences?"

The evolution of branches can be broken down in three main trajectories: growing, declining and stable branches. In order to answer which factors explain these difference, this thesis zoomed in on the evolution of the semiconductor, HDD and consumer electronics. The government institutions, as shapers of the regional environments, have played an important role in the development of all three branches.

The literature described that the presence of an innovation system surrounding a branch has a strong influence on the evolution of this particular branch. The semiconductor branch strongly indicated the presence of a LIS, as a network of innovative firms, a set of supporting research and educational institutions, a series of infrastructure provisions (such as incentives), and the presence of cooperation mechanisms among all actors have been identified. The indicators of a LIS in the HDD branch have been identified to a lesser extent, mostly because a network of innovative firms and cooperation mechanism was partly lacking. In the consumer electronics industry, the presence of a LIS was predominantly absent, in which this branch has clearly lost the focus of the government institutions and universities between 1990 and 2014, leading to a decline in number of firms. The complete 'disappearance' of the branch in Singapore is a realistic possibility in the future.

Characteristic for emerging countries is that the LIS is firm-driven, this has also been the case in the evolution of the semiconductor and HDD branches. Firms, especially MNCs, remain the main leaders in the innovation process of the semiconductor and HDD branches (Van Grunsven, 2013). Although firm-driven, the government institutions have put a relentless effort in transforming the local environment in order to 'fit' the strategic need of MNCs, which led to the emergence of products and upgrading in the semiconductor and HHD branches. The strategic coupling process is dynamic, as the government institutions wanted to realise high value manufacturing activities and the MNCs globally disperse their activities to different regions with the unique characteristics that best 'fitted' their demands.

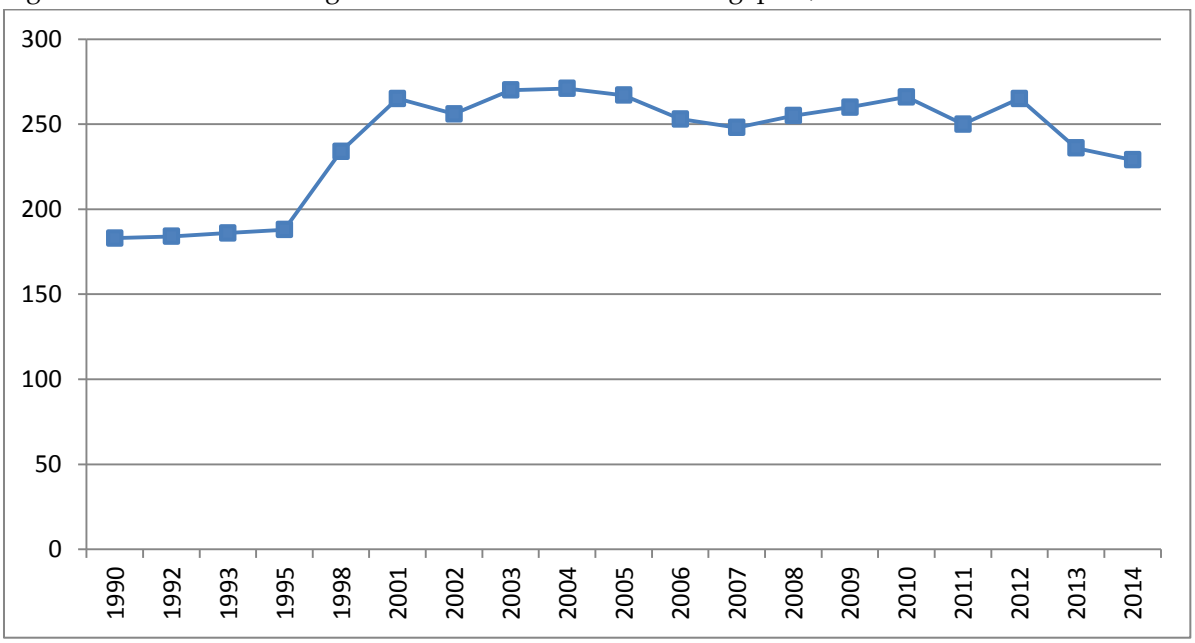
7. Evolution of foreign firms

Chapter 5 indicated that a large amount of foreign MNC subsidiary in the E&E industry were established in Singapore between 1990 and 2010. The Singaporean government have focussed on attracting MNCs to integrate Singapore in the redistribution of their production network. This chapter elaborates on the development of foreign MNCs in the Singaporean E&E industry, and the changing position of Singapore in GPNs; and consists of three paragraphs. The first paragraph will provide a background on the initial development of foreign MNCs in the E&E industry. The following paragraphs mainly focuses on the influence and evolution of American, Japanese European and Asian subsidiaries. The breakdown of economic activities of foreign MNCs in Singapore is addressed in the last paragraph. Throughout this chapter the development of MNC subsidiaries and the shifting position of Singapore in their GPNs are addressed.

7.1 Evolution of foreign firms until 1990

Between 1990 and 2014, a total number of 665 foreign firm establishments were active in Singapore, which is 56 per cent of all firm establishments. In 2014, 229 of these firm establishments were still active in the city-state – indicating a survival rate of 34 per cent. Of the 183 foreign firm establishments operating in 1990, only 30 were still active in 2014. The average tenure of foreign firm establishments is 6.9 years, which is slightly higher than the average of all firm establishments in Singapore (6.7 years).

Figure 7.1: Number of foreign E&E firm establishments in Singapore, 1990-2014.



Source: own data.

The development of the number of foreign firm establishments shows a stable initial phase and a high growth rate of firm establishments in the 1995-2001 period, as the number of firms increased from 188 to 265. The number of firm establishments remained somewhat stable until 2012, when there was an increase from 265 firms to 229 in 2014 (figure 7.1; table

7.1). This evolution shows similarities with the overall development of all firm establishments in the E&E industry between 1990 and 2014.

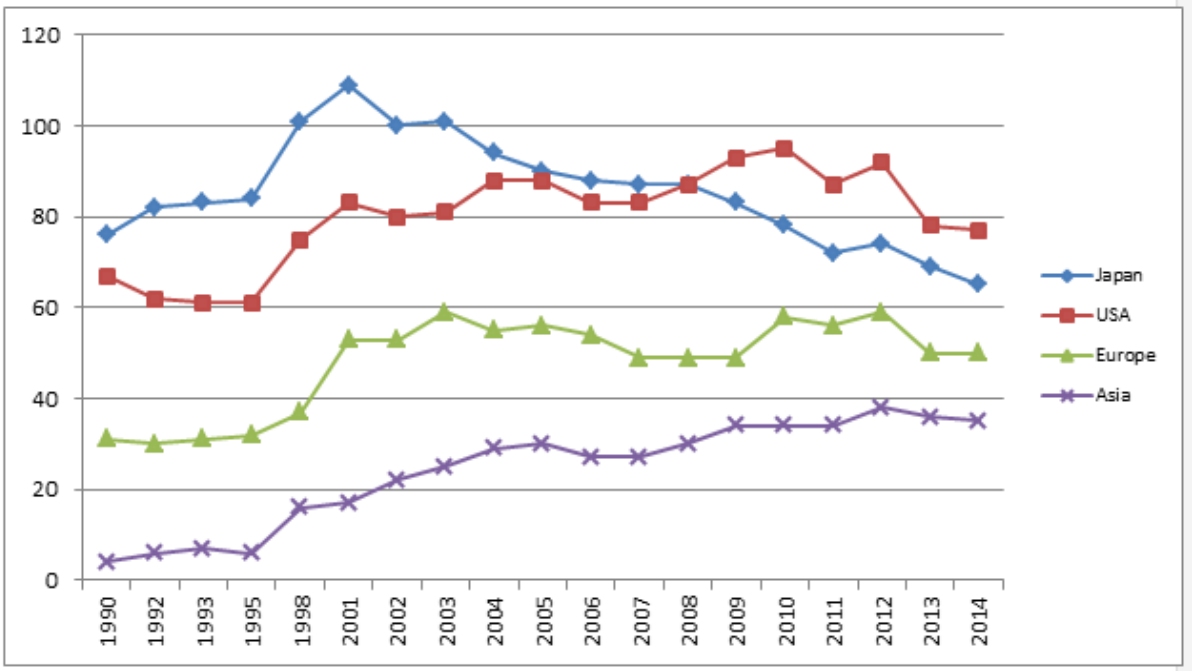
Table 7.1: Development of foreign E&E firm establishments, 1990-2014.

Year	1991	1992	1993	1995	1998	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total firms	301	297	304	314	435	473	447	451	456	454	442	446	458	466	477	460	481	429	412
Foreign firms	182	183	186	188	234	265	256	268	269	265	253	248	255	261	267	251	266	236	230
Share of total (%)	60.5	61.6	61.2	59.9	53.8	56.0	57.3	59.4	59.0	58.4	57.2	55.6	55.7	56.0	56.0	54.6	55.3	55.0	55.8
Annual growth	N.A.	0.5	1.1	1.1	24.5	13.2	-3.4	5.5	0.4	-1.5	-5.2	-2.0	2.8	2.0	2.3	-6.0	6.0	-10.9	-3.0
Entries	N.A.	28	13	12	91	86	28	36	35	16	10	18	29	20	22	9	20	12	6
Exits	N.A.	27	10	11	45	55	37	22	34	20	24	23	22	15	16	25	5	41	13
Balance	N.A.	-1	3	1	46	31	-9	14	1	-4	-14	-5	7	5	6	-16	15	-29	-7

Source: own data.

The high number of foreign firm entries in the years 1998 and 2001, when 91 and 86 foreign firms entered the industry, led to the increase in the total number of foreign firm establishments between 1995 and 2001. This period experienced the highest growth of firm establishments, with a growth of 24.5 and 13.2 percent. The decline in number of firm establishments since 2012 corresponds with the high amount of firm exits in 2013, when 41 foreign firms exited the industry (table 7.1).

Figure 7.2: Number of foreign E&E firm establishments per country, 1990-2014.



*Europe incl.: Germany, Switzerland, France, UK, Netherlands, Italy, Finland, Belgium, Norway, Sweden.
*Asia incl.: China, Hong Kong, India, Malaysia, South Korea, Taiwan, Thailand.
Source: own data.

The high share of foreign firm establishments between 1990 and 2014 has already been discussed in chapter 5. This chapter further elaborated on the largest groups of foreign firm

nationalities (figure 7.2). The following paragraphs have further zoomed in on the evolution of firm nationalities in the E&E industry between 1990 and 2014.

7.2 Evolution of American MNCs

The previous chapter, which addressed the evolution of branches, indicated that American firms have predominantly been the pioneer investors in the E&E industry. These investments focused on a number of branches. In the 1960s and early 1970s, the development of the semiconductor branch was initiated by the relocation of semiconductor manufacturing and assembly activities by predominantly American MNCs. In the 1970s, during the second E&E development phase, the HDD branch emerged as again American firms relocated their disk drive manufacturing activities towards the city-state (Borrus et al., 2000; Rasiah & Xiao-Shan, 2016). Between 1990 and 2014, a total number of 232 American firm establishments (incl. American firm establishments with joint ventures) were active in Singapore, which is 19.4 per cent of all firm establishments. The average tenure of American firm establishments is 6.6 years. The number of firm establishments increased from 61 in 1995, to 83 in 2001, after which its reached a peak of 95 firm establishments in 2010. After 2010, the number of firm establishments declined to 77 in 2014. Although the number of firms increased significantly, the share of American firm establishments slightly decreased from 22.3 per cent to 18.7 per cent of all firm establishments in the industry (table 7.2).

Table 7.2: Development of American E&E firm establishments in Singapore, 1990-2014.

Year	1991	1992	1993	1995	1998	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total firms	301	297	304	314	435	473	447	451	456	454	442	446	458	466	477	460	481	429	412
US firms	67	62	61	61	75	83	80	81	88	88	83	83	87	93	95	87	92	78	77
Share of total (%)	22.3	20.9	20.1	19.4	17.2	17.5	17.9	18.0	19.3	19.4	18.8	18.6	19.0	20.0	19.9	18.9	19.1	18.1	18.7
Annual growth(%)	N.A.	-7.5	-1.6	0.0	23.0	10.7	-3.6	1.3	8.6	0.0	-5.7	0.0	4.8	6.9	2.2	-8.4	5.7	-15.2	-1.3
Entries	N.A.	9	3	5	33	30	11	11	15	2	2	6	11	10	4	2	5	5	3
Exits	N.A.	14	4	5	19	22	14	12	8	2	7	6	7	4	2	10	0	19	4
Balance	N.A.	-5	-1	0	14	8	-3	-1	7	0	-5	0	3	6	2	-8	5	-14	-1

* includes joint ventures

Source: own data.

The previous chapter analysed the role of American firms in the development of the semiconductor and HDD branches. Hence, the high share of American firms active in these semiconductor branch is not surprising. The semiconductor branch experienced the largest increase in number of American firms between 1990 and 2014 (11 to 22). As a result, almost one-third of all firms active in the semiconductor branch in 2014 is of American origin (31.4%). The share of American firms in the HDD branch is even higher, as 3 out of 4 firms active in this branch is of American origin. Other branches that are characterised by a large share of American firms in 2014 are measuring (45.5%), other electric equipment (33.3%) and optical instruments (100.0%). However, these are small branches in number of firm establishments (table 7.3). A reasonable amount of American subsidiaries have been active in the components branch, fluctuating from 10 to 23 firms between 1990 and 2014, with an

average share of 22 per cent. The number of American subsidiaries in the component branch is possibly the result of the firms following the lead MNCs to perform supplier activities (Dedrick & Kraemer, 1998).

Table 7.3: Representation of American E&E firm establishments per branch, 1990-2014.

	1990		1995		1998		2002		2006		2010		2014	
Branches	**Abs.**	%	**Abs.**	%	**Abs.**	%	**Abs.**	%	**Abs.**	%	**Abs.**	%	**Abs.**	%
1. Consumer electronics	1	2.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2. Semiconductor	11	34.4	16	43.2	15	30.6	19	23.5	18	23.1	28	32.6	22	31.4
3. HDD	10	90.9	8	100.0	7	58.3	4	30.8	4	44.4	3	27.3	3	75.0
4. Computer	12	29.3	4	8.5	11	20.4	11	23.9	9	20.0	9	16.7	6	15.8
5. PCB	10	13.7	7	10.0	10	10.1	5	6.3	1	1.6	4	11.4	3	6.1
6. Components	15	25.9	10	21.7	18	17.3	23	25.0	20	24.1	16	18.0	13	17.1
7. Communication	3	16.7	3	23.1	4	13.8	4	15.4	6	19.4	9	15.0	9	16.1
8. Measuring	4	17.4	0	0.0	3	20.0	4	40.0	7	63.6	7	50.0	5	45.5
9. Optical instruments	1	100.0	2	100.0	0	0.0	4	100.0	2	66.7	2	100.0	3	100.0
10. Wires & cable devices	2	8.7	2	10.0	4	12.1	7	19.4	2	8.7	1	3.1	2	6.5
11. Other electrical equipment	0	0.0	0	0.0	0	0.0	7	14.3	1	14.3	3	30.0	2	33.3
12. Electric motors	4	17.4	2	7.4	4	12.1	1	15.8	5	13.2	4	13.8	2	8.0
13. Batteries & accumulators	2	28.6	3	25.0	2	11.1	2	9.5	3	13.0	3	10.7	4	16.0
14. Other (incl. toys & games)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
15. CEM	0	0.0	0	0.0	0	0.0	4	11.1	0	0.0	8	15.1	7	15.9

Source: own data.

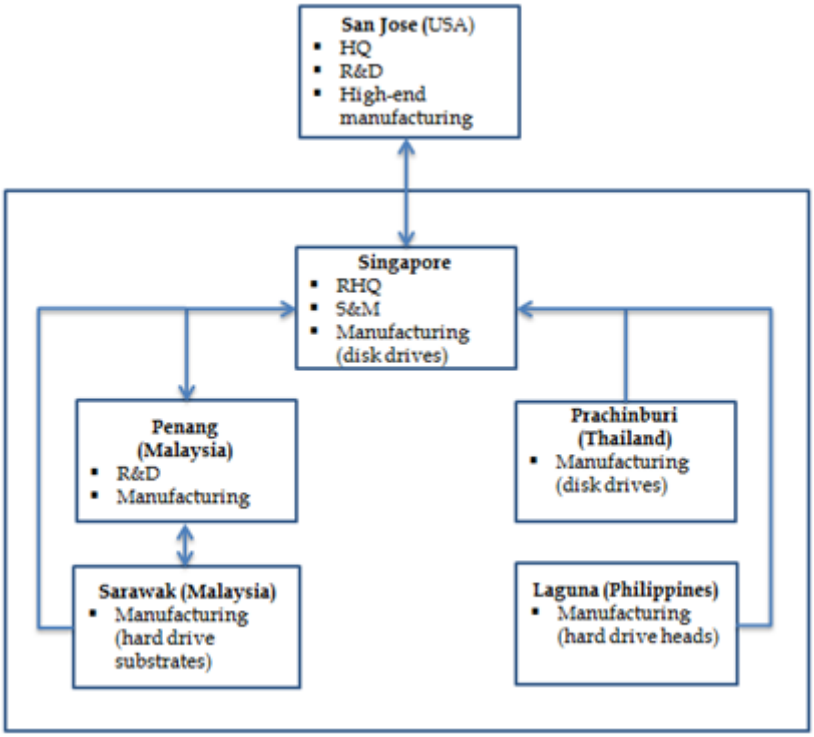
The absolute number of American firm establishments in the computer branch has also been high, decreasing from 12 to 6 firms between 1990 and 2014. An important pioneer in the development of this branch in Singapore has been Hewlett-Packard (HP). As part of its globalisation strategies, HP targeted Singapore as a low-cost location. Since the establishment in 1970, the firm establishemnt had evolved from a simple low-cost manufacturing and assembly facility of calculators, into an operation with global responsibility for portable printers, PC-desktops and servers. During the 1970s and 1980s, HP implemented quality improvement programs and expanded the range of activities. During this processes, HP transferred knowledge and expertise to its Singaporean employees, which had grown to 2700 in 1989. During the 1990s, the establishment carried out manufacturing, R&D of new printers, process design development and chip design. HP operated a network of local firms, supplying PCB and hard disks (Borrus et al., 2003; Brown & Eisenhardt, 1998). Chapter 8 further elaborates on one of the most important spin-offs of HP, Venture Corp. In 2015, HP operates three subsidiary establsihemts in Singapore, together employing around 10 thousand workers. Besides RHQ activities, the establishments are engaged in worldwide R&D operations, regional sales and high-tech manufacturing of PCs, servers, handheld information products, inkjet printers and peripherals; illustrating the

strong and deeply-rooted position of HP in Singapore (Kompass, 2016a; The Straits Times, 2015).

Another pioneering American MNC was Apple. In 1981, Apple established their first overseas manufacturing plant in Singapore, named Apple Computer Singapore (ACS), producing PCBs for its products in the USA. Two years later, 9 local firms developed into suppliers of PCBS for Apple's global market. During the following years, the subsidiary expanded and experienced upgrading (Borrus et al., 2003). In 1985, ACS started to do final assembly of the Apple II (Dedrick & Kreamer, 1998). In 1989, the establishment engaged in component design work and in 1990, the subsidiary assumed finale assembly responsibilities for the iconic Macintosh PC. As a result, the number of component supplier in Singapore, as well as in other Asian countries, increased. During this years, ACS operated a network of a total of 130 major supplier firms in Asia, from which the two largest were located in Singapore (Borrus et a., 2003). In 1993, Apple set up a hardwire design centre. The Apple Design Centre was involved in designing products for the global market, and the product and solutions specifically for the Asian market (Dedrick & Kreamer, 1998). During the 1990s, ACS engaged in more sophisticated branches, such as HDD and semiconductor; increased its production volume; and enlarged its R&D activities (Borrus et al., 2003). After the millennium, the manufacturing activities gradually left the Singaporean establishment, and the facility is currently only involved in RHQ and distribution activities. In 2014, Apple managed a network 17 local and foreign firms in Singapore (incl. Coilcraft, Dai-Ichi Seiko, Fairchild, Micron Technology, Murata, Seagate and Sony). However, this is a small number compared with the supplier firms in China (149) and Japan (139), indicating that the once dominating position of Singapore in the GPN of Apple has diminished (Apple, 2014). The local supplier firms will be addressed in more detail in chapter 8.

Another example of an American MNC operating an extensive network from its Singaporean subsidiary is Hitachi Global Storage Technologies Singapore Pte Ltd (HGST), established in 2003 as a result of a merger between Hitachi and IBM, and had its operation HQ in San Jose. However, HGST Singapore Pte Ltd has a longer history in Singapore, as it operated as part of IBM Singapore's Storage Systems Division. Since 2012, HGST Singapore Pte Ltd is operating as a fully-owned subsidiary of Western Digital (S) Pte Ltd, which has a history since 1988 in Singapore. Throughout its full tenure, HGST Singapore Pte Ltd operated at a single location in Singapore, without further subsidiaries. In 2013, Western Digital (S) Pte Ltd decided to shift the manufacturing of disk drives to Thailand, in a bid to enhance cost competitiveness, downsizing the Singapore operations to focus on engineering and R&D. This resulted in a loss of 500 Singapore employees (ZDNet, 2013). Within Southeast Asia, The Global Centre of HGST Singapore Pte Ltd was responsible for RHQ and S&M activities, and the high-end manufacturing of disk drives (figure 7.3). There are two facilities located in Malaysia: Penang, performing R&D and high-end manufacturing activities; and Sarawak, performing low-end manufacturing activities. The other two locations performed manufacturing activities on different production lines, whereas the Thailand facility performed high-end manufacturing, and the Philippines facility performed low-end manufacturing (HGST, 2016; Kompass, 2016b).

Figure 7.3: RPN of Hitachi Global Storage Technologies Singapore Pte Ltd in 2015.



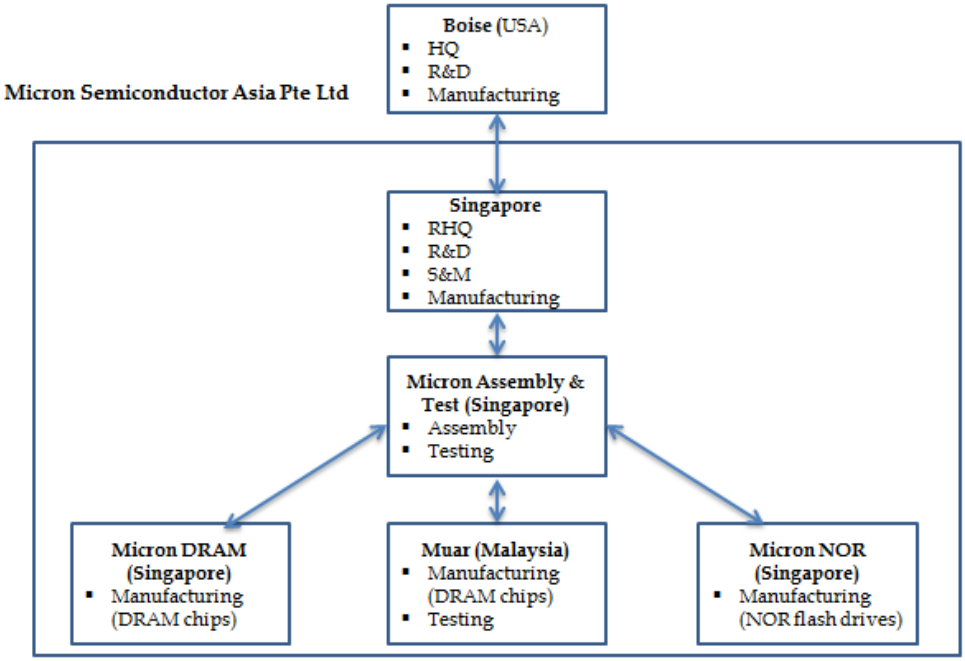
Source: HGST, 2015.

The evolution of Micron Technology in Singapore can also be described as significant. The first investments of Micron in Singapore, in 1991, focussed on a small DRAM facility - manufacturing small volumes of memory chips for semiconductor devices - and later expanded to a small wafer production facility. In 1994, Micron Semiconductor added a sales division in Singapore, to trade semiconductor devices from the DRAM facility and other products from the US to clients in Southeast Asia. In 1998, as the Asian market became more important for Micron Semiconductor, and the Singaporean facilities started to deepen their roots in the city-state, Micron Semiconductor Asia Pte Ltd was established to coordinate the activities of the other subsidiaries. Aside from the RHQ activities, the new establishment performs R&D, S&M and manufacturing of semiconductor devices. In 2006, the DRAM facility was expanded with testing and assembly facilities, doubling its capacity. Another facility was established in 2011, when Micron Semiconductor opened a NAND Flash Memory Operation, a result of a partnership with Intel Corporation. Since 2012, Micron Semiconductor is the sole operator of this facility. Finally, at the end of 2014, Micron Semiconductor opened a NOR flash facility and planned to break ground on FAB expansion (Kompass, 2016c; Micron Semiconductor, 2016).

Like multiple other foreign firm establishments, Micron relocated low value added activities towards other countries, resulting in a more simplified RPN (figure 7.4). The establishment in Singapore operates as a RHQ, and is controlled by the GHQ in Boise, USA. Besides the RHQ, Micron operates three other facilities in Singapore, and one in Malaysia. The Assembly & Test subsidiary is responsible for the assembly and testing of the produced goods of the remaining facilities. The Micron DRAM and the Muar facility both produce DRAM chips, where the Singaporean facility performs the front-end manufacturing, and the

Malaysian facility back-end manufacturing. The Micron NOR facility (Singapore) performs front-end manufacturing as well (Micron Technology, 2016).

Figure 7.4: RPN of Micron Semiconductor Asia Pte Ltd in 2016.



Source: Micron Technology, 2016

7.3 Evolution of Japanese MNCs

In contrast with the investments of American MNCS, the initial major investments of Japanese MNCs came from small assembly firms active in the consumer electronics branch. The Japanese MNCs have been global market leaders in this branch. Japanese MNCs saw Singapore as the (only) gateway into Southeast Asia for their consumer electronics products, as protection barriers from other countries in the region against Japanese exports increased. Consumer electronics soon became the sector that started to dominate the E&E manufacturing investments until the mid-1980s (Borrus et al., 2003; Edgington & Hayter, 2013; Hiroshi & Hitoshi, 1999). Figure 7.2 presented that the Japanese firm establishments constituted the biggest group of firms between 1990 and 2008, after which the number of American firm establishments surpassed the Japanese. Between 1990 and 2014, a total number of 199 Japanese firm establishments (incl. joint ventures) were active in Singapore, which is 16.6 per cent of all firm establishments. The average tenure of Japanese firm establishments is 8.2 years, which is notably higher than the average tenure of American firm establishments. Between 1990 and 2001, the number of Japanese firm establishments increased from 76 to 101. After two stable years until 2003, the number of firm exits started to exceed the firm entries, resulting in a declining number of firm establishments. From 2003 to 2014, the number of firm establishment gradually decreased from 101 to 65. The declining number of firm establishment is reflected in the share of Japanese firm establishments, which decreased from 25.2 per cent in 1990 to 15.8 per cent in 2014 (table 7.4).

Table 7.4: Development of Japanese E&E firm establishments in Singapore, 1990-2014.

Year	1991	1992	1993	1995	1998	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total firms	301	297	304	314	435	473	447	451	456	454	442	446	458	466	477	460	481	429	412
Japan MNCs	76	82	83	84	101	109	100	101	94	90	88	87	87	83	78	72	74	69	65
Share of total (%)	25.2	27.6	27.3	26.8	23.2	23.0	22.4	22.4	20.6	19.8	19.9	19.5	19.0	17.8	16.3	15.7	15.4	16.1	15.8
Annual growth(%)	N.A.	7.9	1.2	1.2	20.2	7.9	12.4	1.0	-6.9	-4.3	-2.2	-1.1	0.0	-4.5	-6.0	-7.7	2.8	-6.8	-5.8
Entries	N.A.	12	5	3	26	17	13	10	7	7	6	5	4	2	1	4	5	3	0
Exits	N.A.	6	4	2	9	28	3	9	14	11	8	6	4	6	6	10	3	8	5
Balance	N.A.	6	1	1	17	-11	10	1	-7	-4	-2	-1	0	-4	-5	-6	2	-5	-5

* includes joint ventures.
Source: own data.

There is a general trend in all E&E branches of a declining share of Japanese firm establishments (table 7.5). The absolute and relative share of Japanese firm establishments in this consumer electronics decreased between 1990 and 2014. The other branches with a high share of Japanese firms between 1990 and 2014 were components (31%) and wires & cable devices (33.6%). The Japanese subsidiaries had a reasonable presence was the wire and cable devices branch, fluctuating from 6 to 11 establishments, with an average share of 29 per cent over the 1990-2014 period. The Japanese subsidiaries active in the component branch fluctuated between 19 to 32 between 1990 and 2014, with an average relative share of 31 per cent. The high share of Japanese establishment in this branches is possibly the result of the high number of Japanese supplier firms that followed the lead MNCs (Dedrick & Kraemer, 1998).

The Japanese firms establishments also had a considerable presence in the semiconductor branch, with an average presence of 21 per cent between 1990 and 2014. Global leading Japanese MNCs in the semiconductor branch, such as Fujitsu, NEC Semiconductor, Sharp Electronics, Panasonic and Renesas, had manufacturing activities in Singapore. Over the recent years the role of Japanese MNCs has diminished in the semiconductor branch relative to the increased role of American and Korean semiconductor manufacturers (HIS, 2014). This could explain the declining number of Japanese subsidiaries active in the semiconductor branch over the 1990-2014 period.

The Japanese MNC disk drive manufacturers have been absent in Singapore because they preferred keeping their manufacturing at home, in despite of the efforts of the attempts of the EDB to attract them. The Japanese believed that the complexity of disk drives was too high to perform in Singapore. The Japanese went offshore in the late 1980, particular to Thailand. The Japanese took advantage of the production network that were created by the American firms, but this was all too late (Dedrick & Kreamer, 1998). The Japanese MNCs active in the HDD branch emerged during the late 1990s (table 7.5).

Table 7.5: Representation of Japanese E&E firm establishment per branch, 1990-2014.

	1990		1995		1998		2002		2006		2010		2014	
Branches	**Abs.**	**%**	**Abs.**	**%**	**Abs.**	**%**	**Abs.**	**%**	**Abs.**	**%**	**Abs.**	**%**	**Abs.**	**%**
1. Consumer electronics	27	57.4	25	83.3	19	63.3	16	72.7	8	34.8	8	44.4	6	46.2
2. Semiconductor	7	21.9	8	21.6	14	28.6	17	21.0	18	23.1	15	17.4	12	17.1
3. HDD	0	0.0	0	0.0	3	25.0	3	23.1	4	44.4	4	36.4	1	25.0
4. Computer	3	7.3	9	19.1	8	14.8	5	10.9	9	20.0	6	11.1	5	13.2
5. PCB	7	9.6	8	11.4	13	13.1	8	10.0	6	9.5	8	22.9	8	16.3
6. Components	20	34.5	19	41.3	32	30.8	25	27.2	20	24.1	21	23.6	19	25.0
7. Communication	3	16.7	2	15.4	11	34.4	3	11.5	3	9.7	4	6.7	4	7.1
8. Measuring	7	30.4	4	33.3	2	13.3	3	30.0	3	27.3	2	14.3	1	9.1
9. Optical instruments	0	0.0	0	0.0	1	33.3	1	25.0	1	33.3	0	0.0	0	0.0
10. Wires & cable devices	8	34.8	6	30.0	7	21.2	11	30.6	10	43.5	9	28.1	8	25.8
11. Other electrical equipment	0	0.0	9	45.0	0	0.0	0	0.0	1	14.3	1	10.0	0	0.0
12. Electric motors	5	21.7	11	40.7	5	15.2	9	23.7	9	23.7	6	20.7	5	20.0
13. Batteries & accumulators	1	14.3	1	8.3	2	11.1	1	4.8	1	4.3	1	3.6	1	4.0
14. Other (incl. toys & games)	2	22.2	2	25.0	1	50.0	0	0.0	0	0.0	0	0.0	0	0.0
15. CEM	0	0.0	0	0.0	0	0.0	2	5.6	2	4.4	3	5.7	1	2.3

Source: own data.

An illustrative example of a Japanese MNC with a dominant role in the consumer electronics branch in Singapore is Sony. Sony was the first Japanese firm to be granted with the status of 'operational regional headquarter' by the Singaporean government in 1987, as it was part of the first foreign MNCs to realise RHQ activities in the city-state (Kompass, 1995). The government started actively promoting RHQs in the city-state in the late 1980s as part of the 'Regional Headquarter Scheme', part of the aim to upgrade MNC activities.

Table 7.6 presents the development of the establishments of Sony in Singapore in 1995, 2005 and 2015. In 1995, Sony operated 6 establishments in Singapore active in the E&E industry, each responsible for different activities and product lines. In 2003, Sony International Pte Ltd changed its name in Sony Electronics Asia Pacific Pte Ltd. In 2005, this establishment operated as a RHQ for Asia Pacific in consumer electronics products. The Sony Electronics (Singapore) Pte Ltd operated as a corporate RHQ. Besides these two establishments, the other establishments focussed on a variety of functions and reflect a shift to manufacturing of high-end products. In 2015, there are only two establishments left in Singapore. This is the result of the relocation of the manufacturing activities of the great variety of products. The current establishments focus on RHQ, R&D, sales & marketing and manufacturing of energy technology products, which are high-end (Kompass 1995; 2005; 2015).

Table 7.6: Development of establishments of Sony in Singapore, 1995, 2005, 2015.

1995	Activities	2005	Activities	2015	Activities
Sony Chemicals Singapore Pte Ltd	Flexible printed circuits, flexible flat cable, thermal transfer ribbons for bar-code use, double-sided adhesive tapes	Sony Chemicals Singapore Pte Ltd	High quality liquid adhesive	Sony Electronics Asia (Singapore)	RHQ and R&D
Sony Display Device (S) Pte Ltd	Manufacturing plant for CRT (Cathode-ray tubes)	Sony Display Device (S) Pte Ltd	Manufacturing of Cathode ray tubes		
Sony International Singapore Ltd	RHQ Southeast Asia. Electronic equipment and components	Sony Electronics Asia Pacific Pte Ltd	RHQ and S&M for Sony consumer products in Asia Pacific		
Sony Precision Engineering Center (S) Pte Ltd	Manufacturing	Sony Precision Engineering Center (S) Pte Ltd	Manufacturing of precision components (optical pick-ups lenses, magnetics head and spindle motors)		
Sony Singapore Pte Ltd	Distribution, S&M and services. Colour TV, Consumer product, Car Audio and Video tape, data cartridge, optical disks, telephone, security systems, video projectors, colour video printer, micro floppy diskettes, broadcast equipment	Sony Singapore Pte Ltd	S&M and service for consumer, recording media, communication, broadcast and professional products		
Sony Systems Design International Pte Ltd	R&D	Sony Electronics (Singapore) Pte Ltd	Regional Corporate headquarter R&D Manufacturing of precision parts and components, cathode ray tubes and integrated tube components.	Sony Electronics (Singapore) Pte Ltd	Sales, marketing and service. Manufacturing mainly focused on Energy Technology
		Sony Ericsson Mobile Communication & International AB	Regional sales offices, marketing and customer support offering mobile multimedia consumer products		
		Sony Supply Chain Solutions Singapore Ltd	Providing solutions to production network in SEA		

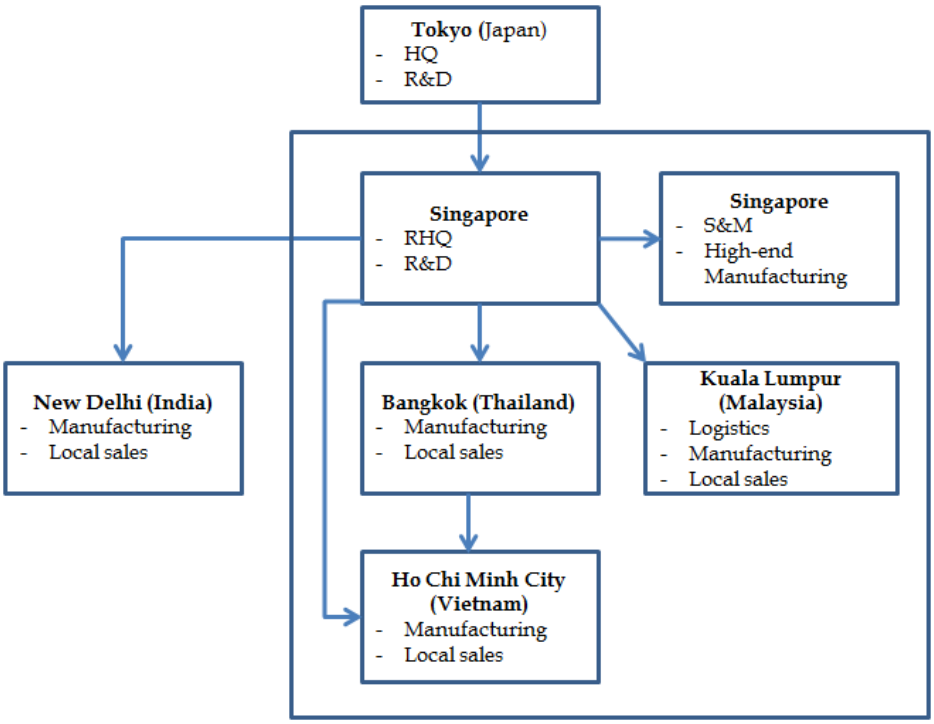
Source: Kompass, 1995; 2005; 2015.

These shifts in the operating network of Sony in Singapore resulted in a changing RPN of Sony, which is illustrated in figure 7.5. The Singapore based RHQ (Sony Electronics Asia (Singapore) Pte Ltd) controls and navigates the subsidiaries in Southeast Asia and India. The Sony Supply Chain Solution Singapore LTd provided supporting services, optimising the networks logistics. The Malaysian subsidiaries (Sony EMCS (Malaysia) Sdn. Bhd.) manufactured TV, audio, video and hi-fi products; and the Vietnamese subsidiary (Sony Electronics Vietnam Company Limited) manufactured TV, DVD, digital cameras, audio equipment, mobile phones and laptops.

Sony is a strong illustrative case of how the profile of the E&E industry evolved in Singapore. Sony was one of the first foreign MNCs to establish a RHQ in Singapore. The low value added manufacturing activities were relocated to other countries in SEA, in which the RHQ in Singapore navigated and controlled the subsidiaries. Product such as colour TV, Car Audio, telephones, video projectors have all left the city-state. The remained R&D and high-

tech manufacturing is in line with the shift towards high value added manufacturing activities in the E&E industry.

Figure 7.5: RPN of Sony Electronics (Singapore) Pte Ltd in 2015.



Source: Sony, 2016.

Another example of a Japanese firm with a long history in Singapore is Hitachi. The first investments of Hitachi in Singapore go back to 1972, when the firm opened a manufacturing facility for consumer electronic products. Since these initial investments, Hitachi increasingly extended its network of establishments in Singapore (table 7.7). In 1995, 8 Hitachi subsidiaries were established in Singapore, performing a wide range of manufacturing activities in the E&E industry. In 2005, the number of Hitachi subsidiaries increased to 14, and logically a shift in activities had taken place. Two of this establishment were RHQs for Asia, Hitachi Asia Ltd. and Hitachi Home Electronics Asia (S) Pte Ltd. The manufacturing of consumer products in the Hitachi Consumer Products (S) Pte Ltd in 1995 had left Singapore, and were controlled and navigated from the RHQ in the city-state in the years 2005 and 2015.

The number decreased from 14 subsidiary establishments in 2005 to 8 in 2015. In 2015 a R&D centre was added to Hitachi Asia Pte Ltd. In 2015 the Hitachi Koki (Singapore) Pte Ltd was upgraded to a RHQ, with an additional S&M division. Also, the product portfolio of the Hitachi Metals Singapore Pte Ltd subsidiary has significantly decreased to only ferrites and soft magnetics in 2015. Over the 1995-2015 period the total product portfolio of Hitachi in Singapore had significantly decreased. The subsidiary Hitachi Cable (S), had left Singapore in 2015. The shift towards lifestyle sciences of the Hitachi High-Technologies (Singapore) subsidiary illustrates the newly emerging and expanding industries, that have enjoy an increased interest from the government and its institutions. Especially between the

years 2005 and 2015 the shift towards higher value added activities and the relocation of low value manufacturing activities is clear. Only a select number product types was left in 2015.

Table 7.7: Development of establishments of Hitachi in Singapore, 1995, 2005, 2015.

1995	Activities	2005	Activities	2015	Activities
Hitachi Asia Pte Ltd	Sales and services of Hitachi products	Hitachi Asia Ltd	RHQ for Asia	Hitachi Asia Ltd	RHQ R&D
Hitachi Cable (S) Pte Ltd	Manufacturing electronic cable devices	Hitachi Cable (S) Pte Ltd	Manufacturer of enamelled copper wires, AC power cords, copper wire, flexible flat cable	Hitachi Chemical Singapore Pte Ltd	PCB manufacturing
Hitachi Chemical Asia Pacific (Pte) Ltd	Semiconductor materials, PCB boards materials, electrical insulating materials, synthetic resins for paints, sol water-heater panels	Hitachi Chemical Asia Pacific Pte Ltd	Semiconductor materials, PCB materials, Electrical insulating materials	Hitachi Chemical Asia-Pacific (Pte) Ltd	PCB manufacturing, semiconductor, batteries and capacitators
Hitachi Consumer Products (S) Pte Ltd	Consumer products	Hitachi Home Electronics Asia (S) Pte Ltd	Strategic planning, marketing & trading of consumer electronics, home appliances & multimedia products in South Asia	Hitachi High-Technologies (Singapore) Pte Ltd	Electronic devices systems, lifestyle science, electronic components
Hitachi Electronic Devices (S) Pte Ltd	Manufacturing of colour picture tubes and colour display tools	Hitachi Kasei Shoji Co. Ltd	Trading of chemicals, E&E products, machinery	Hitachi Data Systems Pte Ltd	R&D, Develop storage solutions built on industry-leading technology
Hitachi Koki (Singapore) Pte Ltd	Manufacturing and assembly of power tools	Hitachi Koki (Singapore) Pte Ltd	Electric power tools and accessories	Hitachi Koki (Singapore) Pte Ltd	RHQ, S&M, Distribution Electric power tools
Hitachi Medical Corporation	Medical equipment, X-ray equipment, MR, Ultrasound scanner	Hitachi Medical Corporation	Medical equipment, X-ray equipment, MR, Ultrasound scanner		
Hitachi Metals Singapore Pte Ltd	Permanent magnet materials for meter, loud speaker, motor. Soft magnetic materials for TV, radio, magnetic heads. Pipe fitting.	Hitachi Metals Singapore Pte Ltd	Permanent magnet materials for meters, loud speaker, motor. Soft magnetic materials for TV, radio, magnetic heads	Hitachi Metals Singapore Pte Ltd	Ferrites and soft magnetics
Hitachi Plant Engineering & Construction Co Ltd	Air-conditioning and electrical engineering, power plant installation, air pollution control system and material handling systems	Hitachi Plant Engineering & Construction Co Ltd	Air conditioning and electrical engineering, clean rooms, power plant installation, air pollution control system.		
Hitachi Powered Metals (S) Pte Ltd	Manufacturing, import and export of power metallurgy products	Hitachi Powered Metals (S) Pte Ltd	Manufacturing, import and export of power metallurgy products	Hitachi Powered Metals (S) Pte Ltd	Manufacturing parts for cars, printers and computers
Hitachi Automobile Appliances Sales Co (South-East) Ltd	Manufacturing	Hitachi Home Electronics Asia (S) Pte Ltd	RHQ. Strategic planning, marketing & trading of consumer electronics, home appliances & multimedia products in South Asia		
		Hitachi Electronics Engineering (Asia) Pte Ltd	Sales and services of semiconductor, manufacturing equipment and hard disks manufacturing equipment		
		Hitachi High-Tech Instruments Service (Asia) Pte	Trading and service electronic components, scientific instrument and industrial systems		
		Hitachi Via Asia Pte Ltd	PCB drilling and routing machine and wire EDM		

Source: Kompass (1995; 2005; 2015).

The previous chapter emphasised the declining number of Japanese firm establishments, as these establishments relocated their manufacturing activities towards other countries in Southeast Asia. According to Chizue Honda (2015) of the Japan External Trade Organization (JETRO), it is likely that in the near future, the Japanese MNCs will shift the remaining RHQ, R&D and S&M activities towards other countries in the region like Thailand, Vietnam and China. Most Japanese firm establishments are active in the consumer electronics branch, and this has lost the focus of the government (Chizue Honda, personal communication, 2015). The decline of Japanese firms in the consumer branch can be labelled as a strategic decoupling process, in which the regional assets no longer 'fit' the strategic needs of the MNCs.

7.4 Evolution of European and Asian MNCs

The previous two paragraphs illustrated that the American and Japanese firm establishments are the two largest group nationalities. Aside from the influence of these two nationalities, European MNCs have also been key players in the emergence of the E&E industry in Singapore. The European subsidiary profile includes firms from Germany, Switzerland, France, UK, Netherlands, Italy, Finland, Belgium, Norway and Sweden. In which the vast majority (over 90%) was of German, Swiss, France, UK and Dutch origin in the 1990-2014 period. Between 1990 and 2014, a total number of 150 European firm establishments (incl. joint ventures) were active in Singapore, which is 12.5 per cent of all firm establishments. The average tenure of European firm establishments is 6.1 years. The number of firm establishments experienced a rapid growth between 1995 (32) and 2001 (53). After gradually decreasing to 49 firm establishments in 2009, the number increased to 59 firm establishments in 2012, after which it declined to 50 in 2014. This development is reflected in the share of European firm establishments, which increased from 10.3 per cent in 1990, to 12.1 per cent in 2014 (table 7.8).

Table 7.8: Development of European E&E firm establishments in Singapore, 1990-2014.

Year	1991	1992	1993	1995	1998	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total firms	301	297	304	314	435	473	447	451	456	454	442	446	458	466	477	460	481	429	412
European MNCs	31	30	31	32	37	53	53	59	55	56	54	49	49	49	58	56	59	50	50
Share of total (%)	10.3	10.1	10.2	10.2	8.5	11.2	11.9	13.1	12.1	12.3	12.2	11.0	10.7	10.5	12.2	12.2	12.3	11.7	12.1
Annual growth(%)	N.A.	-3.2	3.3	3.2	15.6	43.2	1.9	11.3	-6.7	1.8	-3.6	-9.3	0.0	0.0	18.4	-3.4	5.4	-15.3	0.0
Entries	N.A.	5	2	3	19	23	9	8	5	5	3	3	10	4	12	1	5	2	2
Exits	N.A.	6	1	2	14	8	8	2	9	4	5	8	10	4	3	3	2	11	2
Balance	N.A.	-1	1	1	5	15	1	6	-4	1	-2	-5	0	0	9	-2	3	-9	0

* Includes joint ventures.
Source: own data.

Between 1990 and 2014, a total number of 74 Asian firm establishments (incl. joint ventures) were active in Singapore, which is 6.2 per cent of all firm establishments. The Asian subsidiaries include firms from Taiwan, South Korea, Hong Kong, China, Malaysia, India and Thailand. The vast majority of the foreign Asian establishment was from one of the

Asian Tigers between 1990 and 2014. In 1990, only 4 firm establishments were active in the E&E industry in Singapore. This gradually increased over the years, towards 35 firm establishments in 2014. This development is reflected in the share of Asian firm establishments, which increased from 1.3 per cent in 1990, to 8.5 per cent in 2014 (table 7.9). The absolute increase of Asian subsidiaries, of especially Taiwanese, Korean and Hong Kong MNCs, in Singapore reflects the internationalised and expanded production networks of East Asian firms, that have increasingly become competitors of the American, European and Japanese dominance in the GPNs (Borrus et al., 2003; Kimura & Obashi, 2016).

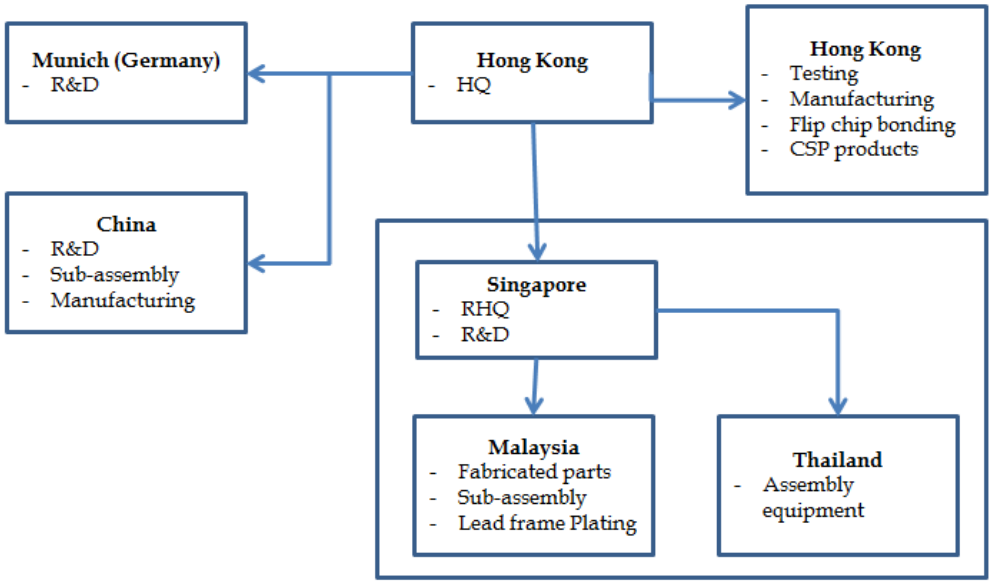
Table 7.9: Development of Asian E&E firm establishments in Singapore, 1990-2014.

Year	1991	1992	1993	1995	1998	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total firms	301	297	304	314	435	473	447	451	456	454	442	446	458	466	477	460	481	429	412
Asian MNCs	4	6	7	6	16	17	22	25	29	30	27	27	30	34	34	34	38	36	35
Share of total (%)	1.3	2.0	2.3	1.9	3.7	3.6	4.9	5.5	6.4	6.6	6.1	6.1	6.6	7.4	7.1	7.4	7.9	8.4	8.5
Annual growth(%)	N.A.	50.0	16.7	-14.3	166.7	6.3	29.4	13.6	40.0	3.5	-10.0	0.0	11.1	13.3	0.0	0.0	11.8	-5.3	-2.8
Entries	N.A.	2	2	1	12	7	5	5	7	2	1	3	4	5	4	2	4	2	1
Exits	N.A.	0	1	2	2	6	0	2	3	1	4	3	1	1	4	2	0	4	2
Balance	N.A.	2	1	-1	10	1	5	3	4	1	-3	0	3	4	0	0	4	-2	-1

* includes joint ventures
Source : own data.

An example of such of an Asian firm that has established a GPN is ASM technologies, founded in Hong Kong. ASM Pacific technology was established in Hong Kong in 1975, as the marketing arm of its Netherlands based parent. Between 1980 and 1990 the firm became active in wire bonding and stamped leadframes, an set up a number of production plants in China to manufacture parts and subassembly. In 1990 parts of the R&D activities were shifted to Singapore. ASM Singapore became a manufacturer of gold wire bonders as well as other equipment. Etched leadframe operation were added into the manufacturing plant. The shift towards Singapore was because of the growing semiconductor cluster, and the company wanted to be closer to its market. By late 1990s, ASM Pacific had become one of the largest semiconductor assembly and packaging equipment manufacturers in the world. The Singapore establishment had been expanded with RHQ operation, navigating and controlling subsidiaries in Malaysia and Thailand. After 2008 the company expanded its number manufacturing plants in China, and established a R&D center in Chengdu, with a one thousand R&D staff recruited (ASM, 2016). The established R&D center in Munich (Germany) illustrates the expanding international production network of Asian MNCs.

Figure 7.6: GPN of ASM Pacific Technology



Source: ASM Pacific Technology, 2016.

STMicroelectronics (previously known as SGS-Thomson) has been an important pioneer in the E&E industry, as it was the first successful and significant firm that established a semiconductor assembly operation in 1969, and was the first in 1981 to establish a wafer fabrication facility in Singapore. Singapore still takes up an important position in the GPN of the French-Italian MNCs, functioning as an RHQ for SEA, carrying out R&D activities and currently employing over 6 thousand workers (STM, 2016).

Aside from the Japanese consumer electronics MNCs that came to Singapore to take advantage of the manufacturing costs, other nationality firms such as Thomson, General Electric and Philips have also been important pioneers. The Dutch firm General Electric opened up a number of manufacturing in Jurong in 1969. The operations have developed, in tandem with the Singaporean government, from low wage assembly towards high technology, value added solutions provider. The subsidiary carries out complex manufacturing and R&D activities. The company addressed that the talent pool, business environment, infrastructure, and research institutions have been important local advantages in the subsidiary's development. The operations have extended far beyond E&E product alone, as the subsidiary is engaged in aviation, healthcare, energy, water, offshore & marine, grid solutions, lightning and cloud, cyber-security & data analytics. Over 3.5 thousand people are employed in the Singapore subsidiary, of whom 1.7 thousand engineers and skilled workers (GE, 2016). Particularly the healthcare division has become a major pillar in the Singaporean establishment, which illustrates the trend of the E&E industry in Singapore is being 'replaced' by other industries. Because the Dutch firm Philips has been an important pioneer in the development of the E&E industry in Singapore, the following subparagraph has addressed the evolution of the MNC in the city-state.

7.4.1 Philips in Singapore

Philips was one of the first foreign firms to establish manufacturing and assembly activities on a large scale in the city-state, and afterwards had an important role in the further

development of the E&E industry, as it engaged in a variety of branches and was involved in various labour programme schemes. The development of Philips is characteristic for the evolution of the E&E industry in Singapore. The first presence of Philips in Singapore was in 1951, when it established a trading company. During the 1960s, the firm started manufacturing activities in Singapore, and established a number of factories. These factories mainly focussed on the manufacturing of (labour-intensive) consumer electronic products, such as TVs, telephones, telegraphs and radios. In the 1970s, more factories were built – in collaboration with the EDB and JTC – centralising in Jurong and employing over 3 thousand workers. As a result, the manufacturing output increased significantly. During this period, Philips and the EDB started training programmes to raise the skilled levels of their workers. In the 1980s, the training of their employees increased as it was needed for the upgrading of activities in Singapore. Philips engaged in the manufacturing of computer products, computer systems, disk drives and colour TVs. Meanwhile, automation and computerisation of the manufacturing process increased (Cheong, 2001).

In the 1990s, the manufacturing of low-tech products had relocated to low-wage countries Indonesia and Malaysia, tapping into the SIJORI 'Growth Triangle' project. Besides, Philips outsourced product lines from Singapore towards the Philippines, Vietnam China, turning the Singaporean subsidiary into a RHQ, coordinating the activities in Southeast Asia, as well as remaining active in the manufacturing of high-tech products, like mobile phones, stereos, disk drives, semiconductors, TVs and DVDs. After the millennium, these product lines were relocated towards other countries in Southeast Asia and the focus shifted to other branches. The realisation of the Innovation Campus was an important endeavour, built to increase the innovation and technological levels, in line with the upgrading of the products and activities such as R&D (Cheong, 2001). The R&D facility employed 800 development engineers, active in multiple branches such as consumer electronics, other electrical equipment, semiconductor, communication and HDD. The new developmental focus complemented the efforts of Singapore to become a knowledge-based economy (Philips, 2000). In the 1960s to 1980s, Singapore had functioned as an outsource base for the Netherlands, in which activities in Singapore from the 1990s were relocated to other Southeast Asian countries (Kotabe et al., 2008).

Figure 7.7: Philips old factory (left) and Philips future RHQ and R&D-facility (right).

Sources: Cheong, 2001 & Philips, 2015.

The focus of Philips has shifted from consumer products in the 1970s towards life sciences and healthcare technologies in the 2010s. The manufacturing activities, including the

consumer electronics branch, have left the city-state. The Toa Payoh Complex, opened in 1997, is the only remaining establishment in Singapore, carrying out RHQ, R&D, and S&M activities in 2014. More recently, Philips has started the construction of new RHQ for the ASEAN and Asia Pacific regions, next to the current location. This new establishment will shift its focus towards the life science and healthcare industries and will contain an extended R&D facility, reflecting the new strategies of the company (Philips, 2016).

7.5 Position of Singapore in GPN

This chapter has analysed the development of firm nationalities in Singapore between 1990 and 2014, in which cases of MNC subsidiaries have been presented. The MNC subsidiaries have shifted from low wage manufacturing and assembly activities towards high value added activities, including RHQ and R&D. In the following subparagraphs fur the number of firm activities in Singapore have been presented.

7.5.1 MNCs' economic activities in Singapore

The changing role of Singapore as a regional and global hub is reflected by the composition of economic activities of MNCs in the E&E industry in Singapore in 2014. Table 7.10 presents that higher added activities constitute a substantial part of the industry. A total of 61 foreign firms operate their RHQ from Singapore, and even 8 their GHQ. With regard to R&D activities, 60 foreign firms execute R&D activities in their establishment. The sales & marketing (S&M) activities, covering the Southeast Asian region, constitute the biggest share of activities, as 154 of 229 foreign firms are performed this activity in their establishments. Finally, 118 out of 229 foreign MNCs perform manufacturing and assembly activities in Singapore in 2014. A substantial number of MNCs have relocated these activities towards other more labour competitive countries in SEA, which has been addressed in the MNC cases.

The American firms comprise the largest share with 19 RHQs (24% of all American firms), Japan follows with 14 RHQs (21%). The number of Japanese RHQs is possible due to the given that Singapore has been evolving as the coordination centre in the region for Japanese E&E manufacturing operations, leading to an increase of high value activities of Japanese firm, such as RHQ and R&D (Edgington & Haytor, 2013). Notable is the high percentage of European MNCs with a RHQ in Singapore, as German (39%), Swiss (38%), French (25%), British (40%) and Dutch (80%) firm establishment have a high percentage of RHQ activities. The Asian MNCs, Hong Kong (10%), Taiwan (6%) and South Korea (50%) are less active in RHQ activities. This is possibly due to geographical proximity to Singapore.

Table 7.10: Function of establishments of MNCs in Singapore 2014, per origin.

Nationality	**GHQ**	**RHQ**	**R&D**	**S&M**	**Manufacturing & assembly**
USA	4	19	19	50	43
Japan	1	15	14	44	34
Europe	2	20	18	36	25
Asia	1	5	8	22	14
Other	0	1	1	2	1
Total	**8**	**60**	**60**	**154**	**117**

*Other includes Canada and Australia. Source: own data.

The development of foreign firms illustrate the changing role of Singapore as a regional and global hub in the E&E industry, with MNCs coordinating the manufacturing process in other Southeast Asian countries through RHQs in Singapore. High value added activities have been actively promoted by the government since the late 1980s. Through the successful strategic coupling processes, the government has continuously influenced the local environment to enable upgrading of MNC activities. The government and its institutions invested in the local assets, such as labour force, research institutions, infrastructure, and provided tax and financial incentives to the foreign MNCs, which 'fitted' the strategical needs of MNCs. Simple manufacturing and assembly activities have been replaced by high value added activities (table 7.10). As a result, the profile of the E&E industry became more sophisticated, since changes occurred in the investment and operating environments of MNCs. Present MNCs did not leave Singapore for other competitive countries, but modified their operations to high value added activities (Cooke et al., 2013).

7.6.2 Global headquarters in Singapore

With regard to the 8 GHQs, the breakdown of the nationalities reveals that 5 out of the 8 are established through a joint venture, with the majority (4) with Singapore as partner, clarifying the presence of the GHQ in Singapore (table 7.11). The other GHQs bring forth various reasons for the shift of their GHQ towards Singapore. For instance, Giken Sakata (S) Limited relocated their GHQ from Japan to Singapore in 1992 - as it was at the centre of their operations - and currently operates without an establishment in Japan (Giken Sakata, 2016). Mr. Fung of Giken Sakata mentioned 'the most strategic location' and the 'easy access to all customers and suppliers ' - as the most important market clients are located in Singapore, - as the main reasons for maintaining to be established in Singapore (Fung Kiat Ming, personal communication, 3 July 2015). Kulicke & Soffa Pte Ltd relocated their GHQ from USA to Singapore in 2010 for similar reasons, as it was in the centre of their market. Kulicke & Soffa Pte Ltd extended its operations in Singapore, and Singapore is strategically placed in their primarily Asian customers base, and well-positioned to capture growth opportunities in the Asian market. The strong partnership with Singapore, with its supportive government, emerging presence as a centre of excellence for science and technology development, and the leverage of a skilled workforce is a good fit for the firm (Kulicke & Soffa, 2014). Finally, Systems on Silicon Manufacturing Co Pte Ltd had been set up in Singapore due to the strong presence of the semiconductor industry (SSMC, 2016). The evolution of Flextronics has been addressed in the following chapter. The increase of GHQs, RHQ and R&D reflects the increased importance of Singapore subsidiaries in the GPN (and GIN) of MNCs.

Table 7.11: List of origin of GHQs in the E&E industry in Singapore in 2014. Source: own data.

Name of firm	**Origin**
ASJ Pte Ltd	USA/Singapore
Aurora Technology Pte Ltd	USA/Singapore
Dage (SE Asia) Pte Ltd	UK
Europtronic Group Ltd	Singapore/Taiwan
Flextronics International Singapore Pte Ltd	USA/Singapore
Giken Sakata (S) Limited	Japan
Kulicke & Soffa Pte Ltd	USA
Systems on Silicon Manufacturing Co Pte Ltd	Netherlands/Taiwan

7.7 Conclusion

Since the embarkation of the E&E industry in Singapore, the share of nationalities is characterised by a large presence of foreign firms. This chapter has elaborated on the evolution of different firm nationalities. As a result of the analysis of the four firm nationality groups: American; Japanese; European; and Asian, the fifth sub question can be partly answered:

5. "Are there differences between nationalities in terms of entry and exit patterns of foreign firms, and which factors explain these differences?"

The number of Japanese firm establishments in the city-state has decreased, especially due to the high exit rates in the 2001 and 2014. The number of American subsidiaries increased between 1990-2012, due to the entries between 2001 and 2012, and decreased between 2012 and 2014 due to a number of exits. The European and Asian firm establishments increased between 1990 and 2014, in which especially the number of Asian firm establishment increased significantly.

Between 1990 and 2008, the Japanese firm establishments have been the largest nationality group. In 2008, the American firm establishment surpassed the Japanese firm establishments and remained the largest group between 2009 and 2014. The decrease in Japanese firm establishment between 1990 and 2014 can be linked to their branch activities, as they were largely represented in declining branches, such as the consumer electronics and the PCB branches. The number of American firm establishments increased, because they were active in growing branches, such as the semiconductor, communication and CEM branches. Additionally, the American firm establishments were largely absent in branches that declined over the 1990-2014 period. Remarkable is that the number of Japanese firm establishments active in the semiconductor declined between 2006 and 2014.

In this chapter, multiple cases of the transformation and development of (lead) MNC subsidiaries in Singapore have been presented. Through this cases the fifth sub question can be answered:

6. "How has the position of position of Singapore in the production networks of MNCs in the E&E industry evolved between 1990 and 2014?"

The manufacturing and assembly activities performed in the 1990s have been relocated towards other countries in Southeast Asia, in which the portfolio of MNCs shifted towards high-tech and complex manufacturing activities. The subsidiaries have been upgraded to RHQs, controlling and navigating the subsidiaries that perform (low-end) manufacturing and assembly activities. A large share of the MNCs in Singapore have established R&D activities in the city-state, which were promoted by the government and were feasible due to the highly skilled labour force.

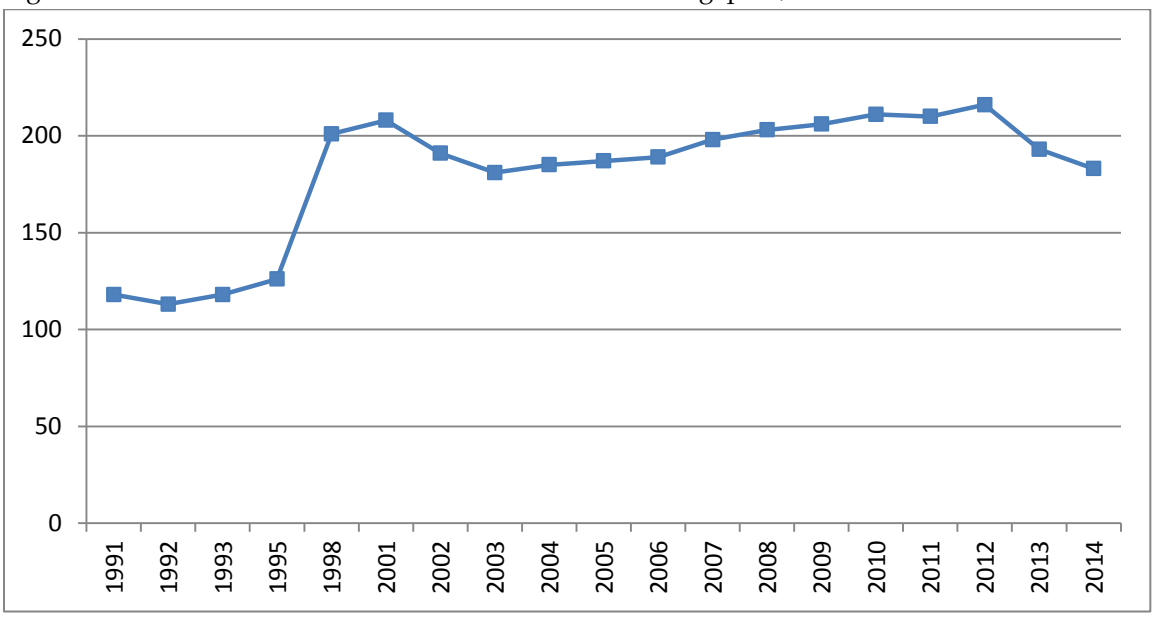
8. Evolution of local firms

Chapter 7 emphasised that Singapore is characterised by a large share involvement of foreign companies in the E&E industry. Besides these well-documented subsidiaries of foreign MNCs, the E&E industry is driven by a number of large indigenous firms and a large range of competitive small-cap local firms supplying components for major producers (Toh, 2013). This chapter focuses on the share of local firms and is divided into three paragraphs. The first paragraph focuses on the overall evolution of the local firm establishments in the industry in number of firms, entries and exits. The branches with a high share of local firms are also addressed in this paragraph. The second paragraph about regionalisation includes a breakdown of subsidiaries of local firms in Asia. The third paragraph includes the conclusion. Throughout the chapter, examples are presented of local firms that successfully grew out to MNCs.

8.1 Evolution of local firms 1990-2014

Between 1990 and 2014, a total number of 533 local firm establishments were active in the E&E industry, which is 44 per cent of the total firm establishments. In 2014, 183 of these firm establishments were still active in the city-state - indicating a survival rate of 34 per cent. This survival rate is equal to the survival rate of all establishments (34%) and the survival rate of foreign MNC establishments (34%). Of the 122 Singaporean firms establishments operating in 1990, only 23 firm establishments were still active in 2014. The average tenure of Singaporean firms was 6.5 years, which is slightly lower than the average of all firm establishments in Singapore (6.7 years) and lower than the average tenure of foreign establishments (6.9 years).

Figure 8.1: Number of local E&E firm establishments in Singapore, 1990-2014.



Source: own data.

The development of the number of Singaporean firm establishments shows resemblance with the overall development of all firm establishments: a high growth rate of firm

establishments in the 1998-2001 period, followed by a short period of decline and relative stabilisation, and a high decline in number of firms after 2012 (figure 8.1). The years 1998 and 2001 are characterised by a high level of firm entries. The highest growth of firm establishments was between 1995 and 1998, with a growth of 60 per cent, from 126 in 1990 towards 201 firm establishments in 1998 (table 8.1; figure 8.2).

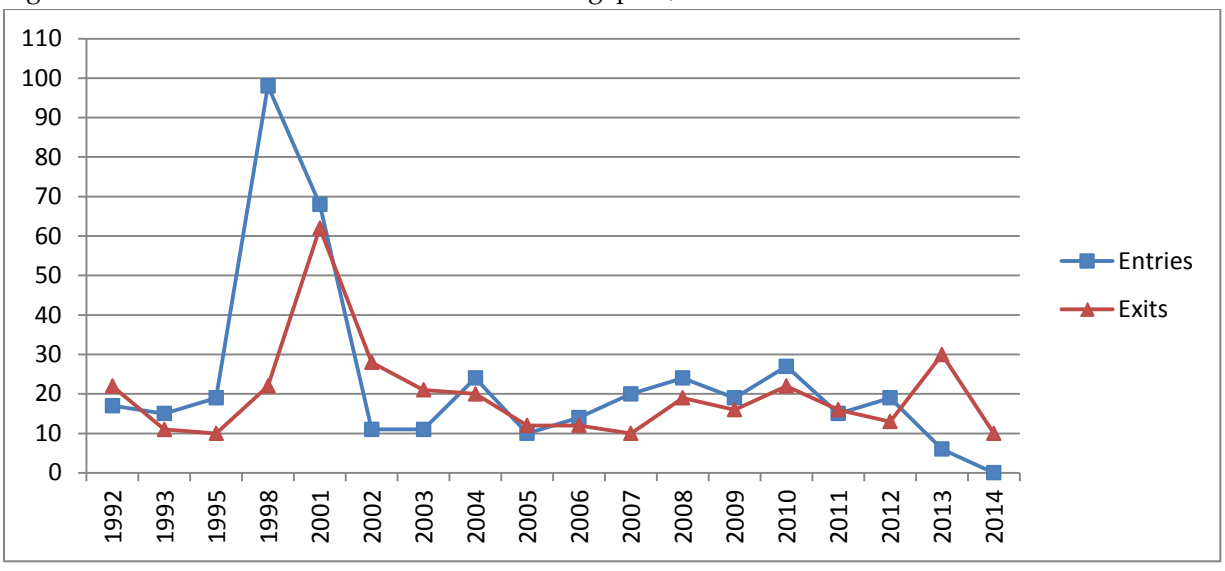
Table 8.1: Development of Singaporean E&E firm establishments, 1990-2014.

Year	1991	1992	1993	1995	1998	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total firms	301	297	304	314	435	473	447	451	456	454	442	446	458	466	477	460	481	429	412
Local firms	118	113	118	126	201	208	191	181	185	187	189	198	203	206	211	210	216	193	183
Share of total (%)	39.2	38.0	38.8	40.1	46.2	44.0	42.7	40.1	40.6	41.2	42.8	44.4	44.3	44.2	44.2	45.7	44.9	45.0	44.4
Annual growth(%)	N.A.	-4.2	4.4	6.8	59.5	3.5	-8.2	-5.2	2.2	1.1	1.1	4.8	2.5	1.5	2.4	-0.5	2.9	-10.6	-5.2
Entries	N.A.	17	15	19	98	68	11	11	24	10	14	20	24	19	27	15	19	6	0
Exits	N.A.	22	11	10	22	62	28	21	20	12	12	10	19	16	22	16	13	30	10
Balance	N.A.	-5	4	9	76	6	-17	-10	4	-2	2	10	5	3	5	-1	6	-24	-10

* includes joint ventures.
Source: own data.

The years 2002, 2003, 2013, and 2014 are characterised by a decline in number of local firm establishments. In 2013 and 2014, the amount of local firm establishments declined with 10.6 and 5.2 per cent respectively (table 8.1). Particularly the low entry rates in combination with high exit rates in these two years could indicate the start of a trend, in which the number of local firms active in the E&E industry declined (figure 8.2). The large decline in number of local firms in the 2013-2014 period is likely linked with the decline in output, export and value added rates over the 2010-2014 period (table 5.1), and the decreasing number of foreign MNC establishments in the 2010-2014 period (figure 7.1), as a large share of the local firms provides supplying activities to MNCs (Tung & Wan, 2012; Yeung, 2007).

Figure 8.2: Local E&E firm entries and exits in Singapore, 1992-2014. Source: own data.



The share of Singaporean firms has risen from 39.2 per cent in 1990 to 44.4 per cent in 2014 (table 8.1). The local firms have taken up an increased share in the economic performance of Singapore, as their output and export-value have increased significantly over the recent decades (Teng, 2011). In the 1980s, the government has shifted its focus towards the development of local firms, as the economy had become too dependent on foreign MNCs. Until the 1980s, the role of indigenous firms had been insignificant, as Singapore lacked experienced manufacturing entrepreneurs. The significance of local firms increased as the government and its institutions started promoting the upgrading process of local firms (Wong, 2000). The government initiated a number of training programmes, tax incentives, financial systems, and R&D schemes to support innovative activities of local firms. The number of local small & medium firms (SMEs) in the industry that perform R&D activities has increased substantially in the recent decade, as well as the R&D expenditure and number of patents (A*STAR, 2013).

With regard to the upgrading process of local firms, the collaboration with foreign MNCs was vital. The E&E industry in Singapore consists of linkages between leading foreign MNCs and local supplier firms. These linkages are characterised by mutual dependency: the foreign MNCs expose training and technologies to Singaporean engineers and technicians and create opportunities for supplier firms as they generate demand for local parts and component suppliers; while on the other side local supplier firms serve MNCs with cheaper products and services, and downsize employment. In order to continuously differentiate themselves from growing competing neighbouring countries, local supplier firms needed to offer high quality products, as foreign MNCs engaged in higher sophisticated manufacturing and assembly activities between 1990 and 2014. The sophistication levels of local firms increased through the collaboration with MNCs (Tung & Wan, 2012; Wong, 2000). For instance, Lin Xi of local PCB manufacturer BH Technologies stated that the upgrading of their products and the development of new products, to supply their MNC clients with higher complex products, were crucial in the survival and success of the firm. As the wages have significantly increased in the recent decades, engaging in higher product processes has been the only way to stay competitive in the city-state (Lin Xi, personal communication, 13 July 2015). Another distinctive example of the upgrading process dynamics of the E&E industry in Singapore is the case of AVI Precision Pte Ltd, the firm of Ronnie Wong, a supplier firm involved in TV manufacturing. Mr. Wong stated that the delivery of his ordered machine had taken too long (more than a year). In this period, his most important clients such as Thomson, Toshiba, Aiwa and Hitachi, had relocated their TV manufacturing activities elsewhere. These type of (partly labour-intensive) manufacturing activities were relocated as the wages in the city-state had become too high. As his company was unable to shift towards other production lines and unable to attract new clients fast enough, his company went bankrupt and his machines were confiscated by the bank (Wong, interview, 2015).

Besides the upgrading of their products, more local firms profited from obtaining detailed design skills and engineering learning processes of foreign MNCs. Since the late 1990s, more local firms have engaged in activities such as product design, R&D for new products and many have transformed from OEMs into ODMS, and even OBMs. The increase of local firms that have been involved in high value added activities, has resulted in an

increase of output and value added in the Singaporean economy (Lim, 2008; Teng, 2011). An example of a firm that followed the path of a small local supplier firm - upgrading their products and processes in collaboration with their MNC clients - into a firm that produces its own products, involved in ODM and OBM activities, is Speedy-Tech Electronics Ltd (framework 8.1).

Framework 8.1: Speedy-Tech Electronics Ltd.

1003. Speedy-Tech Electronics Ltd **established: 1985**

Speedy-Tech Electronics is established in 1985 as a supplier of transformers and switching power supplies, and currently focuses on the assembly of PCB materials and testing of finished products of various electronics applications. In order to adhere to the international benchmarks of accurate diagnoses and quality assurance, Speedy-Tech Electronics has adequate testing facilities for product verification, trouble-shooting, investigation and pre-compliance tests. Speedy-Tech Electronics is part of the IMI Group (Integrated Micro-Electronics, Inc.), a leading worldwide provider of electronics manufacturing services (EMS) and power semiconductor assembly, and has established relationships with customers worldwide. In 2002, Speedy-Tech Electronics won The Enterprise 50 Awards, which was a recognition for their contribution to the development in Singapore and abroad. The company's R&D activities have led to multiple patents (Sun et al., 2010; Zhang, 2000). Speedy-Tech Electronics has set up multiple subsidiaries in China, Hong Kong and the Philippines that are coordinated from Singapore (Speedy-Tech, 2016).

8.1.1 Representation of local firms in branches

Table 8.2 contains the absolute and relative shares of local firms per individual branch. The CEM branch experienced the largest increase in number of local firms between 1990 and 2014 (8 to 35). As a result , almost 80 per cent of all firms in the CEM branch in 2014 are of Singaporean origin. Other branches that are characterised by a large share of local firms in 2014 are PCB (63.3%), wires & cables devices (58.1), measuring (48.2%), and computer (47.4%). The previous chapters analysed the role of foreign MNCs in the development of the semiconductor, HDD and consumer electronics branches. Hence, the small share of local firms in these branches is not surprising (table 8.2). The relocation and technological upgrading of particularly the HDD and semiconductor manufacturing and assembly activities towards Singapore initiated the growth of supporting branches, like CEM, components and PCB. For example, supporting firms started carrying out PCB manufacturing and assembly activities for disk drive manufacturing MNCs (Wong, 2000).

The share in the components branch is relatively low, as firms from Japan and the USA followed MNCs to Singapore to supply their components (Dedrick & Kraemer, 1998). This subparagraph further elaborates on supporting branches, which are characterised by a high share of local firms.

Table 8.2: Representation of local E&E firms per branch, 1990-2014.

	1990		1995		1998		2002		2006		2010		2014	
Branches	**Abs.**	**%**	**Abs.**	**%**	**Abs.**	**%**	**Abs.**	**%**	**Abs.**	**%**	**Abs.**	**%**	**Abs.**	**%**
1. Consumer electronics	9	19.1	1	3.3	7	23.3	16	72.7	7	30.4	4	22.2	2	15.4
2. Semiconductor	9	28.1	11	29.7	13	26.5	17	21.0	23	29.5	23	26.7	20	28.6
3. HDD	0	0.0	0	0.0	1	8.3	3	23.1	0	0.0	3	27.3	0	0.0
4. Computer	21	51.2	22	46.8	30	55.6	5	10.9	23	51.1	25	46.3	18	47.4
5. PCB	39	53.4	49	70.0	63	63.6	8	10.0	47	74.6	33	94.3	31	63.3
6. Components	13	22.4	16	34.8	39	37.5	25	27.2	25	30.1	29	32.6	28	36.8
7. Communication	8	13.0	7	46.7	13	46.7	3	11.5	17	9.1	27	45.0	27	36.4
8. Measuring	3	44.4	4	33.0	7	44.8	3	30.0	1	54.8	3	21.4	4	48.2
9. Optical instruments	0	0.0	0	0.0	0	0.0	1	25.0	0	0.0	0	0.0	0	0.0
10. Wires & cable devices	12	52.2	12	60.0	19	57.6	11	30.6	18	78.3	19	59.4	18	58.1
11. Other electrical equipment	0	0.0	0	0.0	2	50.0	0	0.0	1	14.3	2	20.0	1	16.7
12. Electric motors	6	26.1	7	25.9	15	45.5	9	23.7	15	39.5	11	37.9	11	44.0
13. Batteries & accumulators	2	28.6	3	25.0	8	44.4	1	4.8	12	52.2	12	42.9	9	36.0
14. Other (incl. toys & games)	7	77.8	4	50.0	1	50.0	0	0.0	0	0.0	0	0.0	0	0.0
15. CEM	8	88.9	10	83.3	12	80.0	2	5.6	35	77.8	45	84.9	35	79.5

Source: own data.

The foreign MNCs initiated the development of some strong local firms that engaged in supportive activities to MNCs (Yeung, 2007). Two important pioneers in the evolution of the E&E industry, as illustrated in chapter 7, were the American MNCs Hewlett-Packard (HP) and Apple, which both conceived a networks of local supplier firms. Apple established a subsidiary manufacturing plant in 1981, called Apple Computer Singapore (ACS), producing PCBs for its end-products in the USA. This led to the emergence of a large number of local firms, producing PCBs and other components, supplying to ACS. Over the years, the subsidiary of Apple experienced upgrading, as it engaged in more sophisticated products, increased its production volume, and enlarged its R&D activities. Again, this led to an increase in number of local supplier firms in Singapore, as well as the increase of the sophistication-level of the products of these local suppliers (Borrus et al., 2003).

HP is another firm that initiated the growth of local supplier firms in the computer and PCB branches. HP gradually relocated more activities and responsibilities towards the Singapore subsidiary, where the subsidiary had been given control of their own product lines. The role and responsibilities of the local supplier firms increased as the subsidiary's importance increased; and even a number of spin-offs emerged in Singapore (Borrus et al, 2003). The most successful example of a spin-off is Venture Corporation, which developed its activities from supplying into R&D, product and process engineering, and manufacturing of some high-value and complex products. Over the recent decades, Venture has established an international production network, with a global presence of 40 subsidiaries and ranks 10th in the top EMS firms (Venture, 2016).

Two other local supplier firms that developed into global players are MMI Holdings and WBL Corporation Limited (Yeung, 2007). MMI Holdings, founded in 1989, manufactures components, computer peripherals and PCBs, and is a strategic partner of Seagate and other HDD companies. MMI Holdings has set up a number of establishments in Southeast Asia and China, and acquired competitors in both Southeast Asia and the USA. WBL was an important strategic partner to the Singaporean-based Motorola subsidiary, developing products and processes through this collaboration. In 2014, the company was active in components, PCBs and mobile devices and operates as a supplier firm for companies in the telecommunication, computer, consumer, automotive and industrial E&E industries (Bloomberg, 2016). Another local firm that developed into a world leading firm in the computer branch was Creative Technology, which has been an important supplier to global OBMs such as Acer, Dell and Intel (Yeung, 2007). Creative Technology has developed into a OBM, producing brand products in sound cards and other computer and related multimedia products (Creative Technology, 2016).

The previous cases illustrate that local firms were suppliers to the MNC subsidiaries, in which some of these local suppliers firms evolved into ODMs and OBMs, developing into global lead firms in their fields of expertise. The first forms of knowledge transfer in the E&E industry in Singapore went through the collaboration of supplier and contractor firms with MNCs, rather than through the development of government supported ODMs and OBMs, which has been the case in other Asian developing countries (Wong et al., 2005). In contrast to the other Asian Tigers, Singapore had not sent large number of students towards the USA for training in electronics technologies. Neither did Singapore experience an inflow of entrepreneurs of the Chinese mainland, such as Taiwan and Hong Kong. Local (supplier) firms in Singapore have successfully tapped into the knowledge flows of lead MNCs (Wong et al., 2005). Of these 'supportive' branches, the CEM branch is a somewhat deviating branch, as these firms can be involved in more than just the manufacturing of E&E-related products. Additionally, CEMs have evolved in terms of volume, complexity of products and processes, and scale of operation (Lüthje et al., 2013). Therefore, the next subparagraph elaborates on the development of CEMs in Singapore.

8.1.2 CEM branch

Contract manufacturers (CEMs) are firms that make products under contract of other firms. The use of CEMs by foreign MNCs increased significantly during the late 1980s, as a result of the internationalisation and fragmentation of the MNCs' value chain (Hutchinson, 2014; Sturgeon & Kawakami, 2010). As a result, the CEM branch in Singapore increased significantly over the 1990-2014 period. The CEM branch grew from 9 establishments in 1990 towards 53 establishments in 2010, and since then decreased to 44 establishments in 2014 Between 1998 and 2002, the CEM establishments grew significantly, from 15 establishments in 1998 towards 36 establishments in 2002. The vast majority of the CEM branch in Singapore is represented by local firms (table 8.3).

Table 8.3: Evolution of contract manufacturers by origin, 1990-2014.

	1990	1995	1998	2002	2006	2010	2014
Singapore	8	10	12	29	35	45	35
Foreign	1	2	3	7	10	8	9
Total	9	12	15	36	45	53	44

Source: own data. * Flextronics is labelled as a Singaporean CEM.

The increase in CEMs reflects the increased role of Singapore during the 1990s as a major hub for foreign lead CEMs and a large number of indigenous CEMs in the E&E industry. Singapore obtained this position due to the superior transport and communication infrastructure, as a result of the government investments, and the development of some strong supportive industries. The superior logistic infrastructure and central location were perfect conditions for CEMs to use Singapore as a hub to integrate the flow of parts and components from throughout the region (Wong et al., 2005). These favourable position attracted global CEMs such as Benchmark (USA), Solectron (USA), Flextronics (USA/Singapore), Sanmina-SCI (USA), Celestica (Canada) and Jabil Circuit (USA) to establish manufacturing activities in Singapore. Flextronics is often identified as a Singaporean CEM, as their headquarter had been relocated to Singapore in 1990 (framework 8.2).

In order to succeed, the CEMs have to be well able to adjust to the short product life cycle. Besides the necessity of efficient logistic connections, the CEMs generally require a good spread of technological support, enabling them to react on the dynamic market demands (SUTD, 2013). The various extended training programs for workers, technicians, and engineers; as well as the active involvement of industries trade unions, provided the (local) CEMs with the needed technological support. Additionally, the government's shifted its focus on local firms – providing incentives and support – promoting the upgrading process of local firms, including the local CEMs.

As the quality demand of the clients (MNCs) in Singapore increased, CEMs had to upgrade their products and operations processes (SUTD, 2013). An example of a Singaporean CEM upgrading their products was Giken Sakata (S) Pte Ltd, which significantly upgraded their products to meet their clients demands over the 1990-2014 period. Mr. Fung of Giken Sakata (S) Pte Ltd stated that their new products were more complex, describing the change in technology content of the product portfolio 'from simple mechanical to complex parts'. In this process, an increase in higher skilled employees and extended design and R&D activities was realised. In the past, Giken Sakata had been involved in the production of cassette mechanisms, CD changers, and floppy disk drives, which has shifted towards more sophisticated products ranging from automotive, medical and electronic products. Mr. Fung clarified that the increase of quality products has been a necessity in order to survive, as demand of their clients has increased significantly (Fung Kiat Ming, personal communication, 3 July 2015). This is in line with the trend described in the literature that the sophistication level of the CEMs has increased, as their clients demanded higher quality products and processes (Lüthje et al., 2013). In some cases, CEMs even took over the manufacturing plants of their customers (e.g. the factory operations of Apple were taken over by Omni Industries in 1997), deepening and consolidating the CEM industry (Wong, 2002). During the 1990-2014 period, an increased number of CEMs achieved

to develop their own products, performing R&D activities, and surpassed the role as component supplier firm or CEM, capturing a higher share of the value chain.

The aspirations of (smaller) local Singaporean CEMs to evolve into global players has come to a halt, as major acquisitions by the global players have taken place since the millennium. For instance, Omni Industries was taken over by Celestica Electronics in 2001; NatSteel Electronics got acquired by Solectron Technology in 2001, which subsequently got taken over in 2007 by Flextronics. Flextronics had furthermore acquired JIT Holdings and Li Xin Industries in 2001. Although the CEM is dominated by local CEMs in terms of number of firms, the above mentioned foreign CEMs dominate the branch output in Singapore (Lüthje et al., 2013).

According to Ronnie Wong (who owned a CEM), the rapid development of local CEMs has some unfavourable consequences. As the local CEMs became more competitive and sophisticated, they have become less flexible than their counterparts from Taiwan, resulting in the preference of foreign MNCs to cooperate with Taiwanese CEMs (framework 8.2). The Singapore environment has become increasingly difficult for the operations of CEMs, mostly because of the rising costs and possible labour strikes. Therefore, Wong states that the chances are likely that Singapore will lose ground in the CEM branch to Taiwan (Wong, interview, 2015).

Framework 8.2: Flextronics vs. Foxconn.

Flextronics **established: 1990**

Flextronics is founded in 1969 in the USA, and relocated their operational HQ towards Singapore in 1990. Flextronics is active in 30 countries, operating over a 100 sites, employing 200 thousand workers. The company has shifted to manufacturing, design, distribution and after-sale services activities, operating as OEM and ODM. In 2007, Flextronics bought Solectron for US$3.6 billion dollar, becoming one of the largest CEMs in the world (Flextronics, 2016). In 2014, Flextronics was the second largest CEM, ranked closely after Foxconn (headquartered in Taiwan), both exceeding a revenue of over $130 million, largely exceeding their rivals. The two companies are illustrative for the competition between the two countries in the electronics contract manufacturing sector. Both companies are suppliers to some of the largest lead MNCs in the world, including Apple, Sony and Nokia. The companies have engaged in active R&D programmes, and have sustained rates of worldwide awarded patents. Both companies illustrate the shift of the electronic contract manufacturing towards Southeast Asia, an in the recent decade towards China (Tung & Wan, 2012).

8.2 Regionalisation of local firms

Since the late 1980s, Singaporean firms have increasingly regionalised and eventually internationalised their operations (Sim, 2012; Yeoh et al., 2012). As the context emphasised, the government and its institutions promoted the outward look through its regionalisation programs, stimulating local firms to relocate their low value added labour-intensive manufacturing and assembly activities. The high wages (as a result of the implemented wage policies), the rising costs structures of doing business, and exploiting market expansion

overseas provided further incentives to the relocation strategies of local firms (Sim, 2012; Yeoh et al., 2012; Yeoh & Wong, 2010).

The high share of local firms in the industry that have established manufacturing subsidiaries abroad is illustrated in table 8.4. Of the 183 Singaporean firms active in 2014, 102 had one or multiple subsidiaries abroad, which is a share of 55.7 per cent. 74 of these Singaporean firms had one or multiple manufacturing subsidiaries established in either Batam, Johor, Penang or China; which is a share of 72.5 per cent of all Singaporean firms with a subsidiary; and a share of 40.4 per cent of all Singaporean firms (table 8.4).

Table 8.4: Number of Singaporean subsidiaries in 2014

	Total number of Singaporean firms	Singaporean firms with one or more subsidiary	Singaporean firms with subsidiary in Batam & Johor, Penang and/or China
Number	183	102	74
Share of total (%)	100.0	55.7	40.4

Source: own data. * Firms may have subsidiaries in more than one region.

According to Van Grunsven & Hutchinson (2014), subsidiaries of Singaporean 'MNCs' (referring to Singaporean firms with one or multiple subsidiaries abroad) were most frequently located in the SIJORI region, as their international network is governed by geographic proximity (Van Grunsven & Hutchinson, 2014, p. 33). Of the 183 Singaporean 'MNCs' in 2014, 31 firms operated a subsidiary in Batam and/or Johor (table 8.5; appendix 3). A total of 11 firms operated a subsidiary in Penang in 2014. However, our findings indicate that China was the most popular location among Singaporean firms for the establishment of subsidiaries, as 53 Singaporean firms operate one or more manufacturing subsidiaries in China. This is in contradiction with the assumption of Van Grunsven & Hutchinson (2014, p. 33), Finally, there are also cases of firms which have a presence at multiple locations: 12 firms operate subsidiaries in both China and Batam & Johor; 4 in both Penang and China; and finally 3 at all three locations (appendix 8).

Table 8.5: Number of Singaporean firm subsidiaries in Batam & Johor, Penang or China, in 2014.

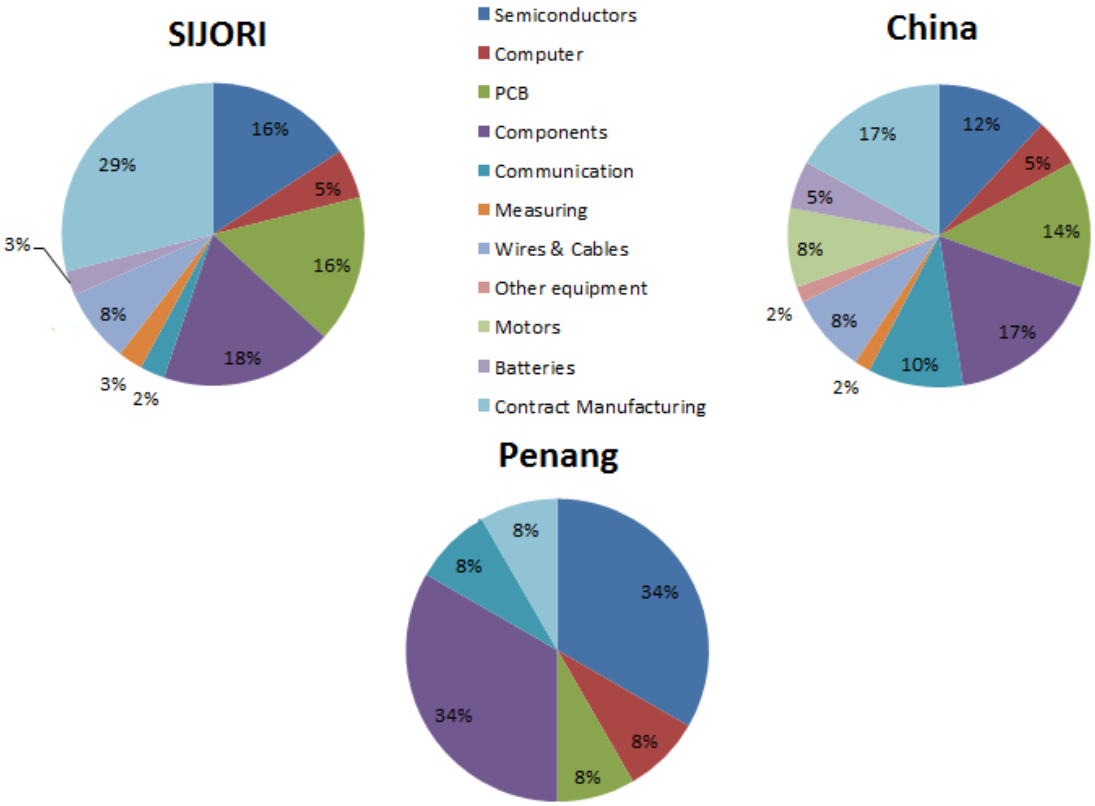
	Total	Batam & Johor	Penang	China
Number	95	31	11	53
Share of total (%)	100.0	32.6	11.6	55.8

Source: own data. * Firms may have subsidiaries in more than one region. ** Number of subsidiaries accounted per region.

The composition of branches at the subsidiaries of Singaporean MNCs in Batam & Johor, China and Penang in 2014 is presented in figure 8.3. In Batam & Johor, the share of subsidiaries involved in the CEM branch is 29 per cent, followed by electronic components (18%), semiconductors (16%), and electric motors (16%). The Chinese subsidiaries are involved in a greater variety of branches, with electronic components and CEMs as the two largest branches (both 17%). In Penang, semiconductors and electronic components (both 34%) account for the biggest representation of subsidiaries. Overall, Penang represents the

smallest variety of branches, which is possibly a result of the small number of Singaporean MNC subsidiaries present in 2014.

Figure 8.3: Share of branches of Singaporean subsidiaries in SIJORI. China and Penang in 2014.



Source: own data.

The subsidiaries in Batam & Johor regions mostly act as supplier of components and parts for Singapore (Rasiah, 2009), which is reflected in the share of Singaporean subsidiaries involved in the components (18%) and PCB (16%) branches. The Singaporean subsidiaries with semiconductor activities (16%) in the region are mostly concentrated in Johor, which has a higher level of sophistication than Batam (Visch & Van Oerle, 2014). The large share of subsidiaries of Singapore CEMs in Batam and Johor is the result of the increasingly offshored low value added (labour-intensive) manufacturing and assembly. However, the absolute number of CEM subsidiaries in China exceeded the amount of CEMs in Batam and Johor, reflecting the increased importance of China in the RPNs of Singaporean CEMs. These CEMs profit from the enormous scale advantages that China has to offer (Chan & Tong, 2014).

The number of subsidiaries in China involved in the semiconductor branch corresponds with the research of Brown & Linden (2009), claiming that China will be increasingly involved in semiconductor activities during the following decades, as a result of the investments in human capital (skilled labour and engineers), wafer fabrication facilities and R&D facilities. As a result, China has become a competitor of Singapore in this branch (Cooke et al., 2013). The shares of components (17%) and PCB (14%) indicate that subsidiaries in China act as supplier of components and parts, or assemblers of final products, which are then exported to Singapore.

The large share of subsidiaries involved in the semiconductor branch in Penang is likely due the evolution since the 1970s of the region into one of the clusters of semiconductor activities. According to Rasiah (2009), Penang is the second most sophisticated region in Southeast Asia (after Singapore) due to the strongly developed semiconductor branch, outranking the other regions in terms of levels of sophistication (Rasiah, 2009, p. 132). Both regions have been described as fierce competitors in the semiconductor branch. The number of Singaporean semiconductor subsidiaries is possibly an indicator of increased synergy between the two regions in the semiconductor branch, in which Singaporean MNCs can profit from the regional advantages of Penang (Rasiah, 2009).

8.2.1 Characteristics of regionalisation

There are multiple cases that illustrate the offshoring of manufacturing activities and upgrading activities in Singapore over the recent decades. For instance, Giken Sakata (S) Pte Ltd, briefly discussed in paragraph 8.1.2. Giken Sakata is originally from Japan, but relocated its headquarters to Singapore in 1992, and operates subsidiaries in China and Batam. In the recent decade, the product volume in China has increased significantly, mostly due to favourable regional which the available workforce, potential market, faster decision making by authorities, and access to a new market were important regional advantages (Fung Kiat Ming, personal communication, 3 July 2015).

Another firm case is A & One Precision Engineering Pte Ltd, which has also gradually relocated manufacturing and assembly activities towards Malaysia and Indonesia in the 1990s. In 1996, it established a subsidiary in Kuala Lumpur, and in 2001 in Batam. Soon after, in 2002, the Singaporean firm established a third manufacturing and assembly subsidiary in Wuxi (China). The expansion of this factory in 2005 illustrates the possibilities in China to produce on a larger scale. In 1998, A & One Precision Engineering expanded its Singapore facility and in 2006 it set up a second facility in Singapore. The original facility in Singapore focusses on HQ and R&D activities, where the second facility operates as a manufacturing facility of high-end products (A&One Precision Engineering, 2016).

Opulent Marketing Pte Ltd was established in 1988 as a manufacturer of electronic components. During the 1990s and early 2000s, the firm has gradually relocated its low value added manufacturing activities towards Shenzhen, China and Penang, and operates two sales offices in Hong Kong and Japan. Eventually, all manufacturing activities have left Singapore, with the local establishment remaining active in HQ, R&D, sales and distribution activities (Opulent Marketing, 2016).

Another example of a firm which has increasingly internationalised its operations is PCI Limited. This firm is originally from the USA, manufacturing PCB in Silicon Valley, but relocated its headquarters to Singapore in 1994 (while still operating a sales office in the US). The explosion of the high demand for high-technology products was the primary reason for the relocation. Since 1990, PCI Limited operates a manufacturing facility in Batam, which was ideal as a cost-efficient location. The relocation of the HQ to Singapore resulted more efficient management of the Batam facility. In 2000, the firm drastically changed its operations, as it entered the CEM branch. In the same year, PCI opened a manufacturing facility in Shanghai, which focusses on manufacturing activities in this branch. The facility in

Singapore focusses on HQ, R&D, sales and distribution activities, as well as assembly (PCI Limited, 2016).

8.3 Conclusion

This chapter addressed the evolution of local firms in the E&E industry. Therefore, the following sub question can be answered:

7. "How has the role and position of local firms in the E&E industry evolved between 1990 and 2014?"

Since 1990, the number and share of local firm establishments increased. The initial development of local firms in the industry was influenced by the relocation of economic activities of particularly American MNCs, active in the semiconductor and HDD branches. This initiated the development of supporting branches, such as PCB, components and CEM.
The upgrading of MNCs induced the upgrading of the local supplier base, as the local supplier companies were summoned to increase the sophistication level of their products. During the 1990-2014 period, there are cases of local firms that evolved from supplier firms to global players, like Speedy-Tech Electronics and Venture. The government actively promoted the upgrading of local firms since the 1980s. Globalisation and fragmentation of the production process, together with the investments of the government in developing Singapore into a regional hub, have amplified the development of CEMs in Singapore. Flextronics is the most outstanding examples, as one of the leading CEMs in the world.

As a result of the changing local environment – wages increased and the costs structures of doing business arose - local firms have increasingly relocated their operations towards other regions in Southeast Asia. The finding that Singaporean MNCs had more manufacturing subsidiaries in China than the regions of Batam and Johor, indicates that Singaporean MNCs could have a wider extensive regional production network than assumed. The presumption that Singaporean MNCs do not have a wide range of locational options for their subsidiaries, and that therefore it appears that "the role of the RPN is less important than the environmental attributes of a specific location in determining upgrading potential", is therefore up to debate. Additionally, the profile of the Chinese and SIJORI subsidiaries indicate that the two regions compete with each other in the semiconductor, PCB and components branches.

9. Conclusion

Throughout this chapter the main research question is answered, which reads as follows:

"How has the structure and the size of the E&E industry evolved in Singapore from 1990 to 2014, given the internal and external factors?"

The second sub question also focussed on the evolution of the industry as a whole, and reads as follows:

"Has the evolution of the E&E industry in Singapore from 1990 to 2014 led to industrial upgrading?"

The following addressed expectations are all related to these two questions. In this chapter, an elaboration on the evolution of the E&E industry is given. Along the way, whether upgrading has occurred in the evolution of the E&E industry is discussed.

Before we answer the main question, the industrialisation process of East Asia is addressed. Japan was the first country in the region that experienced industrialisation, followed by Hong Kong, Singapore, South Korea and Taiwan. The industrialisation process of Hong Kong and Singapore is strongly influence by FDIs of foreign MNCs, in contradiction to South Korea and Taiwan that focused on the development of indigenous firms. Especially Japanese and American MNCs have dominated the inflow of FDIs in Singapore. A second cohort of countries Indonesia, Malaysia, Thailand and the Philippines (referred to as the 'Tiger Cubs') embarked in industrialisation, in which the outflow of FDI from Singapore to these countries increased over the decades. In this process, Singapore has developed itself as a regional hub in Southeast Asia (Rasiah, 2009).

A major pillar in the industrialisation process of Northeast and Southeast Asia has been the E&E industry. In the late 1960s and early 1970s, the first investments by foreign MNCs in Singapore were largely concentrated on the E&E industry, as labour-intensive manufacturing and assembly activities were relocated to the city-state. In the first and second phase of the E&E industry evolution, the American firms have acted as pioneers, being the first MNCs to set up manufacturing and assembly activities in Singapore that initiated the semiconductor and hard disk drive branch, in which the Japanese MNCs followed the American at a later stage. In the early phases, Japanese MNCs have mostly relocated activities in the consumer electronics branch, using Singapore as gateway to the region. The consumer electronics branch has dominated the manufacturing investments until the mid-1980s. American and Japanese MNCs dominated the early phases of the development of the E&E industry (Borrus et al., 2000; Van Grunsven 2013; Edgington & Hayter, 2013). Our expectation that:

3. The American and Japanese MNCs have been the dominant nationalities in the evolution of the E&E industry between 1990 and 2014.

can be adopted, as the American and Japanese MNCs have dominated the number of subsidiary establishments in Singapore from 1990 to 2014. In the year 2010, the American subsidiaries surpassed the number of Japanese subsidiaries as largest group, followed by the European MNC subsidiaries in third place. The fourth group, consisting of Asian firms, has significantly increased in the recent decades. This increase was especially due to the increase of Taiwanese firm establishments from 1 in 1990, to 16 in 2014; and Hong Kong firm establishments from 2 to 10. The increase in foreign firm establishments in Singapore corresponds with the literature that Asian MNCs have increasingly participated in GPNs. The share of indigenous Singaporean firms has increased over the 1990 to 2014 period, possibly as a result of the government's effort to promote local firms.

Since the 1990s, the government and its institutions focussed on upgrading the economy. MNCs were stimulated, via a number of policies and incentives, to engage in higher value added activities. Through the strategic coupling process of MNCs' activities, the share of high value added activities (HQ, RHQ, R&D, S&M and testing) have increased. Of the total 229 foreign firm establishments active in 2014, a total of 8 GHQ, 61 RHQ, 60 R&D and 154 S&M activities were performed in Singapore. At only 118 foreign firm establishments, manufacturing and assembly activities were carried out, which covers just over half of the foreign firm population. The MNC subsidiary cases illustrated that the manufacturing and assembly activities performed in the 1990s, have been relocated towards other countries in Southeast Asia, in which the portfolio of MNCs shifted towards R&D and high-end manufacturing activities. The subsidiaries have been upgraded to RHQs, controlling and navigating the subsidiaries in Southeast Asia that perform (low-end) manufacturing and assembly activities. Based on this information the fifth expectation that:

> 5. The number of high value added activities of foreign firm establishments has increased between 1990 and 2014.

can be adopted.

The evolution of the E&E industry in Singapore is analysed with the concept of branching. As firms enter and exit certain branches, the industry evolves (Neffke et al., 2011). The firms in this research have been assigned to a particular branch. When firms enter or exit the industry, the composition of a specific branch changes, which changes the industry profile. In this research, the sophistication level of branches has been analysed. The development of the semiconductor and HDD branches initiated the development of other branches, such as the CEM, PCB and electronic components branches.

The relative increase of high sophisticated branches as HDD, semiconductors, communication (including the Infocomm sector), in number of firms, output and value added per product are in line with the expectations in the literature that the profile of the E&E industry has become more sophisticated over the recent decades. The HDD branch is an interesting case, as the number of firms active in the branch decreased from 12 in 1990, to 4 in 2014. The hard disk drive manufacturing has been gradually replaced by hard disk media, which is considered a higher sophisticated product group. The city-state accounts for 40 per cent of the world's disk media manufacturing in 2014. The consumer electronics branch has

been an important branch in the early phases of the development of the E&E industry in Singapore. Between 1990 and 2014, the branch has almost entirely left the city-state, as merely R&D, RHQ and S&M functions have remained. The manufacturing and assembly of the product groups covering the consumer electronics branch have relocated to more competitive branches, in which it is possible that the manufacturing and assembly activities in the branch will completely leave Singapore in the future. Especially, the increased wages have negatively affected the trajectory of the branch. The decrease of consumer electronics branch activities in the E&E profile is illustrative for a less-sophisticated branch leaving Singapore, as a result of the implemented policies. Based on this information the second assumption:

> 1. The evolution of the E&E industry has been characterised by a high degree of industrial upgrading, as high-sophisticated branches have increased relatively compared to less sophisticated branches.

can be adopted, as especially the semiconductor branch has relatively increased, contributing significantly to the increase of output and value added over the 1990-2014 period. The increase of the semiconductor branch is in line with the expectation that the profile of the E&E industry in Singapore has become more sophisticated (Lall et al., 2006; UN, 2009).

Due to the cost factors and incentives, MNCs started to shift activities out of Singapore (Van Grunsven & Hutchinson, 2014a). Our research has indicated that MNCs have shifted towards higher value added activities. According to Toh (2014), Singapore-based firms adopted several strategies, gradually abandoning Singapore and maintaining non-production activities in Singapore and engaging in higher value added activities. Based on the narrowing, specialisation and increased sophistication-level of the E&E industry, of which the increased sophistication-level and the increase in high value added activities of foreign MNCs in the E&E profile have been identified, the E&E industry in Singapore was assumed to have experienced a gradual decline in the number of firms. However, this had not been the case in the overall trend of number of firm establishments between 1990 to 2014. Between 1990 and 2001, the number of firm establishments has increased from 300 to 472 firms, which slightly declined in 2002. In the following timeframe of 2001-2012, the fluctuation in number of firm establishments was negligible. In 2012, the number of firms declined significantly from 480 to 408, however this period of time is too short to identify a trend. Therefore the second expectation that:

> 2. The number of firms has decreased between 1990 and 2014, as the profile of the E&E industry became more narrow, specialised and sophisticated.

cannot be adopted. The literature has provided a substantial number of examples of the government and institutions pro-actively investing, facilitating and promoting certain sectors of the economy. As mentioned, the government focussed on upgrading the MNCs' activities through shaping regional advantages that 'fitted' the strategic need of MNC activities, indicating a dynamic process. The government has invested in local advantages such as R&D, skilled workers, wafer fabrication facilities and focussed on increasing the

sophistication-level of the local firms. This would implicate that local innovation system (LIS) around branches have emerged. Three branches were analysed whether the existence of an ecosystem or LIS was present in 2014. The indicators of such an ecosystem were only identified for the semiconductor branch, based on the theoretical framework of Ferretti & Parmentola (2015). However the LIS indicated to be strongly (foreign) firm-driven, which is in line with the expectation that innovation systems are driven by firms. Although strongly firm-driven, the evolution of the LIS has been strongly supported by the government and its institutions. Especially the realisation of wafer fabrication facilities through joint-ventures between local firms and MNCs have been important projects for the government. For the HDD branch, another high sophisticated branch, a strong LIS has not been identified. However, the increased investments in skilled labour and presence of strong research organisations, such as A*STAR and IME, have been important reasons for Seagate and WD to perform their disk media activities in the city-state. Therefore, the expectation that:

> 4. Active government intervention and policy implementation have resulted in the development of strong innovation systems around dominant branches.

can only be partly adopted.

Between 1990 and 2014, the share of local firms in the E&E industry has increased substantially. Besides, since the emergence of the industry in Singapore, the role of local firms has changed significantly. During the 1990s, a lot of local firms were active in supporting branches, supplying components and electronic parts for foreign firms. There are multiple cases of local firms that evolved from roles as supplier firms into independent firms, excelling in a variety of branches. Based on these findings, the sixth expectation can be adapted, which was as follows:

> 6. The role and position of local firm establishments in the E&E has increased between 1990 and 2014.

Besides the growing role and position, local firms have increasingly regionalised their operations. The government and its institutions pro-actively stimulated the regionalisation of operations of local firms, as the economic profile had to shift to more high-tech and high value added activities. Therefore, the relocation of low value added activities were an important part of the regionalisation of operations of local firms. According to Van Grunsven and Hutchinson (2014), the RPNs of Singaporean MNCs are governed by geographical proximity. They assume that Singaporean MNCs do not have a wide range of locational options for their subsidiaries, and that it appears that the role of the RPN is less important than the regional advantages of a specific region in their location choice of their subsidiaries, determining upgrading potential. However, the number of subsidiaries of Singaporean MNCs in China largely exceeded the number of subsidiaries in the SIJORI region. The seventh, and final expectation that:

7. Local firms have increasingly regionalised their operations, with the SIJORI region as the most frequent location due to geographical proximity.

can therefore partly be adopted, as local have increasingly regionalised their operations. However, China has been the most frequent location.

This research attempted to cover the evolution of the E&E industry from 1990 to 2014, through analysing the development of the industry, branches, MNCs and local firms. Thereby it has identified indicators suggesting that upgrading took place, namely an increase in output, value added, decrease in workers and a relative increase of skilled workers. Besides, Singapore takes up a high position in the GPNs of MNCs, and the GVC. Finally, there has been an increase in sophisticated branches, especially due to the development of the semiconductor branch.

9.1 Future research

Future research will have to elaborate on the RPNs of Singapore MNCs, as our result show that more Singaporean MNCs have subsidiaries in China, than in the SIJORI -region. The assumption that the networks of Singaporean MNCs are based on geographic proximity is limited. Additionally, a number of cases have illustrated the globally diffused network of some Singapore MNCs, indicating that the production networks of Singaporean MNCs are less governed by geographic proximity than assumed. Further research may provide more detailed information on the 'scope' of Singapore MNCs' production networks.

A more detailed research on the ecosystems surrounding branches, especially the semiconductor branch, could provide additional information regarding the innovation processes. As the success of (semiconductor) MNCs in Singapore has been assumed to be a result of successful integration with the local supply base, it would be interesting to discover the 'uniqueness' of this system as the driver behind the evolution of the semiconductor branch in Singapore, in becoming one of the leaders of the world.

Finally, it is unfortunate that the 'Infocomm' is not included in the Times Directories as a separate branch. Besides a certain amount of active firms in the applications of ICT, a part of the firms are active in production and services. As the production in the branch comprise products such as, networking systems, mobile phones servers and storage systems, this branch has been a part of the communication branch. Recent published work of Van Grunsven (2013) has indicated the rapid increase in importance of the Infocomm sector in the economy of Singapore. A research that 'maps' the Infocomm sector, especially in manufacturing and services activities, could provide important insights in recent developments of the E&E industry in Singapore.

Due to the fragmentation and globalisation of the production process, we have seen increased dynamics in the networks and activities of firms. Shin et al. (2012) indicated that gross profits of different activities have increasingly shifted along the traditional smile-curve. A clear difference between OBMs, OEMs and ODMs has faded, and the dominant position of

the global lead firms to its 'local' suppliers has become increasingly complex, as firms have engaged in a number of activities and products. As well as the difference between S&M and manufacturing activities, in which high-tech manufacturing activities may largely exceed the value of most S&M activities. Future research may have to develop an alternative way to research the networks of firms, as the traditional firms networks increasingly complicated, intercalated and diversified at the same time.

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List of figures and tables

Chapter 6

Chapter 7

Appendix 1: Number of firm establishments per country**.**

Year	1991	1992	1993	1995	1998	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total firms	301	297	304	314	435	473	447	451	456	454	442	446	458	466	477	460	481	429	412
Singapore	118	113	118	126	201	208	191	181	185	187	189	198	203	206	211	210	216	193	183
Japanese	76	82	83	84	101	109	100	101	94	90	88	87	87	83	78	72	74	69	65
USA	67	62	61	61	75	83	80	81	88	88	83	83	87	93	95	87	92	78	77
European	31	30	31	32	37	53	53	59	55	56	54	49	49	49	58	56	59	50	50
Asian	4	6	7	6	16	17	22	25	29	30	27	27	30	34	34	34	38	36	35
Other	4	3	4	5	5	3	1	2	3	1	1	2	2	2	2	2	3	3	3
Share (%)																			
Singapore	39.3	38.0	38.8	40.1	46.2	44.0	42.7	40.1	40.6	41.2	42.8	44.4	44.3	44.2	44.2	45.7	44.9	45.0	44.4
Japanese	25.2	27.6	27.3	26.8	23.2	23.0	22.4	22.4	20.6	19.8	19.9	19.5	19.0	17.8	16.3	15.7	15.4	16.1	15.8
USA	22.3	20.9	20.1	19.4	17.2	17.5	17.9	18.0	19.3	19.4	18.8	18.6	19.0	20.0	19.9	18.9	19.1	18.1	18.7
European	10.3	10.1	10.2	10.2	8.5	11.3	11.9	13.1	12.1	12.3	12.2	11.0	10.7	10.5	12.2	12.2	12.3	11.7	12.1
Asian	1.3	2.0	2.3	1.9	3.7	3.6	4.9	5.5	6.4	6.6	6.1	6.1	6.6	7.4	7.1	7.4	7.9	8.4	8.5
Other	1.3	1.0	1.3	1.6	1.1	0.6	0.2	0.4	0.6	0.2	0.2	0.5	0.4	0.4	0.4	0.4	0.6	0.7	0.7

	8 year period (1990-1998)	8 year period (1998-2006)	8 year period(2006-2014)
Singapore	39.2	44.0	44.3
Japanese	24.6	22.8	18.8
USA	21.3	16.3	17.7
European	9.3	10.4	10.0
Asian	1.3	3.6	6.6
Other	1.3	0.4	0.4

Source: own data.

Appendix 2: Interview Ronnie Wong

Interview with Ronnie Wong - Chief operating officer at AIES: Association of Electronic Industries in Singapore. Singapore. 25 June 2015.

Hjarald: "Thank you for having us here, Mr. Wong. Could you explain to us what kind of organisation AIES is?"

Wong: "Yes…what now…our association do is…we try to bring business opportunity to our members. Normally, our members or any business they will be looking for, come for mainly two things: one is funding, to help the company grow; two…business. What funding concerns, we can't do anything…we don't have the money to fund our members and our government have their own agency since this is SPRING, who provide funding for Singapore company and it is 100% managed by SPRING. So, the next thing is bringing…to bring business for our members, which we are concentrating at the moment, is to bring our members oversea for exhibition, so to look for business…cause Singapore is too small."

Hjarald: "Your main focus is taking companies overseas then?"

Wong: "Oversea yes. Because if Singapore company remains in Singapore…none of their can grow because our market, our size, is just too small. And there's just too many entrepreneurs…everybody wants to be the boss, because it is easy to set up business, easy to get financing…you can go to the bank, you want to buy some machine and start a company in this country is very easy. So there is a lot of entrepreneurs, a lot of this companies, a lot of business set up…small, small companies…one man show, two men show, three men show, like that…But, when you get a business, Singapore is just too small…it's just too small…for everyone. So, Singapore company must go oversea. So we have to look at Asia as our market, not just Singapore, we look for Asia and Singapore company have been doing it, looking Asia for thirty, forty years, because Singapore company know that you can't survive just concentrating on Singapore. So, what we do as association, we add in finding some good shows, especially around Asia and in seek government founding, which is AIE Singapore. And AIE Singapore, the role is to bring Singapore company out…EDB is to bring company into Singapore. So AIE Singapore, international enterprise Singapore is to bring Singapore company out. And…so we get…funding for AIE Singapore, when we bring this Singapore company oversea for exhibition."

Hjarald: "So there is like a bonus system for AIES, when Singaporean companies go overseas?"

Wong: "Yeah, we get subsidies back…yeah, we get subsidies back. And further away, the further away we bring them, the more subsidies we get back. Because if we go to the US, or Europe, it is very expensive to exhibit their travel and stay there…and the government is prepared to help by giving some high subsidies. So we are very good in doing business and

most our members are…happy to join us, because we provide this facility. So we are…we concentrate all our energy on bringing members oversea to take business opportunities."

Hjarald: "Which countries are mostly targeted by the AIES?"

Wong: "OK…most, right now…right now, the most…important countries to go is Vietnam…Vietnam, followed by Thailand…third Philippines…four, India…fifth Indonesia…then, Malaysia. Why Vietnam? Some Japanese and Korean are moving in and they are going big in Vietnam…you know…the Japanese have some relation…relationship problem to go to China. Actually China supposed to be the factory of the World. Everybody is supposed to go there, because of the population and the market. You…you…if you…if you want to expand, you want 10000 worker by next month, you can get it in China. You can, haha, if you want…you want 10000 worker in USA, the recruitment agency will say: "Sir, you got to give me one year", you know, hahaha, you know, you got a lot of time. But in China, you advertise and they queue the people outside, waiting. So, if you want large size factory, you have to go to China. But unfortunately, the Japanese are having some relationship problem with China. So they are fear, because…once there is a problem, they boycott Japanese product, you know, so if they would boycott the Japanese factory, you will be big trouble, if you have a huge factory in China and it gets shut down, you, you will be in big trouble. So, Japanese, even the Korean are looking for opportunities. They do have presence, big factory in China, but they are looking for other opportunities, in case there is a problem in China, when a mystery is running, Vietnam is better to getting over. This is true for many industry and it happen in many time, like few years ago Thailand when there was a great, when there was a flood, many factories was flooded and everything stopped and Western Digital move out their production to Malaysia. They have a small operation in Malaysia, but away was in Thailand, because Thailand was flooded, they had to move to Malaysia."

Hjarald: "So it is more about risks, then about costs? Or is it a combination of both?"

Wong: "Yes. I would say costs, they consider cost also, because if they don't consider cost, then they won't go to…they won't go to Vietnam, they go to Malaysia, this is more established, but Vietnam costs is much lower than Malaysia."

Hjarald: "Is in that case, maybe China getting 'too expensive' for companies?"

Wong: "Yes, maybe the cost gap is narrow. Then, what they offer, Vietnam and Thailand, you know Thailand today, for Asia, Thailand is more like a powerhouse now as far as manufacturing offices, because of the closeness to China. You see, Western D and Seagate…the two largest hard disk manufacturer…and they make most of the hard disk in Thailand. Why they make in Thailand? Right, the market is in China, all the PC, laptop and their stock is assembled in China and why they go for example in hard disk drive in Thailand? So, they are good reason why they want manufacturing in Thailand. Why, probably, they have been there for a while. Singapore was the world's largest hard disk

manufacturer before and one by one they move to Thailand and maybe because of costs. And they are comfortable in Thailand, because the factory is very productive…and they have moved some operations to China, but they do face some problem, sometimes IP situation…today you show someone your product…you know…tomorrow someone would say: "I have this here". Someone can copy it very fast in China. So maybe because of that, one other problem, because that's a key problem."

Hjarald: "Is the Singapore government trying to keep the hard disk companies in Singapore, and are they successful?"

Wong: "Yeah. Haha…it was effective for a few years. Eventually, the Singapore are all gone and what Singapore government managed to maintain is the media…the media…which goes into hard disk drive…is still made in Singapore, and Singapore is still the number one of that media. So the outside, the body, maybe Thailand and anywhere…but the heart is made in Singapore. Why Thailand and Vietnam? One good reason is because they are next to China and you can truck your product into China. Okay? The hard disk drive go into China, and you can truck into China, cheap and good you stock, because it is easier to truck than to ship or to airfreight…airfreight cost…ship go round the South China Sea…the risks higher and in time…but trucking from Thailand into China, into the factory to deliver all your hard disk drive."

Hjarald: "Are the roads built by China? Or do the companies also invest in better roads?"

Wong: "Yes…but, yeah…so even Chinese company moving southern, moving to Vietnam…because three years ago they have some problem, South China Sea, they buying the Chinese factory in Vietnam. But, Chinese do oversee the opportunity, because if Japanese and Korean are going to Vietnam, some Chinese company better go there and they can get some order from these…yeah…today Samsung is huge in Vietnam, especially in Hanoi, part of the mobile phone and the LCD TV, making in Vietnam now."

Hjarald: "Are the higher value-added activities, like R&D, shifting abroad as well, or do they stay in Singapore?"

Wong: "Okay…in economy generation, there is three parts: one is to create, so you create a new product, new process, new material, new apps, new software, which is created. After you create, you manufacture…making. Because, after you create a product, after you make, you sell…you make money. Third is manage. That's why: the business manages the money. So there is three steps: you create, you make, then you manage your business. Singapore is small and less of population and size, Singapore can be very choosy. So, Singapore want to concentrate on the first two. Most important thing is to create, that's why in Singapore today there is a lot of business park, not industrial park, business park. And Singapore is encouraging the creation…R&D, research, researcher, scientist…all these people are, they can create something, because if you, if you create something, it can be very small, very new, like apps, you know…one man can create good apps, and it's worth millions of

dollar…okay? There is big wealth, of course in managing…but, if you…in Singapore encouraging creativity in Singapore. You create an app, but after you create your app, you sell for 200 million or so, you bring your money back to the US and you say: "US, California, enjoy your sunshine". Singapore lose everything, you know? So Singapore is encouraging you get your apps, do your research, create here in Singapore. After creation, you must manage your business here. You can go back to California and enjoy the sea, but the business is managed in Singapore. Stay here. And money stay here, because you can take back some money to California, but the money stay here, the daily money you collect got to be channelled to Singapore. So the Singapore economy still benefits, because the daily money coming in and out. So Singapore are to concentrate on the two, and leave the manufacturing to some other people. And, we have been doing it since mid-90s, because before Singapore is…in the 60s Singapore encouraging manufacturing…you know…encouraging Japanese, Americans, to everybody to come here. Semicon…first semicon assembly came here in 1969. First electronic, or consumer electronic manufacturing came here in 1967. In those days they made cassette player, the portable radio with the cassette player. So, they came in 67 and in Asia, Singapore was the first one, the Japanese, when the Japanese leave the shore, the first place they look was Singapore…they came. And in…by the end of 95, all the consumer electronic manufacturer…100% out of Singapore. So as far as assembly concentrating in Singapore, all gone…you know, all gone in…We migrate from radio cassette to TV…one time, all the TV branch, Matsushita, Mitsubishi, Aiwa, Toshiba…everybody was here, all assemble for export. Then they add the videorecorder, the VCD, the videorecorder…everybody was assembling here, but second half of 90s…is 95, beginning of 96, all are getting out of Singapore, because some move to Malaysia and abroad, some move to Thailand, and some try Indonesia, but eventually also get out."

Hjarald: "How is the relationship between Singapore and Johor/Batam at the moment? Because we see that a lot of Singaporean companies perform manufacturing activities at these locations, but manage these activities from Singapore. Are Singaporean companies still interested in Batam and Johor, or are they already focussing on other locations, like Vietnam and Thailand?"

Wong: "It depends on what product they are looking at and what's their volume. There are some electronics or electrical products, but because the volume is not that huge…so it is better managed if you sub it to Batam, or if you sub it to Malaysia. But if the volume is huge, then you'll be advantage to sub it to further away, maybe China, because China is the cheap, but they want volume…they want volume, if no volume, they are not talking. So if your volume is not that big, I think Malaysia and Batam is still attractive for alternative. And not only Singapore companies, government is encouraging to create…Singapore government is asking all companies…all nationality to encourage their…to move to Singapore, move the R&D, the creation part of your company, move to Singapore…and the government is help…if you move, can be Siemens, can be Panasonic, you know, if you move your R&D to Singapore, the government will help, the company encouraging."

Hjarald: "Is this an effective policy?"

Wong: "I think it is an effective policy, because there are many company have moved their R&D to Singapore. Siemens: huge R&D staff…even Seagate: they can make the hard disk drive in Thailand 100%...they are going to set up the R&D here and they are going to set up a new business park near here…is 100% corporate R&D."

Hjarald: "Is this all because of policies, or also because of human capital: the diffusion of knowledge which is present in Singapore?"

Wong: "Yes…okay, years ago, when HP came out with inkjet printer, inkjet printer…it is not open to everyone, but what we understand is that Singapore government push HP and fund their further development…okay, but you have to keep this business in Singapore, maybe for twenty years. And I don't know how much money for exchange, Singapore government funds HP to further develop this inkjet printer. And in…after that the manufacturing of this inkjet printer…done in Singapore…okay…HP do not want assemble, not assemble, but they have to sub it to someone in Singapore, so that manufacturing was in Singapore. So, manufacturing of this inkjet printer business is in Singapore. And now that period is over, HP can move anywhere, you can get it done, sub it to Chinese company place in China, it doesn't matter, but that period is over. And Singapore benefit immensely with this strategy. They fund your R&D, but you keep your business here. So, financially the Singapore economy benefit. So, this is still happening…okay…we know of a lot of companies…it can be electronic, it can be in aerospace…if you can move your R&D, your creativity to Singapore, Singapore government prepare to help financially to support that thing and then you have to manage whatever come out, you have to manage it in Singapore."

Hjarald: "Do you think that for the next twenty years, the high-end manufacturing will leave Singapore as well?"

Wong: "It is possible that those will leave. But what remains in Singapore, what will come in Singapore…I really can not predict, because I was fascinated when I look back what was happening…I never predict, I think I know this will happen…you know…even my own business…you know…when the TV manufacture, all the TV manufacturer was here, I went into sup-con, I become a sup-con for so many brands, for Thomson, Toshiba, Aiwa and Hitachi…everybody need, because of the volume, they can't cope, so they are looking for sup-con: "can you do 2000 parts for me every day"…you know…so I went into sup-con…I buy machine and I could not cope with the business and I order machine and I wait for one whole year for the machine to be delivered, but the time when the machine arrive, I am no more contract…my customer is moving out. So I never predict this would happen. I thought this was just the beginning…so I would try to buy as many machines to be a sup-con…I even get a job from Sony in Malaysia, they could not find enough sup-con to assemble the parts for them…TV only, just the TV part, this is a big part…and I dare not to even cope to the customer, costumer ask me to cope, I do not cope…because if I cope, maybe three day later they would deliver a container of PCB to my factory…see: "I want the first article to be developed by three day times for two day"…you know…so I would not…when I cope, I can

not order…I can not do for that…so that was a scenario…and it changed suddenly, I got short on my line, I big financial problem and I had to shut it down. Even…no, only in Singapore, it happened in Malaysia, Johor. When TV and video was a majority in Singapore, the audio part, the radio cassette…car radio cassette, the whole radio cassette, it was concentrated in Johor, Malaysia…they concentrate…there are so many: Aiwa, Anchor, so many are there. So I set out a factory in Johor to be the sup-con, to do the audio part, audio part and other smaller part…the business was very good also. But suddenly I got caught…suddenly everybody was getting out, they were moving away…and no more, no more audio product contract for me…and I got working in Johor Bahru, no job, machine are not running…Singapore, the same thing also. So I never predict this would happen and that break me down. I was making good money and when that happened, I finish, because I borrow huge amount from the bank… as I told you, for entrepreneur it is very easy here…the bank is very relent to lend you as long you buy your machine, because if you don't pay, they can pull back the machine…so it is a secure loan – so it is very easy, you go the bank and say: "I want to buy a machine". They provide you the loan and spread over five, seven, ten years the repayment. So it is very easy, very easy and when that happened, I got caught: the factory not running, no money and I got to pay the bank…so I get into trouble financially. So I can not predict what would happen. I will not know what will be the scenario right? I hope…I hope a reverse…at one time everything go to China…now by China, bit by bit is getting out…you know…things like, all the big consumer electronics, big consumer electronic or electrical product, washing machine, fridge, TV…no longer 100% assembled in China. Last time, yes, but today, no longer. Because…because they are getting so huge, the TV are getting so huge and to ship that from China to Brazil is expensive and very time-consuming. You know, if it take a month to reach Brazil, or even to Europe, maybe it take two weeks, three to four weeks to reach Europe and you still got to truck overland to another European country. So big electronic products or little products are not longer to be assembled in China. And what I understand is the TV manufacturer, they are still contract manufacturers…the TV manufacturer all the basics are the same: do what I ask…then they label and pack differently, maybe this is for Sony, this is for Hitachi, this is for Samsung or what other brand in Europe, maybe this is for telephone company, this is for…so all leads to an end: the casing, the boxing, the manual are different, but the first part: all the same. And the contract manufacturer today, they source all the material for you. You give the specification, they get all the material for you. Even China, it is the same. Like iPhone…Apple don't buy any other parts. Apple would develop with supplier and qualify those parts: the connector, the casing, the switch and will qualify them. So why should they qualify? The least qualified the supplier is, I give it low costs. I give low costs to every low qualified supplier in Asia. So Apple buy nothing, off course you can buy the material. And…why…why…why China? Today for example, almost everything and huge volume…all these contract manufacturer in China…most of them are Taiwanese…and Taiwanese is a different breed of Chinese. They are not the normal Chinese, like Singaporean or Hong Kong Chinese. Taiwanese is a different breed of Chinese. Anything a Singaporean can do, a Taiwanese can do much better. Eating or drinking liquor: they can drink more than any Chinese. Eating spicy food: the Taiwanese can beat you. That's why Chinese…Taiwanese when they move to China, they become so successful. Because they are

very deterministic: everything they do, they want to be the best. Okay, they are very aggressive. They can be drinking all night and in the morning they can still go to work, and you go like…and they carry on. I got hangover. And it works, they cooperate. How Foxconn can get iPhone order? iPhone today say: "I want every month 20 million iPhones 6 out". Next week, iPhone can tell Foxconn: "No, no, no, no, sales is good, now we want you to increase to 30 million. Okay? When we sign iPhone, Apple can go to cost low, sales is deep, cut it out. 10 million a month. How can Foxconn react to this market? Really this market figures. How Foxconn can take it? Foxconn share the product with all the supplier. Okay? Foxconn want plastic company who make plastic parts, plastic for computer, for desktop. Okay? They, the Taiwanese, even though they are competitors…you are plastic maker, plastic injection…for Singaporean, you are my competitors and my enemy, you are my enemy, because you are chasing for same order, you are fighting for same order, you are fighting for same order…enemy, enemy, enemy. Taiwanese, no: "we are all brothers…we are all friends…okay? If there's an order, let's work together, let's go, get it and share! Get it, share! Get it, share! So Apple say: "thirty % out scheduled…no problem…you take two, two, two, two, two…okay?...cope, cope, cope, cope"…they share everything. They are very flexible, because not one people carry the product, they share it."

Hjarald: "Do the Singaporean contract manufacturers also need to be flexible in order to survive?"

Wong: "Yes. Unfortunately, Singaporean CEMs…we are not that flexible. That's why we feel in many indicators: one of the joke was, when a Singaporean manage a factory of Chinese workers, the Singaporean will commission a strike. When a Taiwanese manage a factory of workers, the workers will commission a strike. You know that…that Foxconn…you know…Taiwanese are so strict in managing, the worker can't take it…the worker commission a strike, they can't take it anymore. How cruel is the Taiwanese management control? The control is just so tight, that worker can't take it. When no Singaporean…we are so weak…the worker make a story wire …the other way around. So Taiwanese is, I already said that, a different kind of Chinese. They are so powerful, controlling the people and they get: "no worker should talk about what we do in the factory", the moment you exit…nobody should talk about it. I think when Apple i6 come out, I see you think: "how nobody knows?" There are hundreds of workers inside there, none of them there dare to talk about it when they leave. So, reporter company of would be interested in…there is a lot of companies that is interested in how the iPhone would look like, because they want to make the casing. The moment i6 is launched, the casing is available, and the first, the first one to come out with the casing will make a lot of profit, because in one week time, there will be hundreds or thousands of brands come out, then you get fucked. Then the price drop. So everybody want to know how iPhone, i6 is look like. So you get the casing and prepare all accessories. But, hundreds and thousands of worker in this factory don't talk about it outside. How they can control? How they can control the people? So there must be…there must be…really the Taiw is really powerful. They are able to make the worker shut up the moment they leave the factory. So nobody knows what is happening inside the factory. The worker can't even look

up when the control is passing by…or higher management passing by, not even allowed to look up. "You just do your work, twelve hours, and leave and shut up, keep quiet"."

Hjarald: "How do you foresee the future of American and Japanese firms in Singapore?"
Wong: "Yes…the manufacturing part has gone, both for American and Japanese. But, we are encouraging regional HQ or R&D to be here. And then we have one advantage among all Asian countries…Singapore is number one in Asia in three advantages…one is the language, trilingual…a lot of Singaporeans speak three languages. So is Malaysia and what happened is in Malaysia the back-end office operation is very huge industry now in Malaysia, because initially those call-centres go to India and Philippines because they speak English. But, not many Indians or Filipino can speak any other language. But Singapore and Malaysia have got that advantage. We speak three languages. For me, you are a kind mister, you speak two languages frequently. So we have our advantage to be the call-centre. But unfortunately…unfortunately Malaysia is not looking for call-centre. This call-centre is low-end, Philippines can have that, but we go for back-end office operation. I mean, the HSBC bank can be here, but HR is sitting in Malaysia, in a cyber city…there is many cyber city set up in Malaysia. Even IPA, RBS, Standard Chartered, even pharmaceutical companies are setting up back-end office operation in Malaysia, because the costs are low and they have very conducive…very conducive turns. So, a call coin is gone to Malaysia. Even IBM, if you want to buy IBM hardware or software, you can't go to Singapore, you need to go to Malaysia. And if a bank got no avid company who buy and manage their bank because of the costs, then they will give it to IBM and IBM hosted this centre in Malaysia. So all, all the companies important to Malaysia, any program support is in Malaysia, banking and business is in Malaysia. This is very big industry now in Malaysia. So the first cyber city in KL, they are now all over Malaysia. And this, they call it back-end office. So for, in Singapore I believe, the American and the Japanese will maintain their presence here. But not manufacturing, but maintain their RHQ here, because of the language, the language capability we have and the connectivity and like…time to process things…things work, you get things done here fast. You want to do something, you want research something, you want finance something, you get this out very fast. So I believe this was attractive to attract American and Japanese. To let the HQ remain here, or maybe move the HQ to here."

Hjarald: "Do you think Singapore will stay the financial node of the ASEAN countries?"

Wong: "Yes, you see, Singapore and my members, when we bring oversea for exhibition, this year…they can beat a similar company in Malaysia or even Thailand, they are selling to, and they can sell cheaper than Singapore, but people still want to buy from Singapore for one good and best reason is: today everything you buy from big iPad to small tiny chip can be fake, even fake iPhone…you get so many fake iPhone…so, you…if you, if you are buying a chip to put into your product, you want it to be reliable. You do not want…haha…to buy fake chips and put inside and break down later and spoil your reputation. So, the cheapest way…the safest way is to buy from a Singapore company, because if this Singapore company supplies you a fake, you sue the company, you get a hearing in court, you get justice down, you get settlement, very fast. If you sue a China company, you are further

away, maybe your son…you don't get a court hearing. By then, the guy who has closed the show and moved somewhere else. Is waste of money, to get a lawyer to file a sue. Not only China, it can be in Malaysia, it can be in Singapore…I'm sorry it can be in new Asia, in Thailand. It is difficult to get justice. But in Singapore, it is easy and efficient and fast to get justice, so that's why people from other countries…if it is critical…better buy from Singapore. Good reputation."

Hjarald: "Finally, we would like to ask some questions about the organisation itself. How many members do you have? Are all members still manufacturing in Singapore? And is it voluntarily to join?

Wong: "We have 200 members, all in the electronics. Almost non-existent manufacturing. Most of them, they have moved the manufacturing operations to elsewhere. Or they have stopped manufacturing and just get from someone and then…so most our members are agents today…or get some agency of which they get some products from and sell. So most our members, I consider as trader. And they are volunteers and they pay us 300S$ member fees a year, which is actually insufficient to run an agency. We are 42 years old association, but we make money to cover our operation costs from the trade shows. We bring our members overseas for a trade show. We trust the company and…we identify the show we want…say, after next week we are going to Bangkok for Nepcon Thailand show, which is a big electronic show in Thailand. So, we know how to find…this show is the biggest in Thailand. Every country we look for the biggest show in that country. We talk to the organiser: "I got to bring a group of Singapore company to your show, give us better rate." So we earn from the rate and we earn charging our members who come with us and we charge them with a fee. So, a member or a company can join us and pay 300S$ a year, but if this company join us at five shows, we make five times more from him, because every show we charging 300 entry fee, to come with us. You know, because of the work we do, we get the ground and find the funds abroad. So we make a lot of money for this entry fee we charge this company who follows us overseas. And then off course the better rate caught from the organiser to us, we make the difference, so that's how the association survive from all these funds."

"We tried a lot of things to assemble members, but it didn't work. Because Singapore, the majority is Chinese and the Chinese always want to be together, grouping, clan, gang. So when the Chinese come to Singapore, they have…haha…they are gangster, they have a group of gangsters, barber, the coffee shops…you know…so there's a lot of clans, grouping and counter association, trade association, also, Singapore got plenty…everybody want to group together. So there's thousands of associations in Singapore and Singapore government don't like it and Singapore government in 80-90s, saw this a problem and take out resources, take out manpower and a lot of stations. So the Singapore government, even put all the Chinese together. There were many English papers and none make good money, because there is a lot competition. Singapore government put all the newspapers together. One company publish one English, one Malay, one Chinese, one Indian. Only now in the days, a few come out in the afternoon, we got new papers, but the main paper is the Strait Times, we

got only one morning paper. So you most coordinate all the newspapers together into one. It takes a lot of manpower and even…they save a lot of managing directors, because each company has one managing director, but you put them together and there's only one managing director. You fear the manpower, so is the bus company. Singapore before, there were many, many bus company. Everybody want to ride the Orchard Road, because that's a high café area. And so, Orchard Road gets jammed out, you know, but further away there's less people standing, no bus company want to go there, because that route is funny. At the end of the day, most of the bus company don't make good money and they can not upgrade their busses, because they don't make good money. So what government do? Merge all into one. So instead of six companies, six groups, six management groups, put them together: one management group, the fine management group, free to do all the directing."

Hjarald: "Are there multiple associations for the electronics industry or is AIES the only association?"

Wong: "No, we are not the only one. There is SSIA, Singapore Semicon Industry Association. There is Singapore Hightech Association. Sometimes, we hear about these associations. So we seldom come together and each of us have different sector, members. For electronics tradeshows overseas, we are the only one. Because we concentrate and we do well, so I think it is difficult for them to come in and compete with us. And the organiser want to work with us, because we are aggressive. So we concentrate…we push…we advertise…we broadcast…we respond to company actively, very fast. So, we are good at this job, that's why each of these show we go, bring Singapore family, all the Singapore company together, Singapore family, with a big Singapore logo on top. Most of the shows we go, Singapore is the biggest family and most prominent. The Taiwanese come big as well, but we are always the biggest family. So the organisers are very confident of working with us. If we get interesting news, we share this among our members. We collect namecards…every show, we collect namecards…we hire pretty ladies…hahaha…to give our brochures you know. Every show we publish our brochures for the Singapore family. This is our brochure for Vietnam and those companies coming with us are inside. So we give these out and ask for namecards. So these namecards, I share them among our members. And then we work with the Institute of Higher Learning, NUS, Sintech, and have some interesting seminars for them and broadcast it to our members and encourage our members to go. And we organise members gatherings twice a year. One is at HHM, one is at Atena. But then the response is always not good, not good. Because most of our members are small company and the boss, the owner of the company, is also the chief sales person, so he is always busy…you know…running his business, because they all small companies. So often, they don't have the time. When they are big, you can talk to the HR, the HR is the only person who would deal with it, the external interviews or press. But small companies is very difficult, you know, at many companies the boss handles the sale, he handle the delivery, he run the company, so he work long hours and then when we have a diner, we used to have gatherings at five, six, seven o'clock and then the response is poor. Maybe only 20% will turn up. We try to find interesting venue. We have a gathering at Clarke Quay, free floor at Clarke Quay…you know…plenty of ladies to watch and then only 20% turn up. We book the whole upstairs,

20% turn up and we are supposed to have a speech and exchange our ideas, but in the end it is totally ineffective, because most the people get a jar of beer, they go out because…out of the bar…and go outside because there is plenty of hot ladies to watch…hahaha…so now upstairs is only a handful, balance, and everybody collect and finish and go upstairs, take their beer, they go downstairs, you know, and watch the people passing by. So, it defeats the purpose. Then we move to Chinatown, there was a conservation building, there is some Italian bar there, we have it there. So, but the turnout is so poor and then again a lot of people get their beer, they see outside and are sitting at the road, where we hang and talk and discuss and we have some people do some talking. And we have it at a restaurant also, the turnout is poor and then we are coming out with one in August, we have it in a hotel and we book the ballroom and then we give all our members 'free to attain diner' – a table cost a 1000S$ - so all the members are given a seat and the response now coming in is lower than 10%. Now, our members say they can't make it. It is free, we pay a 1000S$ for a table, it is…we call it annual diner, and then we are giving away a lot of prices. But our members are not attracted."

Appendix 3: List of subsidiaries of Singaporean MNCs in SIJORI. Penang and China in 2014.

SIJORI (31)	Penang (11)	China (53)
8. A&One Precision Engineering	24. Adampak Limited	8. A&One Precision Engineering
28. Add-Plus International Pte Ltd	32. Adspark Technologies Pte Ltd	24. Adampak Limited
95. Asis Technologies	240. Daviscomms (S) Pte Ltd	29. Addvalue Communication Pte Ltd
97. ASJ Pte Ltd	301. Emerges-Lite Pte Ltd	52. AGVA Technologies Pte Ltd
156. C&W Electronics Pte Ltd	393. Futani Engineering Pte Ltd	94. Asian Micro (S) Pte Ltd
173. CEI Contract Manufacturing Limited	504. International Press Softcom Limited	129. Axomic Pte Ltd
176. Centurion Corporation Limited	547. Kenshi Singapore	131. Aztech Systems/Groups Pte Ltd
190. Circuits Plus Pte Ltd	551. KES Systems & Service (1993) Pte Ltd	156. C&W Electronics Pte Ltd
261. Disk Precision Industries Pte Ltd	596. M A Electronics Pte Ltd	173. CEI Contract Manufacturing Limited
281. E-Direct Technologies Pte Ltd	751. Opulent Marketing Pte Ltd	179. Chartered Electronics Co Pte Ltd
370. Flextronics International Singapore Pte Ltd		189. Circuit Image Mfg Pte Ltd
391. Fullmark Pte Ltd		190. Circuits Plus Pte Ltd
409. Getronics (S) Pte Ltd		222. Creative Technology Ltd
475. Hybrionic Pte Ltd		268. Dura-Metal (S) Pte Ltd
528. Jovan Tech Pte Ltd		281. E-Direct Technologies Pte Ltd
547. Kenshi Singapore		287. Elec & Eltek International Co Ltd
735. NSP Tech Pte Ltd		298. Eltron Interconnection System Pte Ltd
751. Opulent Marketing Pte Ltd		302. Empro Technology Pte Ltd
757. Osi Electronics		333. Eurotronic Group Ltd
772. PCA Technology Limited		370. Flextronics International Singapore Pte Ltd
776. PCI Limited		393. Futani Engineering Pte Ltd
808. PNE Translite Pte Ltd		395. Futuristic Technic Electronics Pte Ltd
878. Rising Technologies Pte Ltd		409. Getronics (S) Pte Ltd
886. Rokko Ventures Pte Ltd		435. Gul Technologies Singapore Ltd
954. Sinco Technologies Pte Ltd		494. Innomedia Pte Ltd
999. SP Manufacturing Pte Ltd		504. International Press Softcom Limited
1076. Tectron Developments Pte Ltd		547. Kenshi Singapore
1146. Venture Manufacturing (S) Pte Ltd		551. KES Systems & Service (1993) Pte Ltd
1148. VGS Technology Pte Ltd		553. Kinergy Pte Ltd
1160. WBL Corporation Limited		591. LNE Precision Engineering Pte Ltd
		606. Manufacturing Integration Technology Ltd
		609. Mapconn Singapore Pte Ltd
		642. Mentor Media Ltd
		647. MI Technologies Pte Ltd
		648. Mica Technology Pte Ltd
		751. Opulent Marketing Pte Ltd
		776. PCI Limited
		810. Polytech Component Pte Ltd
		853. Radiance Group Limited
		867. Redtec Industries Pte Ltd
		906. Santak Electronics Pte Ltd
		973. SJ Manufacturing (2003) Pte Ltd
		984. Sol Industry Pte Ltd
		1003. Speedy-Tech Electronics Ltd
		1010. ST Electronics (Info-comm systems) Pte Ltd
		1017. Stats ChipPAC Ltd
		1031. Summit CD Manufacturing Pte Ltd
		1036. Superworld Electronics (S) Pte Ltd

		1038. Swann Industries Pte Ltd
		1134. United Test and Assembly Center Ltd Utac
		1146. Venture Manufacturing (S) Pte Ltd
		1148. VGS Technology Pte Ltd

Source: own data.

Industry	2000	Industry	990	try
26 MANUFACTURE OF COMPUTER, ELECTRONIC AND OPTICAL PRODUCTS			28	MANUFACTURE OF FABRICATED METAL PRODUCTS, MACHINERY AND EQUIPMENT
261 MANUFACTURE OF ELECTRONIC COMPONENTS AND BOARDS	311	MANUFACTURE OF ELECTRONIC VALVES AND TUBES AND OTHER ELECTRONIC COMPONENTS		
2611 Manufacture of Semiconductor Devices	3111	Manufacturing of Semiconductor Devices	3844	Manufacture Of semiconductor devices
26111 Manufacture of discrete devices (eg diodes, light-emitting diodes transistors and rectifiers)	31111	Manufacturing of discrete devices (eg diodels, transistors and rectifiers	38441	Manufacutre of diodes and rectifiers (including light emitting diodes
26112 Semiconductor wafer fabrication	31112	Semiconductor wafer fabrication	38442	Manufacture of transistors
26113 Assembly and testing of semiconductors	31113	Assembly and testing of integrated circuits	38443	Manufacture of integrated circuits
26114 Manufacture of solar wafers	31119	Manufacture of semiconductor devices nec	38449	Manufacture of semiconductor devices nec
26115 Manufacture of solar cells				
26119 Manufacture of semiconductor devices n.e.c.				
2612 Manufacture of Other Electronic Components and Boards	3119	Manufacture of electronic valves and tubes and components nec	3846	Manufacture of Other Electronic Components
26121 Manufacture of capacitors	31191	anufacture of electron tubes	38461	Manufacture of capacitors
26122 Manufacture of resistors	31192	manufacture of capacitors	38462	Manufacture of resistors
26123 Manufacture of printed circuit boards without electronic parts	31193	manufacture of resistors	38463	Manufacture of PCB without electonic parts
26124 Manufacture of printed circuit boards with electronic parts	31194	manufacture of PCB without electronic parts	38464	Manufacture of PCB with electonic parts
26125 Manufacture of piezo-electnc devices (eg quartz crystals quartz crystal filters delay lines)	31195	manufacture of PCB with electronic parts (excl CEM)	38465	Manufacture of piezo-electric devics (eg quartz crystals, quartz crystal filters, delay lines,
	31 196	CEM (PCBA and Elctronc sub-systems)	38466	Manufacture of electronic display devices except light emitting
26126 Manufacture of electronic display devices except light emitting diodes	31197	Manufacture of piezo-electric devies (Eg quartz crystatal, quartz crystla filters	38469	Manufacture nof electonnic components
26127 Manufacture of electronic connectors	31198	Manufacture of electronic display devices excepti light emmting diodes		
26129 Manufacture of other electronic components and boards n.e.c	31199	Manufacture of electronic compontens nec		
262 MANUFACTURE OF COMPUTERS AND PERIPHERAL EQUIPMENT	314	MANUFACTURE OF ELECTRONIC OFFICE AND RELATED EQU PMENT		
2620 Manufacture of Computers and Peripheral Equipment	3141	Manufacture of computing and data processing equipment and accessoires n	x	Does not exist as a SSIC-group in 199(
26201 Manufacture of computers and data processing equipment except computer peripheral equipment	31411	manufacture of computers and data processng equipment except computer p	38411	Manufacture and repair of computers and data processing equipment except computer peripheral equ
	31412	manufacture of disk media		
26202 Manufacture of disk drives (including CD-ROM drives, DVD-ROM drves, optical drives, flash drives tape drves solid state drives storage subsystems)	31413	manufacture of disk drves (inc cd-rom drves, optic dives, floppy dirves and remoables disk	new item	
	31414	manufacture of tape drves		
	31415	manufacture of printers		
26203 Manufacture of printers	31416	manufacture of computer perhpheral equipment	38413(part)	Manufacture and repair of computer perpheral equipment (eg pnnters, monitors)
26204 Manufacture of smart cards and related products (eg smart card readers	31417	manufacture of storage subsystems	38413	
26209 Manufacture of computers and peripheral equipment n.e.c.	31419	manufacture of computng and data processng equipment and accessoires a	38419	Manufacture and reapir of industnal/commercial electronic products nec
	3149	Manufacture of other electronic office equipment		
	31491	manufacture of phtolcopyng quipment		
	31499	manufacture of electronic office equment nec		
263 MANUFACTURE OF COMMUN CATIONS EQUIPMENT	312	MANUFACTUR NG AS COMMUNICATION EQUIPMENT		
2630 Manufacture of Communications Equipment	3120	Manufacture of communication equpment	x	Group did not excist
26301 Manufacture of telecommunications apparatus (eg PBX equipment, telephones except cellular)	31201	Manufacture of telecommunication apparatus	38415	Manufacturing and repair of communication equipment (eg radio-telephones, t Part of: 3841 Manufact
	31202	Manufacture of networkng products		
26302 Manufacture of networkng products (eg routers switches)	31203	Manufacture of wireless communication equpment	new productgroup	
26303 Manufacture of wireless communications equipment (eg cellular phones)	31209	Manufacture of communcanication equipment nec	new productgroup	
26304 Manufacture of electronic security systems including electronic sensors burglar and fire alarm systems)			38491	Manufacture of electronic security system (incl burglar and fire alarm systems)
26309 Manufacture of communications equipment n.e.c.			new productgroup	
264 MANUFACTURE OF CONSUMER ELECTRONICS	313	MANUFACTURE OF TELEVISION AND RADIO RECEIVERS SOUND OR VIDEO RECORDING OR REPRODUCING APPARATUS AND ASSOCIATED GOODS		
2640 Manufacture of Consumer Electronics	3130	Manufacture of television and radio receivers, sound or vieo recoreding or re	3482	Manufacture of Audio and Video Consumer electonics
26400 Manufacture of consumer electronics	31301	Manufacture of radio receiving sets and sub-assemblies	34821	Manufacture of radio receiving sets and sub-assemblies
	31302	Manufacture of television and sub-assemblies (incl television chassis)	34822	Manufacture of television and sub-assemblies (incl television chassis)
	31303	Manfucature of microphones, loudspeakers and amplifiers	34823	Manufacture of microphones, loudspeakers and amplifiers

		31304	Manufacture of sound reproducing and recording equipment	34824	Manufacture of sound reproducing and recording equipment
		31305	Manufacture of video reproducing and recording equipment (incl television ca	34825	Manufacture of video reproducing and recording equipment (incl television cameras)
		31306	Manufacture of audio and video combinationa equipment (eg radios, televisio	34826	Manufacture of audio and video combinations equipment (eg radios, television sets, record players and
		31309	Manufacture of television and radio receivers, sounds or video recording or r	38429	Manufacture of audio and video consumer electronic products nec
				3843	Manufacture of Other consumer electonic products except watches and clocks
		multiple industry groups			
265	MANUFACTURE OF MEASURING, TESTING, NAVIGATING AND CONTROL EQUIPMENT; WATCHES AND CLOCKS			386	Manufacure of instrumentation equipment, photographic and optical goods (incl professional, scientific
		323	MANUFACTURE OF WATCHES AND CLOCKS		
		321	MANUFACTURE OF MEDICA APPLIANCES AND INSTRUMENTS AND APPLIANCES FOR MEASURING, CHECKING, TESTING, NAVIGATING AND OTHER PRUPOSES EXCEPT OPTICAL		
2651	Manufacture and Repair of Measuring, Testing, Navigating and Control Equipment	3212	Manufacture of instruments and appliances for measuring checking, testing, n	3861	Manufacture of Engineering and Scientific instruments
26511	Manufacture and repair of engineering and scientific instruments	32121	Manufacture of electrical/electronic engineering and scientific instruments	38611	Manufacture of electrical/electomic engineering and scientific instruments
		32122	Manufacture of non-electrical/non-electronics engineering and scientific instr	38612	Manufacture of non-electrical/non-electronic engineering and scientific instruments
26512	Manufacture and repair of measuring devices (eg meters)	32123	Manufacture of electrical/electronic measuring and controlling devices (Eg m	3862	Manufacture of Measering and Controlling Devices
		32124	Manufacture of non-electrical/non-electronic measuring and controlling devic	38621	Manufacture of electrical/electronic measuring and controlling devices (eg meters)
26513	Manufacture and repair of process control equipment and related products			38622	Manufacture of non-electrical/non-electronic measuring and controlling devices
2652	Manufacture of Watches and Clocks	3320	Manufacture of Watches and Clocks (incl parts and accessories)	3865	Manufacture of watches and clocks (incl parts and accessories)
26521	Manufacture of fully electronic watches and clocks	32301	Manufacture of fully electomic watches and clocks	38651	Manufacture of fully electronic watches and clocks
26522	Manufacture of electro-mechanical watches and clocks (eg watches and clocks with moving parts and battery)	32302	Manufacture of electro-mechanical watches and clocks (eg watches and cloc	38652	Manufacture of electro-mechanical watches and clocks (eg watches and clocks with moving parts and
		32303	Manufacture of mechanical watches and clocks		
26523	Manufacture of mechanical watches and clocks	32304	Manufacture of parts and accesories for watches and clocks	38653	Manufacture of mechanical watches and clocks
26524	Manufacture of parts and accessories for watches and clocks			38654	Manufacture of parts and accesories for watches and clocks
266	MANUFACTURE OF IRRADIATION, ELECTROMEDICAL AND ELECTROTHERAPEUTIC EQUIPMENT				
2660	Manufacture and Repair of Irradiation, Electromedical and Electrotherapeutic Equipment	x	Grown out to a seperate SSIC-group from one productcode	x	Grown out to a seperate SSIC-group from one productcode
26601	Manufacture and repair of electrotherapeutic devices	32119	Manufacture of surgical equipment and orthopaedic appliances nec (eg medi	38663(part)	Manufacture of medical supplies (eg test kits, syringes, tubes, fluid administration sets;
26602	Manufacture and repair of irradiation and electromedical equipment and instruments				new item
267	MANUFACTURE OF OPTICAL INSTRUMENTS AND PHOTOGRAPHIC EQUIPMENT	322	MANUFACTURE OF OPTICAL INSTRUMENTS AND PHOTGRAPHIC EQUIX		NOT SEPERATE SSPIC PRODUCT GROUF
2670	Manufacture of Optical Instruments and Photographic Equipment	3220	Manfucture of optical instruments and photographic equipment	3864	Manufacture of Photographic and Optical Goods
26701	Manufacture of photographic equipment and parts (including lenses)	32201	Manufacture of photographic equipment and parts (incl lenses)	38641	Manufacture of photographic quipment and parts (incl lenses)
26709	Manufacture of optical instruments and photographic equipment n.e.c	32202	Manufacture of spectacles, sunglasses and parts	38642	Manufacture of spectacles sunglasses and parts
		32209	Manufacture of optical instrument and photographic equipment nec	38643	Manufacture of photocopyin equipment and supplies
				38649	Manufacture of optical goods and equipment nec
268	MANUFACTURE OF MAGNETIC AND OPTICAL MEDIA	322	MANUFACTURE OF OPTICAL INSTRUMENTS AND PHOTOGRAPHIC EQIx		GROUP DID NOT EXCIST YET, EMERGE FORM ONE PRODUCT GROUF
2680	Manufacture of Magnetic and Optical Media	3220	Manufacture of optical instruments and photograpchic equipment		
26801	Manufacture of disk media	32201	Manufacture of photographic equipment and parts (incl lenses)		new item
26802	Manufacture of blank magnetic tapes, diskettes, Bluray technology discs, CDs, DVDs and VCDs	32202	Manufacture of spectacles, sungalasses and parts	39097	Manufacture of blank magnetic tapes and diskettes
		32209	Manufacture of optical instruments and photographic equipment nec		
27	MANUFACTURE OF ELECTRICAL EQUIPMENT				
		2 branches together			
271	MANUFACTURE OF ELECTRIC MOTORS, GENERATORS, TRANSFORMERS, ELECTRICITY DISTRIBUTION AND CONTROL APPARATUS	301	MANUFACTURE OF ELECTRIC MOTORS AND GENERATORS		
		302	MANUFACTURE OF ELECTRICITY DISTRIBUTION AND CONTROL APPARATUS		
2710	Manufacture and Repair of Electric Motors, Generators, Transformers Electricity Distribution and Control Apparatus	3010	Manufacrure of Electric Motors and Generators	3831	Manufacture and Repair of Electrical Industrial Apparatus Except Instruments
27101	Manufacture and repair of electric motors	30101	Manufacuture and repair of electric motors		
27102	Manufacture and repair of electric generators	30102	Manufacture and repair of electric generators	38311	Manufacture and repair of electric motors
27103	Manufacture and repair of transformers	3020	Manufacture of electricity distribution and control apparatus	38312	Manufacture and repair of electric generators
		30201	Manufacture and repair of transformers	38313	Manufacture and repair of welding equipment (incl arc welding electrodes) Dissapeared

2720	Manufacture of Batteries and Accumulators	3040	Manufacture of accumulators, primary cells and primary batteries	3833	Manufacture of storage and primay batteries
27201	Manufacture of primary batteries	30401	Manufacture of lead-acid storage batteries	38341	Manufacture of lead-acid storage batteries
		30402	Manufacture of nickel cadmium storage batteries	38342	Manufacture of nickel cadmium storage batteries
27202	Manufacture of secondary batteries	30403	Manufacture of primay batteries (eg dry cell batteries)	38343	Manufacture of primay batteries
		30409	Manufacture of accumulators, primary cells and primary batteries nec	38349	Manufacture of storage and primary batteries nec
273	MANUFACTURE OF WIRING AND WIRING DEVICES	303	MANUFACUTRE OF INSULATED WIRE AND CABLE	X	DOES NOT EXCIST AS SSIC
SSIC 2015		SSIC	SSIC 1	Indus	
2732	Manufacture of Electronic and Electric Wires and Cables	3030	Manufacture of insulated wire and cable	3833	Manufacturing of Elettrical Cables and Wires
27321	Manufacture of telecommunications cables and wires	30301	Manufacture of telecommunication calbes and wires	38331	Manufacturing of telecommunicabon cables and wires
27322	Manufacture of electric power cables and wires	30302	manufacture of electric power calbes and wires	38332	manufacturing of electric power calbes and wires
27323	Manufacture of enamelled wires (used for winding of motors, transformers etc)	30303	manufacture of enamelled wires (ues for winding of motores, transformers etc)	38333	manufacturing of enamelled wires (used for winding of motors, transformers, etc.)
		30304	Manufacture of wire and cable assemblies and harnesses	38334	Manufacture of wire and calbe assemblies and hernesses
27324	Manufacture of wire and cable assemblies and harnesses	30305	Manufacture of connectors	38335	Manufacture of connectors
27329	Manufacture of other electronic and electric wires and cables n.e.c.	30309	Manufacture of electrical cables and wires nec	38339	Manufacture of electrical cables and wires nec
		309	MANUFACTURE OF OTHER ELECTRICAL EQUIPMENT NEC		
2733	Manufacture and Repair of Wiring Devices	3090	Manufacture of other electrical equipment nec		And converge with extra two productsgroup added to the group of 2015
27330		30900	Manufacture of other electrical machinery, apparatus, appliances and supplies	3831	Manufacture and repair of electrical industrial apparatus except electrical instruments
				38319	Manufacture and repair of electrical industrial apparatus except electrical instruments nec
				3839	Manufacture of electrical machinery, apparatus, appliances and supplies nec
				38390	Manufacture of electrical machinery, apparatus, appliances and supplies nec (including electrical insulators except porcelain and
274	MANUFACTURE OF ELECTRIC LIGHTING EQUIPMENT	305	MANUFACTURE OF ELECTRIC LAMPS AND LIGHT EQUIPMENT	X	DID NOT EXCIST AS SEPERATE SSIC GROUP
		309	MANUFACTURE OF OTHER ELECTRICAL EQUIPMENT NEC		
2740	Manufacture and Repair of Electric Lighting Equipment	3050	Manufacture of electric lamps and lighting equipment	3835	Manufacture of Electrical Lighting Equipment, Fittings and Parts
27400	Manufacture and repair of electric lamps and lighting equipment (including silver reflectors, fittings and parts)	30500	Manufacture of electric lamps and lighting equipment (incl silver reflectors, fittings and parts)	38350	Manufacture of Electrical Lighting Equipment, Fittings and Parts
		3090	Manufacture of other electrical equipment nec		
		30900	Manufacture of other elctrical machinery, apparatus, appliances and supplies nec (incl sound or visual signalling appratus, electrical insulators except porcelain or glass)		
275	MANUFACTURE OF DOMESTIC APPLIANCES	293	MANUFACTURE OF DOMESTIC APPLIANCES NEC	X	DID NOT EXCIST AS SSIC GROUP
2750	Manufacture of Domestic Appliances	2930	Manufacture of domestic appliances nec	3836	Manufacture of Electrical Household Appliances
27501	Manufacture of electrical household appliances (eg refrigerators, hot plates, toasters, food mixers, cookers, hair dryers, fans, shavers)	29301	Manufacture of electrical household appliances (eg refrigerators, hot plates, to	38360	Manufacture of Electrical Household Appliances (eg refrigerator, hot plates, toasters, food mixers, cookers, hair dryers, fans, sh
		29309	Manufacture of other domestic appliances nec	3819	Manufacture of fabricated metal products except machinery and quipment not elsewhere classified
27509	Manufacture of domestic appliances n.e.c. (eg non-electric cooking ranges, grates, stoves)			38199(part)	manufacture of fabricated metal products except machinery and equipment nec
				more productgroups	
279	MANUFACTURE OF OTHER ELECTRICAL EQUIPMENT	X	DIDNT EXCIST AS SSIC INDUSTRY GROUP	X	DID NOT EXCIST AS SSIC INDUSTRY GROUP
2790	Manufacture of Other Electrical Equipment	3090	Manufacture of other electrical equipment nec		
27901	Manufacture of fuel cells	30900	Manufacture of other elctrical machinery, apparatus, appliances and supplies r new item		
27902	Manufacture of electrical machinery, apparatus, appliances and supplies (including sound or visual signalling apparatus, electrical insulators except porcelain or glass)			38319	Manufacture and repair of electrical industrial apparatus except electrical instruments nec
				38390	Manufacture of electrical machinery, apparatus, appliances and supplies nec (including electrical insulators except porcelain and