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**The Hsinchu Model:
Collective efficiency, increasing returns and higher-order capabilities in
the Hsinchu Science-based Industry Park, Taiwan**

JOHN A. MATHEWS*

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*Eni Chair in Competitive Dynamics and Global Strategy
LUISS Guido Carli University
Viale Romania 32 00197 Roma, Italy
Email jmathews@luiss.it

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Abstract

The dynamics of industrial clusters, networks and other forms of suprafirm structures such as platforms and development blocs remains a topic of perennial interest to strategy scholars, not least because real economies demonstrate that such structures are critical to competitive success. The interest in industrial districts that was sparked by Marshall's insights of a century ago, into the operation of external economies, and which has been enriched by the study of industrial districts (for example in Italy) as organizational alternatives to large, integrated firms, has in the 21st century evolved to an interest in industrial clusters as the settings where countries and regions can best hope to build competitiveness, particularly within the designated Special Economic Zones that are now proliferating in both China and India. In this context the success of the Hsinchu Science-based Industry Park in Taiwan is of special relevance, offering an opportunity for reflection as the 30th anniversary of its founding in 1980 approaches. In this Address I sketch the history of the HSIP and dwell on its capacity to generate significant industrial clusters, particularly in the associated fields of integrated circuits, flat panel displays, IC design and now in optoelectronics (solar photovoltaics and light-emitting diodes). The sources of advantage for firms that elect to operate in clusters, drawing on the resource extensions made available through interfirm linkages and knowledge spillovers, are assessed, and the circular and cumulative processes at work in Hsinchu (generating a 'chain reaction' of industrial development and upgrading) are analyzed. The firms within the Hsinchu park generate value-added (revenues less costs as a proportion of total revenues) of 50% -- compared with a figure of 30% for manufacturing firms in Taiwan outside the Hsinchu park. This means that ***the firms in the Park are 66% more productive than firms outside the park*** (a ratio of 5 to 3), and have been so for the past decade. I view this as evidence of the reality of the increasing returns generated by the clustering of firms in the Hsinchu park. I suggest that there is every reason to anticipate further successes as the Hsinchu model is emulated elsewhere, first in Taiwan itself along the west coast through a series of interlinked science parks (now generating no less than 15% of Taiwan's GDP), then in China and India through the proliferation of SEZs and through Taiwan's own 'unofficial' replication of its Hsinchu model in the greater Suzhou region of China, and throughout the rest of the developing and even the developed world. The ***Hsinchu model*** is more relevant and accessible for most countries than the Silicon Valley model, in that Hsinchu blends the public and private; it allows the private sector full capacity to engage in endless creativity after the public institutions have laid the foundations and established the basic rules. Taiwan has demonstrated that the Hsinchu model works. I conclude by suggesting that Taiwan has in the Hsinchu model a powerful diplomatic asset.

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1. Introduction

This year, in December, Taiwan celebrates the 30th year anniversary of the founding of the Hsinchu Science-based industry park, which has provided the setting within which Taiwan has emerged from obscurity to take a lead role in the world's high technology industries. Hsinchu has become a spectacular success in Taiwan, and is home to the country's principal high-tech industries; it remains the gold standard for all high-tech industrial clusters created through government intervention in Asia, and beyond. It has not only been a powerful generator of wealth, and a means of guiding Taiwan firms from imitation to innovation, but it has even more significantly provided the institutional setting within which Taiwan has developed new industries, from IT and semiconductor chips, to flat panel displays and optoelectronics, and now to silicon solar photovoltaic systems and low-carbon technologies in the 21st century.¹

But this year also sees two further 30-year anniversaries of relevance to the success of Hsinchu in Taiwan. The first of these celebrates thirty-plus years since the Florentine scholar Giacomo Becattini published his pathbreaking paper in 1979, an article perceptively titled 'From industrial 'sector' to industrial 'district' – meaning that the mainstream practice of aggregating industrial statistics into sectors was missing the point that firms tended to cluster, in self-reinforcing and sustaining groups that Becattini characterized as Marshallian industrial districts, in ways that should be statistically evident if efforts were made to identify them. Becattini's article opened the gates to a stream of work on industrial districts and clusters that is getting stronger and stronger, and placed Marshall as the clear intellectual font for much of this work – and for the industrial clustering that is so evident in Taiwan, by design and by good fortune. This work is counterposed to the mainstream view that continues to divide the world of the economy into firms (in fact, large firms) and industries – and ignoring everything in between.²

A third 30th anniversary celebrates the founding in China of the first Special Economic Zone, at Shenzhen, in 1979/80. Under the guidance of Deng Xiaoping, the SEZ was created as a means of allowing some degree of experimentation in the ailing Chinese economy at the time, to draw from the prior experiences of East Asian success stories like Taiwan, and to go beyond the prior experience of industrial enclaves such as export processing zones and free trade zones. Important as these enclaves were for attracting foreign direct investment and providing employment, they were not kick-starting autonomous industrial development in China itself – which is what Deng Xiaoping wanted to do. The Shenzhen SEZ has turned out to be a spectacular success, its economic output growing by more than 25% a year for 30

¹ Hsinchu (or in the standard transliteration, Xijiu) means 'new shoot', as in new bamboo shoots. In this sense the name is entirely appropriate, as the Hsinchu cluster has shaped the creation of new industries such as FPDs and PVs as 'new shoots' from the earlier established industries.

² See Becattini 1979. The journal in which he published the paper, *Rivista di economia e politica industriale* [Review of Industrial Political Economy] has remained central to debates in Italy over the significance of industrial clusters to the wider economy.

years, and housing several industrial clusters focused on ICT sectors including electronics, semiconductors, and flat panel displays. As foreseen, the Shenzhen SEZ sparked emulation elsewhere, as China's State Council created further such zones, and these have provided the engine that now drives the Chinese industrial revolution. The Chinese success with clusters is now being emulated in India, and will no doubt kick-start much new industrial cluster activity elsewhere in the developing world. China's SEZs also draw from the same intellectual and institutional pool that has nourished Hsinchu in Taiwan.

Three anniversaries – one celebrating a major scholarly breakthrough, and two celebrating major institutional initiatives in Asia – provide an appropriate starting point. What I find so interesting is that the scholarship on the industrial cluster phenomenon in the advanced countries, in Europe, North America and Japan, while developing in varied and important ways such as through investigating the evolution of Marshallian industrial districts and markets-as-networks, has failed to take by storm the disciplines of economics and strategy, or even organization theory and entrepreneurship studies. Clusters and other suprafirm phenomena such as platforms remain on the margins of scholarship, despite their real-world significance. But it is the rise of industrial clusters in China, and no doubt in India as well, spurred by the creation of SEZs, that is undoubtedly going to change the situation drastically. My contention is that the success of these emerging industrial giants of the 21st century cannot be understood without reference to the industrial cluster phenomenon that is embedded within them, housed within such institutional settings as SEZs and science-based industry parks. All the intellectual machinery developed to understand the rise of clusters in the advanced world is now going to have to be applied in order to make sense of this same phenomenon in the developing world, but in a new context defined by globalization and the emergence of global production networks and global value chains.³ And the insights generated through the study of emergent industrial clusters in China and India, and their interaction with global firms and the global value chains that they have been creating, will in turn have repercussions on our understanding as to how such clusters work in the developed world. They shed light for example on how groups of firms within a cluster generate process platforms that serve as a basis for mass customization. And so the process of mutual scholarly influence will proceed, in a 'circular and cumulative causation' pattern that emulates the processes identified for economies more generally.⁴

The most successful cluster in East Asia remains the Hsinchu Science-based industry park. Its success is attested not just by its own performance in driving Taiwan's ascendancy of a strong position in high-technology industries (the tri-trillion dollar industries of electronics, semiconductors and flat panel displays) but also by the degree of emulation of Hsinchu, in China and elsewhere.⁵ Hsinchu has long outgrown its small land allocation 80 km south of Taipei, even after two extensions, and is now accompanied by two further major science

³ An explicit connection between regional issues (industrial clusters) and global production networks in an East Asian setting has been forcefully made by Henry W.C. Yeung (2009).

⁴ The phrase 'circular and cumulative causation' was first used by the Swedish development economist Gunnar Myrdal, in his 1957 book *Economic Theory and Under-Developed Regions*, and was taken up by the brilliant Cambridge economist Nicholas Kaldor, as a way of encapsulating the real development processes in real economies. The concept dates back to the work of Allyn Young in the 1920, and beyond that to earlier Italian Renaissance theorists of the growth of wealth in cities.

⁵ These three industries each generate revenues in excess of NT\$1 trillion, and this is how they are referred to in Taiwan.

parks along the west coast of Taiwan – one at Tainan in the south, and one at Taichung in the central area. Together the 500-plus technology companies in these three parks accounted for no less than 15 percent of Taiwan’s gross domestic product in 2007 – amounting to NT\$2 trillion, or US\$60 billion. Their R&D expenditures amounted to 4.3% of sales, well above the national Taiwan average, and above almost all the advanced countries.⁶ By any standards, this is a remarkable result. While Silicon Valley remains the distant goal for many, the case of Hsinchu provides a more immediate, realistic and attainable model, underpinned by its strategies of technological and financial leverage and fast follower industrial dynamics. In this Address I bring out these features of the ‘Hsinchu model’ that have served Taiwan well and can now provide a template for countries around the world. Hsinchu is indeed Taiwan’s premier diplomatic asset – and one to be utilized as such, as a point of attraction for technological visitors from around the world.

2. Network/cluster organizational paradigm

It is now a truism that “no business is an island” (Håkansson and Snehota 1989). It is widely recognized that firms that cluster together generate knowledge spillovers – that the secrets of the trade ‘are in the air’. It may be clearly evident that firms generate mutual advantages from clustering together; it may even be evident that firms acquire their identity through the relations they build with other firms (just like other social creatures) and that the more interfirm relations a firm builds, the broader its strategic options. Nevertheless this fact continues to be ignored in neoclassical economics, which treats firms rigorously as atomistic entities, and until recently it was ignored in strategic management as well, where the firm was considered an independent and autonomous agent in terms of its strategizing. But for those who can see, industrial clusters are recognized today to be powerful engines of wealth generation. In this Address I depict them as microcosmic versions of the economy at large – and full of interesting and challenging detail that is passed over in silence by mainstream economics and even by much of strategy. I discuss how firms enlarge their strategic options through forging connections with each other and in enhancing and deepening the interfirm knowledge flows that result. Firms that form part of a network have access to many more resources than would be available to them individually, and such firms can contract with third parties to accomplish many more activities than would otherwise be under their control, thus expanding the market that is available for their products or services. And as the market expands, so the scope for specialization and intermediation grows (exactly as foretold by Adam Smith, and earlier by Italian political-economic theorists like Antonio Serra and Giovanni Botero).⁷ This generates a series of positive feedback loops that can be described as a chain reaction, resulting in the cumulative and circular causation of enhanced production

⁶ Taiwan’s GDP in 2007 was US\$396 billion, according to statistics from the Council of Economic Planning and development. Gross revenues for all Science parks in 2007 amounted to NT\$1.966 trillion, which at an exchange rate of NT\$33 to the US\$, gives revenues of US\$60 billion, or 15% of GDP. R&D expenditure by firms in all Science Parks in 2007 amounted to NT\$84 billion, which is 4.3% of total revenues.

⁷ Adam Smith’s *Wealth of Nations* (1776) needs no introduction. Italian scholars who anticipated his ideas and elaborated on the role of urban clusters more forcefully must certainly include Antonio Serra (*Breve Trattato delle cause che possono far abbondare li regni d’oro e d’argento dove non sono miniere*, 1613: Brief treatise on the causes that can increase wealth in terms of gold and silver where there are no mines) and before him Giovanni Botero (*Delle cause della grandezza delle città*, 1590: Causes of the greatness of cities). On the significance of their ideas for a long-lost tradition of political economy, but one which is highly relevant to the study of clusters, see Reinert 1999.

capacities in clusters; this gives a “spring” or “bounce” to a network that surpasses whatever is available to a firm on its own. The network can reconfigure itself as needed, with inter-firm relations being activated, de-activated and re-activated as circumstances warrant, leading to a shuffling and reshuffling of the resources embodied in these firms and institutions. This gives rise to the evolutionary dynamics that generate knowledge spillovers, common resource pools and interconnections that can then be translated into synergies and systemic returns – that are better known in economics as increasing returns. I characterize the reshuffling of resources within the cluster as an analogue to the reshuffling of the genome of a biological species through Darwinian experimentation and selection; and the shifting activity networks in the cluster that are made possible by this resource reshuffling as the phenotypical expression of these changes in genotype. With due regard to the limitations of biological analogies in the business world, it strikes me that this is undoubtedly a fruitful way to view industrial clusters and to gain insight into the sources of their advantages over the single, isolated firm.⁸

Economies consist of multiply-connected value chains, or criss-crossing value-adding processes, that can be described as value constellations or value configurations or what Alderson called (in a wonderful terminological innovation, transvections) – or, in other words, as complex and highly connected interacting systems for the production of value.⁹ Rather than seeing markets or hierarchies (firms) as the primal economic institutions of a business system, and networks as a ‘hybrid’ between the two – as in the case of Williamson (1985) – many scholars have adopted instead a network paradigm, and see markets as networks and firms as networks, each connected to the other to make a seamless web of connections (Thorelli 1986; Jarillo 1988; Grandori and Soda 1995; Maskell and Lorenzen 2004). It would make a lot of sense for the strategy field to re-adopt the Aldersonian term *transvection* as its primary object of interest (as opposed to the transaction). As transvections forge connections with each other (just like neurons in the brain) so dense networks are formed that generate extra value-added. In such a setting, pure atomistic markets, at one extreme, and pure hierarchical unified firms at the other extreme, are merely the end-points of a spectrum of real interfirm relational dynamics. In such a setting, the management of the network becomes just as important as the managing of the firm itself – and the development of collaborative capabilities becomes a prime feature of entrepreneurial success.

The concepts that I group together as ‘suprafirm structures’ include production networks and global value chains, industrial clusters or industrial districts, on which a voluminous literature exists, as well as development blocs (Dahmén 1950), growth poles (Perroux 1988), *filières* (Antonelli, Petit and Tahar 1992), production systems (Storper and Harrison 1991), local production systems (Crouch et al 2001), technological systems (Carlsson and Stankiewicz 1991) and competence blocs (Carlsson and Eliasson 2003), and regional innovation systems (Cooke 2001). All these entities may be grouped together in what Foss (1996) calls instances of a *meso-level of analysis* (between the micro and the macro) while Richardson referred to

⁸ Nelson and Winter (1982) in their justly famous *Evolutionary Theory of Economic Change* characterize intra-firm routines as the economic-level analogue of the replicators of a biological system. But the problem is that this notion of routines as replicators does not admit of an easy identification of genotype and phenotype, which is fundamental to the biological conception, whereas to take the argument to the cluster level admits of such an analogue in terms of cluster resources and activities.

⁹ Alderson (1965) introduced the term *transvection* as a term to capture the total system of supply relations culminating in a product offered to consumers. It is a value-chain counterpart to the notion of a single *transaction*. Alderson’s focus was on the way that management initiatives would carry implications throughout the transvection embodying the firm – just as we say today that firms strategize around the upstream supply links and downstream customer links.

them as instances of the ‘organisation of industry’ (as opposed to industrial organization, with its neoclassical economics overtones). In the category of suprafirm structures I also include such entities as (technological) platforms (Gawer and Cusumano 2002) and modular systems which impose a structure on multiply-connected firms. The point is that all of these meso-level categories (or suprafirm structures) have no place in mainstream neoclassical economic analysis – and are duly ignored in such analysis. But they are real, and important. They are the engines of wealth generation.

All of these suprafirm structures capture different aspects of the interlinkages between firms, or the inter-dependencies, when the structures are viewed as self-sustaining wholes, or systems. The point of interest in such a perspective is the *systemic gains* that become available to the firms participating in the structure – in the cluster, or network, or consortium or platform. A way of capturing the embeddedness of firms in multiple relationships, extending upwards through their supply chains and downwards through cascading transvections to their customers, is to describe value flows associated with the *extended enterprise*, in a strategic setting (Kinder 2003). Such a perspective helped to spawn the *industrial network* approach to marketing and procurement, and now informs the strategic conception of interconnected value chains of suppliers and customers as *ecosystems* (e.g. Pitelis and Teece 2010).

Firms that come together to form a cluster need to do more than collect external returns from each other (and from outside the cluster); what they need to do is to establish an identity, as a self-identified cluster, in some form of joint action. This could be a process through which an export market is created, via the cluster firms combining their efforts and capital to create an export consortium, and/or establish trade fairs both within the cluster (to bring customers to the cluster) and in key export destinations (to reach customers otherwise unattainable).¹⁰ It could be a process through which the cluster firms create a joint services organization, to provide training for recruited labour, as well as marketing intelligence, and promotional activities. It could be joint action to set up and operate an R&D institute, to solve technical problems and pass the solutions to all the members of the cluster, thereby enhancing their joint collective advantage. Schmitz (1999) introduced the idea of *collective efficiency* as accruing to firms that are able to mount joint action (an active concept) with the collection of external economies (a passive concept). The idea is that clusters, to be successful, need to fashion a form of joint action that directly involves the member firms, and helps them give the cluster an identity. This is indeed a fundamental observation, amply validated in the clusters that Schmitz and colleagues have looked at, and in more advanced versions such as Hsinchu.¹¹

As firms within an industrial cluster learn to work as a group, each one drawing from the strengths of the others – as the firms in Hsinchu have done – then we might speak of a fundamental collective process that is best characterized as economic learning. The concept of *economic learning* refers to a process through which an economy adapts to new circumstances using measures that go beyond random, price-guided reactions. Learning involves adapting intelligently to new circumstances by developing a repertoire of routines

¹⁰ Marshall himself was at pains to point to this feature of the British and German industrial districts, where he noted the significance of industry and trade associations in giving the district an action-orientation and, thereby, an identity. On this, see Belussi and Caldari (2009).

¹¹ See for example the accounts of the shoe clusters in Brazil (Schmitz 1995), in Mexico (Rabellotti 1995) and the surgical instruments cluster in Siot, Pakistan (Nadvi 1999). For a summary statement of the ‘collective efficiency’ perspective, see Schmitz (1999).

that are stored in memory and which can be drawn on as circumstances change. Examples of such economic learning routines would include firms learning to work collaboratively in R&D consortia to accelerate the process of new product development, or firms cooperating in export consortia, or public sector research institutes taking a lead in a new technology and diffusing the fruits of its development efforts across to constituent firms. In their influential article, Miner and Haunschild (1995) characterize as *population-level learning* the kind of institutional borrowing that goes on in such settings. They use the case of R&D consortia, and the U.S. case of Sematech in particular – but as I discuss in a moment, the case of R&D consortia in Hsinchu actually fits the case better. Population learning is clearly linked to the notion of collective absorptive capacity, and both are linked to the idea of knowledge spillovers. Foss (1996) was indeed on the mark when he called these instances of development of higher-order capabilities.

It is worth drawing attention to the striking analogy between the well-connected economy (inter-firm connectivity) where higher-order capabilities are generated through repeated interactions, and the human brain. Consider Fig 1, which shows a set of human neurons. The essence of this picture is the interconnected character of the cell. Indeed a picture of the developing human brain reveals neurons in a frantic scramble to make connections; those that succeed (through capturing some kind of neural pathway initiated from external stimuli) are able to live and flourish, while those that fail to make connections, die.

Fig. 1 about here

The resulting brain is a powerful organ that differentiates humans from all other products of biological evolution. Rather than talking of perhaps thousands of elements, with tens of thousands of connections – as in the case of the economy – we talk in the case of the brain of upwards of 100 million neurons, making over *100 billion* connections with each other. It is *inter-neuronal connections* that drive brain performance – which we experience in terms of thoughts, volitions and consciousness. In the development of the individual person, it is now suggested that the nervous system and brain develops along Darwinian lines (or through the operation of what Calvin calls a neural “Darwin machine”) and that thoughts too are the product of a Darwinian selection mechanism, where a number of alternatives (represented by alternative neural pathways) are presented, and a single pathway is selected.¹² Thus we may think of thought itself as a Darwinian process of generation of varieties of inter-neuronal connections, and selection of the pattern best adapted to the occasion.

The parallels between this process and the economy are manifest.¹³ Firms likewise *strive to build connections with each other*, not through neuronal synapses, but through the device of *contractual relations* of one kind or another. The contracts governing these relations can be extensive, with many clauses, or they can be as simple as an expectation of mutual obligations and repeat business. But in all cases, the firms acquire something of each other’s identity through the contractual encounter – a glimpse of each other’s resource base, or routines or activity structures. Just as we “select” our thoughts in a Darwinian process, so we may view the “market process” through which firms adjust their operations, as a fast-motion Darwinian process. The economic analog of consciousness is the *increasing returns* or *added*

¹² See Calvin (1996) for an overview of this perspective.

¹³ Garud and Kotha (1994) likewise use the brain as a metaphor for flexible manufacturing systems, and at the same time provide an enlightened discussion of the use of such metaphors.

value generated through interconnectedness between firms in the wider economy – or what I am choosing to call here the systemic gains arising from interconnectedness, and the higher-order industrial capabilities they represent. The more interconnected the economy, the greater its capacity to generate variety, and to promote innovation and economic learning. A poorly connected economy, where firms stand in splendid isolation from each other, has the appearance of a desert. It is unlikely that firms in such an economy will flourish.

The industrial cluster, or industrial district (as described by Marshall) is simply a more concentrated version of this general economic phenomenon. Firms exist to satisfy economic wants – but they do not exist in a social and economic vacuum. They are created, and conduct their operations, in terms of economic and social norms – such as prices, standards and contracts. Connections between firms can be viewed from two quite different perspectives. From one vantage point they can be viewed as constraints; the connected firm is seen as suffering a diminution in its freedom of action. This is the neoclassical economic view, consistent with its characterization of firms as atomistic entities. But from a different, evolutionary vantage point, inter-firm connections can be viewed as the means through which firms expand their strategic options, through accessing resources beyond their own, and through connecting with activities which provide increasing returns. This is the vantage point that informs the construction of networks and clusters. It is actually a venerable tradition, going back for hundreds of years, as captured by Italian Renaissance writers for example who first pointed to the economic advantages of clustering in manufacturing cities. It is the tradition that Erik Reinert has memorably characterized as ‘the Other Canon’ of economic thought.¹⁴

The economy may thus be viewed as a totality that is highly structured, consisting of networks of networks and other suprafirm structures. None of these suprafirm structures arise spontaneously, or deterministically: they are instead the outcome of strategizing, on an individual as well as a collective basis. The object of strategizing in each case is to capture the ‘extra’ that is available from the interactions between the agents or institutions. Following Leibenstein (1996), these may be characterized as ‘x-efficiencies’ of the economic structures. The goal of strategizing can then be formulated as the capture of the x-efficiencies available within such structures, viewing them from a strategizing perspective as potential systems, and capable of yielding *systemic* returns from the totality. In the words of Tesfatsion describing a simulation approach to this totality:

“[T]he actions of each unit depend upon the states and actions of a limited number of other units, and the overall direction of the system is determined by competition and coordination among the units subject to structural constraints. The complexity of the system thus tends to arise more from the interactions among the units than from any complexity inherent in the individual units per se” (Tefatsion 1997: 534)

¹⁴ See Reinert (1999) for an exposition of ‘the Other Canon’ of economic thought, including reference to Italian theorists such as Giovanni Botero and Antonio Serra; Reinert and Reinert (2003) provides an accessible introduction to Serra’s economic thought. Serra analyzed the sources of the difference between the wealth of Venice and the poverty of Naples (his home city). Like Porter nearly 400 years after him, he constructs a ‘diamond’ of four elements that lead manufacturing cities to become wealthy:

1. The number and variety of professions (*la quantita degli artificii ... diversi*) – i.e. the division of labour and specialization;
2. The quality of the population (*la qualita delle genti*);
3. The presence of a great commerce (*il traffico grande*); and
4. The regulations of the state (*la provvisione di colui che governa*) – the need for sound government policy and good laws.

The Hsinchu science-based industry park is an exemplary case of such supra-firm structures in operation where complementarities and specialized intermediaries (such as the silicon foundry business model) contribute to increasing returns and to the generation of ‘new shoots’ of industrial activity. How exactly was this achieved?

3. The Hsinchu Science-based industrial park

The ‘gold standard’ cluster created *de novo* in East Asia, and which remains the ideal that both China and India are striving for, is the Hsinchu Science Park in Taiwan. Although I have dealt many times with this highly successful innovation in my writings over the past decade and a half, the basic facts bear repetition.¹⁵ Founded in 1980, on army surplus land located an hour’s drive south of Taipei, the Hsinchu park was modelled initially on Taiwan’s earlier experiences with very successful export processing zones in Kaohsiung and Taichung. But Hsinchu was to be a ‘science park’ in the sense that it was subject to a governing institutional authority that only allowed firms into the park if they met certain criteria (such as higher than normal levels of R&D expenditure) and in return for which they enjoyed considerable advantages, such as tax holidays for the first five years, and tax concessions on industrial upgrading initiatives. The park was deliberately located close to the main public R&D facility in Taiwan – the Industrial Technology Research Institute (ITRI) – as well as the campuses of the two leading technology-focused universities, National Chiao Tung University and National Tsinghua University (both originating as Taiwan-based replicas of their Chinese originals, which at the time were just recovering from the difficulties of the Chinese Cultural Revolution). This combination has proven to be highly fortuitous, as companies attracted to the Hsinchu park have been able to count on the universities for supplies of skilled professional staff, while they have been stimulated by exposure to the technological innovations emanating from ITRI.

These technological innovations were not new to the world, but they were certainly new to Taiwan – and in this sense ITRI acted as a powerful driver of technology diffusion within Taiwan (initially within the Hsinchu park) while acting as a powerful absorber and aggregator (or leverage agent) of new technologies sourced from abroad. Indeed the process has been so successful, and so many firms have been clamouring to enter the park, that Hsinchu expanded its geographical limits (twice) until there was no more land available, and then a second such park in southern Taiwan (on land released by the national sugar monopoly) was opened – the Tainan science park – with a new emphasis on biotechnology, food and health sciences, as well as TFT-LCD flat panel displays. For good measure, ITRI opened a southern campus at Tainan as well. A third park in central Taiwan, the Taichung science park, has since opened as well. The three parks (covering around 3,700 hectares) constitute Taiwan’s ‘Silicon Island Project’ and house its three ‘trillion dollar’ (NT\$) industries. The parks, forming a corridor along Taiwan’s west coast, are shown in Figure 2.

Fig. 2 about here

As detailed in Chen (2008), the Hsinchu park was initially anything but a success. The first firms to locate there were not start-ups or multinationals, but Taiwan firms in the IT sector (Acer and Mitac) that were sub-contractors for major IT firms. Over the first decade, IT and PC assembly firms dominated the park’s population, and while enjoying agglomeration economies in the sense of a shared labour pool, shared utilities and shared infrastructure (not

¹⁵ See for example Mathews (1997); Mathews and Cho (2000); Mathews (2001; 2002a; 2002b).

to mention tax advantages), they were not generating common scale or scope advantages through inter-dependence. But things changed rapidly in the second decade, in the 1990s, as the Taiwan government took active steps to promote the creation of a semiconductor industry, almost all of which was concentrated (large fabricators plus upstream IC design firms and suppliers) in Hsinchu. From a modest population of 121 companies in 1990, employing 22,356 employees and producing revenues of NT\$65.6 billion, the park expanded rapidly in the second decade, numbering 369 firms in 2003, employing 101,763 employees, and generating revenues of NT\$857.8 billion – a twelvefold expansion. During the second decade, the related industry of flat panel display fabrication, together with a rich supply chain of components and sub-systems producers, also located in Hsinchu – as well as in the second park in Tainan, where there was also an attempt to cluster firms in biotech, health and foodstuffs industries.¹⁶ In the 2000s one can see the solar photovoltaic (PV) industry emerging as a ‘third pillar’ of Taiwan’s high-tech industrialization efforts. These industries have all been phenomenally successful, and clearly owe much to their clustering in Hsinchu, near to ITRI, to each other, and to the universities.¹⁷

By the end of 2001, after two decades of operation, firms in Hsinchu were generating revenues of around US\$32 billion; HSIP had attracted more than US\$912 million in infrastructure investment by the government; had attracted 312 companies employing more than 96,213 people (at a very high level of skills attainment). More than 7500 highly qualified staff had moved from ITRI to the private sector, mostly in Hsinchu. The Park houses several national labs or R&D facilities, including the National Centre for High-Performance Computing; the Synchrotron Radiation Research Centre (as in ZJHP) and the National Space Program Office, plus the Precision Instrument Development Center, the Chip Implementation Center and the National Nano-Device Laboratories. Firms within HSIP spent US\$1.6 billion on R&D in the year 2000, representing 5.4% of sales revenues.¹⁸ Firms in Hsinchu apply for and receive around 3000 patents every year: the total peaked at 3,101 in 2004, and in 2009 it was 1,867. The decline can be attributed to Taiwan firms focusing on quality rather than quantity in their patenting strategy, and the rise of other science-based industry parks.¹⁹

¹⁶ By 2009, the parks now counted as part of Hsinchu (Jhunan, Tongluo, Longtan, Yilan and Hsinchu itself as well as Hsinchu Biomedical science park) housed 440 companies with a combined workforce of 132,161 and NT\$1.1 trillion in paid-in capital, generating revenues of NT\$883 billion. The Central Taiwan science park complex (Taichung, Houli, Huwei, Erlin and Chung-Hsing) housed 66 companies (including AU Optronics) and employed just under 20,000 people and generated revenues of NT\$240 billion. The Southern Taiwan science park (Tainan, Kaohsiung) had by 2009 solicited 123 companies with a collective workforce of 48,626 and revenue generation of NT\$461 billion.

¹⁷ Chen (2008) provides the best current account of Hsinchu’s success as a purposively developed industrial cluster. For earlier insights, see Lee and Yang (2000), Chen (2002) and Tsai and Wang (2005), particularly on the IT sector. Guerrieri and Pietrobelli (2006) include a prominent place for Hsinchu in their comparison between clusters in Taiwan and Italy, while Bresnahan, Gambardella and Saxenian (2001) include Hsinchu in one of their ‘new’ Silicon Valleys that generate ‘social increasing returns’.

¹⁸ As noted above, by 2007 firms in all three science parks expended NT\$84 billion on R&D (around US\$2.6 billion) or 4.3% of revenues. In Hsinchu itself, firms spent NT\$67 billion on R&D in 2007, representing 5.6% of sales revenues.

¹⁹ On patenting activities in Taiwan as a measure of national innovative capacity, see Hu and Mathews (2005; 2008).

To what extent has Hsinchu behaved like a ‘cluster’ with an emphasis on expanded output for the firms involved, and tight inter-linkages between the firms, with growing specialization for intermediaries emerging as the market expanded? The Hsinchu park has acted in the same way as a SEZ in China, in the sense that it now houses several clusters, focused on ICs, computers and peripherals, telecommunications, optoelectronics and flat panels, as well as precision machinery and, most recently, biotech.²⁰ All these clusters are developing a rich ecosystem of suppliers and customers (vertical supply chains) as well as horizontal linkages, together with major links to the global economy – both through contracts with leading global firms in these sectors, as well as direct export sales, and openness to return immigrants from Silicon Valley and elsewhere who bring back their skills and contacts to Hsinchu.²¹ It is the variety of clusters within the Hsinchu regional agglomeration that surely accounts for the vibrancy of the region today. The remarkable build-up around Hsinchu of forward and backward linkages within the flat panel display cluster – forward to users of FPDs such as high-definition digital television producers, and backward linkages to key component suppliers, is shown in Figure 3. This constellation of linkages stands as the key to cluster success, in Taiwan and elsewhere.

Fig. 3 about here

4. Marshallian externalities at work in Hsinchu

The first real attempt to provide evolutionary theorizing to the economy was employed by Alfred Marshall, in his studies of industrial districts and their emergence in Britain in the 19th century. In particular, Marshall was concerned with the metals cluster in the Sheffield industrial district, where he conducted field work over the half-decade 1885-1890, resulting in a celebrated chapter on economic location in the first edition of his masterwork, *Principles of Economics*, in 1890.²² This work stands at the very origins of our understanding as to how clusters work, and remains of continuing relevance for the acuity of Marshall’s insights. Marshall identified three sources for what he described as the localisation of an industry, namely the capacity of firms to call on a common pool of skilled labour; the economies resulting from interdependencies between firms; and the knowledge spillovers generated. In modern parlance, we would characterize these as the sources for the competitiveness of an industrial district – and bear in mind that in 1890, Sheffield was at the very zenith of its wealth and its emergence as a ‘growth pole’ for British manufacturing industry.

²⁰ In 2004, of total sales revenues of \$NT1086 billion, 72% came from ICs, 12% from computers and peripherals, 11% from optoelectronics, 5% from telecomms, with the balance coming from precision machinery and biotech (Hsinchu Science Park Administration, annual statistics).

²¹ Saxenian (2002) has emphasized the role played by Taiwan skilled immigrants in helping to build Silicon Valley – but of course in a reverse direction these same people have also given enormous benefits to Taiwan, and to Hsinchu in particular, which they have favoured as a location for their entrepreneurial start-ups – see also Hsu and Saxenian (2002) and Saxenian and Hsu (2002). Yang et al (2009), drawing on the global production network literature, label this as an instance of ‘strategic coupling’ between Hsinchu and the global economy.

²² See Marshall 1890 and its subsequent many editions. The chapter on localization is Book [IV.X](#) *Industrial Organization (Continued) The Concentration of Specialized Industries in Particular Localities*. The eighth edition containing this chapter is now available online, at: <http://www.econlib.org/library/Marshall/marP.html>

So important have these three sources of competitiveness for an industrial cluster become that we know them now as ‘Marshall’s trinity’. They are: a pool of skilled labour; local supplier linkages (forward and backward); and local knowledge spillovers. What did Marshall mean by these three emergent features? First, as firms co-locate and specialize in the same activity (or ‘trade’ in Marshall’s terminology), they would exchange skilled workers and thereby create a pool of skilled labour that all firms could draw on. The specialization of activities within the cluster, and their underlying resources, creates the pool of skilled labour, and the existence of the pool of skilled labour thereby attracts further firms and further specialization – thus launching the cumulative processes (or ‘chain reaction’) observed in successful clusters.

Second, local specialized firms create external economies in the form of lower transport and logistics costs, lower communications costs, and (to the extent that utilities are shared) lower infrastructure costs. This may be described in terms of co-evolution of firms, their specialized suppliers and specialized institutions (or what Lane (2002) calls the ‘scaffolding’ of the network). Richardson (1972; 2002) captured this idea in the form of the expanding market creating opportunities for specialized intermediaries appearing – and as they grow and form linkages, so they create further opportunities for specialization and market expansion, in a cumulative process.

Third, local knowledge spillovers enable firms in the cluster to tap into the latest market intelligence, new designs, new markets, new technologies; this is what Marshall meant by stating that in an industrial district, the ‘secrets of the trade are ‘in the air’ ... We could give a more recent version of this phrase by saying that the cluster generates a ‘buzz’.²³ In this way Marshall was actually the first to develop a ‘knowledge-based theory’ of the cluster, in the sense that he saw knowledge spillovers as fundamental – the knowledge being ‘in the air’ in a cluster. But this has to be linked with an economic account of the lower costs enjoyed by firms within the cluster – their capacity to draw external economies from the cluster, and thereby generate the increasing returns that were clearly evident at the cluster level. This is the classic Smith-Marshall-Young argument that has its grounding in the evolutionary dynamics of clusters.²⁴

In short, the argument on the microeconomics of clusters is that the circular and cumulative process that enables specialized firms to form as the market expands, thereby generating greater variety of output and thus attracting greater demand (expanding the market) which in turn creates more opportunities for specialization – this argument underpins the salience of clusters and other suprafirm structures like platforms and networks. We may generalize the Marshallian externalities as systemic attributes consisting of resource pools (e.g. common infrastructure and labour pool); technological intermediates (specialization); and knowledge spillovers (complementarities) – whose combined operation generates increasing returns.

²³ Or we could use the phrase introduced by Malmberg et al (1996), namely ‘agglomeration forces’ which drive firms to seek the advantages that are generated from clustering.

²⁴ Of course the identification of sources of agglomeration economies did not stop with Marshall’s trinity – important as these are. Porter (2000) draws attention to other factors including local demand conditions and cluster interdependencies that are also important.

A particular aspect of this process of building complementarities within a high-tech cluster involves the creation of common ‘process platforms’ that can be shared by firms along a value chain or more generally across a value constellation. Such process platforms are indispensable in facilitating mass customization.²⁵ While recognized in the case of firms and their process technologies, the emergence of such process platforms across firms within industrial networks is a more subtle affair.

But there is clearly another side to all of this. While specialized labour works to the advantage of a cluster in its expansionist phase, continued dependence on such specializations will tend to lock-in a cluster to a declining set of products and activities, and in the absence of other interventions, make it harder for the firms in the cluster to start new lines of development. Thus the specialized pool of labour can turn into a constraint that locks all firms into a declining market. Likewise the network of specialized firms can lock each other into a specific set of products and activities and make it hard to break out into something new. And the secrets that are ‘in the air’ (the higher-order capabilities) can become locked-in to a particular field of knowledge, thereby excluding other fields from intruding.

Far from this being a rare kind of development, with evolution (growth and expansion) becoming a process of involution (decline and lock-in), it is in fact the fate that awaits most clusters unless they take active steps to seed multiple lines of development, or (what amounts to the same thing) take steps to forge connections between one cluster and another, so that the two become the core of a self-generated network that can expand and encompass other clusters, at a higher level of recursion – at the level of a town, or city.²⁶ Thus Sheffield itself, where Marshall did his pioneering field work, has in subsequent years declined to become one of the poorest regions in Europe – and the reason must be that it allowed itself to become locked-in to an overly narrow set of skills, activities and products. The regions that continue to thrive – such as Silicon Valley, or Hsinchu in Taiwan – do so demonstrably through their capacity to seed new lines of development, and create a dense network of interdependent firms located within interdependent value chains, or transvections.

So Marshall’s sources of local external economies can work against a cluster as much as for it, in the absence of equilibrium-destroying innovations and entrepreneurial ventures that

²⁵ Jiao et al (2007) provide a rigorous account of process platforms as a foundation for mass customization, but largely confined within the scope of the individual firm (although they do mention the extended enterprise), while Halman et al (2003) emphasize the trade-off between the greater initial costs involved in setting-up platforms and the subsequent savings in facilitating product changes. Helper, MacDuffie and Sabel (2000) are getting at the same idea with their notion of pragmatic collaborations across value chains and the ‘chunking’ of design components, as are Hobday, Davies and Prencipe (2005) in the notion of Complex Production Systems that span several organizations and the systems integration challenges they face. Hobday et al seem to be correct in their evaluation of such interfirm systems integration capacity as a core competence of the corporation – but they stop short of identifying it as a higher-order capability of the cluster as a whole. All of this points to platforms as being fundamental to multi-firm success – as recognized by Gawer and Henderson (2007) in their study of the Intel platforms.

²⁶ In a striking study, the British economic geographers Antony Potter and H. Doug Watts (2010) have replicated Marshall’s own field studies in Sheffield, but 120 years later, when Sheffield and its surrounding area is now classified by the EU as one of the poorest regions in Europe and one requiring Community assistance. They demonstrate how the very factors that helped Sheffield to expand in the 1880s and 1890s (Marshall’s trinity) now work in the reverse direction to lock the region into outmoded economic activities.

initiate new lines of development. This was of course the province of Schumpeter, who remains the 20th century economist of most relevance to China, India and other emerging industrial giants, precisely because he insisted on a view of the economy that focused on the seeds of new developments and their creation, rather than on what already existed. A modern evolutionary perspective would see Marshall as the champion of evolutionary gradualism, and Schumpeter as the champion of saltationism – and a way of bridging the two perspectives being found in the framework of ‘punctuated equilibrium’, where populations of firms are viewed as existing for long periods in a relatively stable state (subject to incessant adaptation and learning) broken by occasional bouts of rapid, discontinuous change (caused, for example, by the arrival of a new technology, or a new flagship global firm) that forces complex reconfiguration of existing activity networks.²⁷ Depending on the results of the punctuated disturbance, and its source as external or internal to the cluster, the cluster may be driven in a continuation of its existing trajectory or pathway, or to break with it and start a new line of development.²⁸ Applications of such a perspective in concrete, empirical scholarship tracing the evolution (or involution) of real clusters with their real cluster industrial dynamics, remain to be performed.

Take the case of the Hsinchu science-based industry park as test case. Here was a conscious attempt on the part of the Taiwan government to seed a new kind of advanced technology cluster, with the government playing the role initially of collective entrepreneur, both in leveraging technology from likely sources (particularly in Silicon Valley) through the institutional vehicle of ITRI, and in leveraging venture capital, again through vehicles initially established expressly by the Taiwan government. In its first decade the cluster drifted, without generating any substantial spillovers or complementarities. But things changed in the second decade, under the impact of government efforts to create a semiconductor industry located within the park, with associated upstream and downstream linkages, and where the newly created TSMC played a major role as *specialized intermediary* providing foundry IC fabrication services to third party producers. TSMC was the epitome of a specialized intermediary offering services to the cluster as a whole, becoming viable as the market reached a certain size, and through its own activities further expanding the market, in a classic process of circular and cumulative causation. In this case there was a strong element of innovation in terms of business model; TSMC was not just copied from elsewhere. But it sparked competitive emulation, particularly from UMC (the first spin-off from ERSO/ITRI in the IC sector) which shifted its business model to become a foundry just like TSMC, providing the spur of competition that has been to the benefit of the whole cluster.

The entrepreneurial creation of these specialized intermediaries sparked consequences in the aggregation of complementary firms within Hsinchu. The specialized fabrication services provided by TSMC and UMC enabled a cluster of upstream IC design firms to become established, which worked closely (in both senses of the word) with TSMC and UMC in creating new IC designs based on ‘generic’ MPU products from Intel, each new design adapted to some new function in a new product such as mobile phones. The role of TSMC and UMC as silicon foundries was buttressed by another shared facility, namely a Common

²⁷ Antonelli (2007) provides just such a perspective, in a way that invites concrete empirical investigation of actual cluster trajectories and their punctuated equilibria. Gould and Eldredge introduced the notion of punctuated equilibrium (1977) and it is now widely accepted in the biological sciences – while its application in the social and management sciences remains fragmentary.

²⁸ Much work in evolutionary economic geography is now devoted to explicating the sources of path dependence (and possibilities for breaking free of it); for a recent critical review, see Martin and Sunley (2006).

Design Centre for IC design, making expensive design equipment available to smaller firms. (The Taiwan firms quickly outgrew this government initiative.) And the growing scale of production by TSMC and UMC enabled real economies of scale to be reaped, which could then be enjoyed by downstream customers such as the OEM contract houses like HonHai building huge numbers of products under contract, such as mobile devices. The whole upstream and downstream transvection enjoyed the advantages of a common labour pool (provided by the two local universities, the National ChiaoTung university and the National Tsinghua university, as well as engineers leaving ITRI for the private sector) and other common specialized suppliers, including in particular Venture Capital firms that paved the way for further expansion of the industrial cluster. While government provided the initial collective entrepreneurial effort, it was careful to stay out of the way of the private sector as it evolved and grew – but with government intervening to maintain the pressure on firms to upgrade their process technology, and providing the stimulus for ‘new shoots’ of industry such as LEDs, solar PVs and CSP and EVs to maintain the innovation momentum.²⁹

The outcome is that Hsinchu is now capturing the increasing returns that the theoretical economic literature predicts would flow from the knowledge spillovers and common infrastructure and interfirm connections generated within the park. The HSIP Administration has been collecting the relevant data, and can now demonstrate that firms within the Hsinchu park generate value-added (revenues less costs as a proportion of total revenues) of 50% -- compared with a figure of 30% for manufacturing firms in Taiwan outside the Hsinchu park. This means that ***the firms in the Park are 66% more productive than firms outside the park*** (a ratio of 5 to 3), and have been so for the past decade. These productivity gains come from the agglomeration economies identified in the 19th century by Marshall through his studies of Industrial Districts in Britain, but even more importantly from the systemic gains generated by firms’ interconnections and inter-relatedness along the value chain. For example a large silicon foundry like TSMC will depend for efficient operation partly on its own internal efficiencies (its superior chip fabrication management routines) – that Marshall termed ‘internal economies’ – but also on efficiencies reaped through its presence in a cluster, termed ‘external economies’. Local firms supplying various fabrication services will specialize more and more in order to link with TSMC’s special requirements and routines, competing with each other to do so – whereas a TSMC fab located away from such a cluster, such as its fab in Camas, Washington state, on the US northwest coast, would generate few if any such external economies. It is these external economies, generated by the network of firms with which a Hsinchu firm interacts repeatedly, that account for the productivity enhancement enjoyed by firms within the Hsinchu park. Another measure of the increased returns accruing to firms in the Hsinchu cluster is that the Hsinchu firms pay 1.8 times the level of salaries as firms outside the cluster.³⁰ They can pay higher salaries because of the

²⁹ In this context it is interesting to compare the rival Chinese clusters based in the Pearl River Delta (PRD: with lead cities Guangzhou, Shenzhen and Hong Kong) and the Yangtze River Delta (YRD: with lead city Shanghai) turn on precisely this point (Chen 2007; Yang 2009). A town in the PRD like Dongguan has the appearance of a high-tech centre, with its strong clustering of IT firms producing or contracting towards desktop computers. But when contrasted with Suzhou in the YRD, where the next stage of PCs – namely laptop computers – is clustering, then Dongguan appears to be at an evolutionary standstill. In the absence of determined intervention by the provincial Guangdong authorities, to force upgrading of Dongguan firms (which also calls for collaboration with global PC flagship firms like Acer) then Dongguan may be destined to follow the path of Sheffield.

³⁰ These higher salaries paid by firms within the Hsinchu park doubtless reflect the profit-sharing schemes, stock options and bonuses paid by high-tech firms in Taiwan – but not by other firms. For a review of

higher productivity levels they enjoy. The higher the salaries paid, the greater the incentive to invest in innovation – and indeed the HSIP Administration observes that firms within the Hsinchu park account for around 30% of all R&D expenditure in Taiwan – compared with their accounting for 9% of total turnover (meaning that their expenditure on R&D is much higher than for firms outside the park).³¹ In this way Hsinchu becomes an engine of innovation, over and above its being a powerful engine of production. These are all concrete measures of the increased returns generated by firms within the Hsinchu cluster through their agglomeration and through their interactions. These data mean that the Hsinchu park *works as a cluster*, with firms capturing systemic gains, and thereby provides a model for the rest of the world.

5. The people who created Hsinchu

Behind the success of Hsinchu as a high-tech industrial cluster, there are the strategies of financial leverage and technology leverage and fast-follower industrial dynamics – and the people who invented and implemented them.³²

The roots of Taiwan's first, tentative moves towards semiconductor activities go back to the plans and strategies of some remarkably prescient men. In the early 1970s, Mr Y.S. Sun, a technologist-politician who had headed up Taiwan's electric power utility, and had become the Minister for Economic Affairs, was laying the foundations for Taiwan's technological upgrading – at a time when the rest of the world saw the country as a source for plastic toys and low-cost running shoes. It was under his stewardship of the ministry that the Industrial Technology Research Institute (ITRI) was founded near Hsinchu, south of Taipei, in 1973. This organization would prove to be the driving force behind Taiwan's industrial upgrading. No sooner was ITRI established than Mr Sun was developing plans for advanced industries like semiconductors, designed to feed into the country's nascent electronics industry, and for export purposes. In August 1974 Mr Sun met with his colleague and friend, Dr Pan Wen-Yuan, in Princeton, New Jersey, at Dr Pan's home. Their topic of discussion: how to take Taiwan into the 'knowledge-intensive' industries then being pioneered in the USA by companies such as Fairchild, and being emulated by Japan. Dr Pan was a brilliant electrical engineer employed at RCA, at the David Sarnoff Laboratories, then one of the premier industrial labs in the USA. They agreed that the electronics industry would be the key to Taiwan's future high technology development, and that it would need to have a foundation in a semiconductor and IC industry whose elements would have to be leveraged from abroad. They identified Chinese engineers working in US technology companies as their key to launching the new industry. Dr Pan then acted on his initial meeting to form an advisory group at Princeton. It met regularly and came to be known as the Technical Advisory Committee. Specific recommendations for starting a new semiconductor industry were framed by this committee, and taken to Cabinet by Mr Sun. It was agreed to establish a specialist laboratory under the auspices of ITRI to kick-start the process. This was the origin of ERSO, founded in 1974. The head of ERSO was immediately charged with the task of developing the technological capabilities needed to generate a semiconductor industry.

these matters, see Han and Shen (2007), who argue that the bonus system has been a material factor in the superior performance of the Hsinchu-based firms.

³¹ All data supplied by the Hsinchu Park Administration, at my request.

³² This section is based on the chapter on Taiwan in Mathews and Cho (2000).

ERSO scoured the world for knowledge of IC fabrication, emulating Japanese methods of study tours and knowledge leverage, and utilizing the Princeton-based network of advisors meeting with Dr Pan. Under his influence, RCA was prevailed upon in 1976 to transfer its obsolete IC fabrication technology to the fledgling ERSO. From RCA's perspective, it was at this point thinking of getting out of semiconductors, and saw no harm in earning some royalties on its 7-micron technology, then severely behind the world LSI best of 2-micron circuit design. From ERSO's perspective, the technology transferred from RCA was a window into the secret world of advanced technology. A group of young and enthusiastic engineers spent the best part of a year, in the USA and at ERSO, learning the technology of IC fabrication from RCA. It was out of this group that virtually the entire senior echelons of the subsequent semiconductor industry in Taiwan will be formed.

ERSO built its pilot IC fabrication plant, under RCA guidance, and started producing its own experimental chips. Chips for ICs such as those in electronic watches were produced first, utilizing RCA designs. Later the ERSO engineers were able to produce their own designs, and tweak their equipment to improve the yields – so much so that by 1978 or 1979 ERSO was securing better yields than RCA itself. RCA started buying chips from its erstwhile pupil, albeit on a very small scale. But it showed that the dreams of Taiwan's leaders for a high technology future were not entirely ludicrous.

Principal amongst these leaders, apart from Mr Sun himself who became premier in 1979, was Dr K.T. Li. He served as Minister for Economic Affairs prior to Mr Sun, and went on from there to the Ministry of Finance. Dr Li had been a brilliant young Chinese physicist educated at Cambridge, where he performed original research in the Cavendish Laboratory before being caught up in China's war with the Japanese in the 1930s. His contribution to China's war effort was a radio-based detection system used to provide advance warning of air raids. Subsequently he transferred to business and rose to be head of a shipbuilding company which left the mainland and crossed to Taiwan with the KMT in 1949. He soon became involved in government affairs, taking over the Ministry of Economic Affairs in 1965, followed by the Ministry of Finance in 1969, from where he directed the flow of capital into Taiwan's industrialization programs. His most notable achievement up to this point had been the creation of Taiwan's first Export Processing Zone, outside Kaohsiung. It was the world's first example of a duty-free manufacturing enclave, modelled on the duty-free ports established by Britain in Singapore and Penang in the 19th century.

As ERSO was embarking on its semiconductor venture, Dr Li retired from the Ministry of Finance, and looked around for ways of stimulating the country's high technology development. His first act was to call together the country's scientific and technical elite to consider the country's future. This conference, staged in 1978 and attended over several days' discussion by 400 of the country's best and brightest, proved to be a landmark event. The conference adopted a 'Science and Technology Development Program' which was subsequently endorsed by Cabinet. This document targeted semiconductors as well as computers, energy, materials and automation, as the sectors of most strategic value for Taiwan. It called for the creation of a new permanent advisory body, to be named the Science and Technology Advisory Group, chaired by Dr Li.³³ Most significantly, it called for the

³³ I had the honor of meeting Dr Li at the STAG offices in Taipei, in 1997. Dr Li was then in his nineties, and spoke lucidly for over two hours on Taiwan's development policies. For some apposite remarks on Dr Li's career, from one who was his equal in Singapore, see the text of the Fourth K.T. Li Lecture delivered at Harvard

creation of specialist infrastructure needed to support advanced industries like semiconductors.

Such a project was championed by Professor Shu Shien-Siu, who had been President of the National Tsing-Hua University, and served as President of the National Science Council and as Chairman of ITRI.³⁴ From these influential positions he shepherded the idea of a specialist knowledge-intensive industry park, as a public sector counterpart in Taiwan to Stanford's Silicon Valley. This became a special project of the National Science Council, which overcame considerable opposition and scepticism in the Taiwan Cabinet to have the new park created, under the auspices of the NSC, and secure land for it from the Taiwan military, near Hsinchu, and close to the campus of ITRI and the Tsing-Hua University as well as Chiao-Tung university. The new park was duly launched in 1980. The Hsinchu/ITRI/Tsing-Hua/Chiao-Tung complex has been an extremely important element in Taiwan's semiconductor success, housing all the firms founded through the 1980s.

The first of these was not a creation of the private sector, but of ERSO itself. By 1980, while Taiwan had many firms engaged in 'back-end' IC activities such as packaging and testing, there were no LSI 'front-end' activities. So the step taken by Premier Sun and Dr Li, working with the head of ERSO, Dr Hu Ding-Hua and head of the IC pilot plant, Dr Chintay Shih, was to create such a company. ERSO was charged with formulating the plan for the launch, which resulted in the formation of the United Microelectronics Corporation (UMC) in 1980. It was established with \$20 million in capital, 49 percent of which was provided by state investment vehicles. Its founding marked the beginning of a commercial semiconductor industry in Taiwan. UMC was in fact the first company to locate on the new Hsinchu Science-based industrial park. It has prospered there ever since, evolving to a group of companies engaged by the end of the 1990s in a broad range of semiconductor activities and earning \$1 billion-plus in revenues.

Taiwan's semiconductor industry took an enormous leap forward in the mid-1980s, with the founding of Taiwan Semiconductor Manufacturing Corporation (TSMC) as a joint venture with the multinational, Philips. TSMC was the brainchild of Dr Morris Chang, who joined ITRI as its new president in 1985. He had a long career behind him in the world semiconductor industry, heading up Texas Instruments' global semiconductor operations, before becoming President of General Instrument. From here he was recruited to head up ITRI, a far-sighted move on the part of Taiwan's leaders. Dr Chang brought with him the concept of a silicon foundry, then being practised as a sideline by semiconductor firms to use spare capacity in building chips for third parties. Dr Chang saw that the costs of establishing wafer fabs would continue to rise, and that there would be a market in future for a full-time silicon foundry. Such a venture could also play a critical role in fabricating ICs for Taiwan's small chip design firms which could not afford to build the chips themselves. TSMC was

by Dr Goh Keng-Swee, in 1993. Dr Li gave his own account of the evolution of policy behind Taiwan's successes in Li (1988).

³⁴ Shu Shien-Siu (1912-2001) was born in Yongjia, Wenzhou city in Zhejiang province of China, and died in Taiwan in 2001, aged 89. He studied at Brown University in the US where he took his PhD in 1948 in applied mathematics, then taught at Princeton, MIT and Purdue, where he rose to be Chair of Applied Mathematics. In 1961 Shu founded the Department of Mathematics at Tsinghua University in Taiwan, and served as President of the University from 1970 to 1975. He directed the National Science Council from 1973 to 1980, and from 1979 to 1988 he was Chairman and Director-General of ITRI. It was his advice that was crucial in establishing the Hsinchu Science-based Industry Park in 1980.

launched in 1986 as the world's first 'pure play' silicon foundry, working on contract with IC firms and not producing products of its own. Its operations, thanks to the technology transferred from Philips, brought it abreast of the world technological frontier. Dr Chang became the chairman of TSMC, and in that capacity oversaw its expansion into DRAM fabrication (as major shareholder in the new Vanguard Semiconductor venture in 1995) and its expansion overseas in the form of WaferTech, which built a wafer plant in Camas, Washington, in a joint venture with US semiconductor firms. He has thus guided the development of Taiwan's industry, working from his office in central Taipei with its beautiful Chinese wall hangings and precious vases, over the past 15 years.³⁵

At the same time, the first steps were being taken to create a Venture Capital industry in Taiwan to provide seed capital to fledgling enterprises that would seek to build operations in Hsinchu, in many cases founded by return immigrants from Silicon Valley ('reverse brain drain'). In 1980, the year of Hsinchu's founding, the Executive Yuan voted the then substantial sum of NT\$800 million to a new venture fund, targeted at companies making their home in Hsinchu, and managed by the state-owned Bank of Communication. But the VC industry really got going with private sector involvement. One of the first private sector ventures was Hambrecht & Quist Asia Pacific, founded by Hsu Ta-Lin, a Silicon Valley financier, with US\$26 million from various industry groups and \$24 million from government funds. The next year in 1987, two overseas Chinese engineers, Peter Liu and Tan Lip-bu, founded a second VC firm, the Walden International Investment Group. These funds then helped new firms such as Acer and Microtek (a scanner company) to become established in Hsinchu. On their own these were small beginnings – but they initiated a process that gathered momentum, particularly driven by overseas Chinese looking to return home to Taiwan and attracted by prospects in Hsinchu.³⁶

ERSO continued to spin-off new ventures, both officially (like UMC and TSMC) and unofficially, as clever engineers left to start their own firms (usually with the full blessing of ERSO, which was in the business of building a viable semiconductor industry in Taiwan). One of these was Dr Yang Ding-Yuan, who left with his staff in 1987 to found a new company. Dr Yang had held various posts in ERSO, most recently as analyst of its various business ventures, prior to making the break in 1987. He secured financial backing from the Walsin Lihwa corporation, and founded Winbond (whose Chinese characters, Hua Bang, can be interpreted to mean a 'self-governing community of professionals'). Winbond has grown rapidly under Dr Yang's guidance, to become the island's largest producer of branded ICs. The company has paired off with the world's leading multinationals, like HP and Toshiba, to secure advanced technologies and act as second source producer. In this way, Winbond entered DRAM production in the mid-1990s, through a technology transfer and 'second source' production agreement with Toshiba. It has continued to expand its wafer fabrication facilities, opening a fourth plant in 1998 in Hsinchu, and was planning at the end of the 1990s to open several more facilities in Taiwan's second science-based industry park at Tainan.

The scale and breadth of the semiconductor industry and the more recent industries such as flat panel displays and solar photovoltaics in Taiwan is based firmly on these strong

³⁵ Dr Chang granted me a lengthy interview in his office, in March 1996.

³⁶ AnnaLee Saxenian and Charles Sabel (2008) provide an enlightening discussion of the foundations of the VC industry in Taiwan and its influence on Hsinchu, in a paper based on Dr Saxenian's Roepke Lecture.

foundations laid by visionary pioneers. The wide range of firms producing at the world's technological frontier in Taiwan reflects the depth of training provided to the original cadre of engineers in ERSO's pilot plant in the late 1970s. Mr Sun, and Drs Pan and Li would be pleased with all this, but probably not surprised. After all, this is what they planned for.

6. Economic learning at Hsinchu

As detailed in these brief biographies, the success of Hsinchu was not pre-ordained. Rather it arose from a pragmatic and entrepreneurial frame of mind that was prepared to allow experiments to proceed, learning from the results. This is very much the process of economic learning that was involved in the formation of Taiwan's R&D alliances, which have been a source of industrial revitalization in Taiwan now for two decades and more, and a source of the 'new shoots' that drive Taiwan's moves into new industries.³⁷

A series of collaborative R&D ventures emerged in Taiwan, within a quite distinctive institutional framework. Unlike the case of many of the collaborative arrangements between established firms in the US, Europe or Japan, where mutual risk reduction is frequently the driving influence, in the case of Taiwan it is technological learning, upgrading and catch-up industry creation that is the object of the collaborative exercises. Taiwan's R&D consortia were formed hesitantly in the 1980s, but flourished in the 1990s as institutional forms were found which encourage firms to cooperate in raising their technological levels to the point where they can compete successfully in advanced technology industries. Many of these alliances or consortia were in the information technology sectors, covering personal computers, work stations, multiprocessors and multimedia, as well as a range of consumer products and telecommunications and data switching systems and products. But they also emerged in other sectors such as automotive engines, motor cycles, electric vehicles, and in the services and financial sector as well – and now in the 2000s in such new sectors as solar PVs and new Electric Vehicles. ITRI has been responsible for putting together over 50 of these alliances, bringing together firms, and public sector research institutes, with the added organizational input of trade associations, and catalytic financial assistance from government agencies. The alliances form an essential component of Taiwan's national system of innovation (Lin 1994; Hou and Gee 1993).

Taiwan's high technology industrial success rests on a capacity to leverage resources and pursue a strategy of rapid catch-up. Its firms tap into advanced markets through various forms of contract manufacturing, and are able to leverage new levels of technological capability from these arrangements. This is an advanced form of *technological learning*, in which the most significant players have not been giant firms (as in Japan or Korea), but small and medium-sized enterprises whose entrepreneurial flexibility and adaptability have been the key to their success. Underpinning this success are the efforts of public sector research and development institutes, such as Taiwan's Industrial Technology Research Institute (ITRI). Since its founding in 1973 ITRI and its laboratories have acted as a prime vehicle for the leveraging of advanced technologies from abroad, and for their rapid diffusion or dissemination to Taiwan's firms. This cooperation between public and private sectors, to overcome the scale disadvantages of Taiwan's small firms, is a characteristic feature of the country's technological upgrading strategies, and the creation of new high technology sectors such as semiconductors.

³⁷ This section is based on Mathews (2002b).

It is Taiwan's distinctive R&D consortia that demonstrate most clearly the power of this public-private cooperation, in one successful industry intervention after another. Taiwan's current dominance of mobile (laptop) PCs for example, rests at least in part on a public-private sector led consortium that rushed a product to world markets in 1991. Taiwan's strong performance in communications products such as data switches, which are used in PC networks, similarly rests on a consortium which worked with Taiwan's public sector industry research organization, ITRI, to produce a switch to match the Ethernet standard, in 1992/93. When IBM introduced a new PC based on its PowerPC microprocessor, in June 1995, Taiwan firms exhibited a range of computing products based on the same processor just one day later. Again this achievement rested on a carefully nurtured R&D consortium involving both IBM and Motorola, joint developers of the PowerPC microprocessor, as external parties. Taiwan established an R&D consortium to develop a 1.2 liter 4-valve engine, as part of an attempt to create a fresh start in the automotive sector. Again, this was the product of a public-private collaborative research endeavor involving three companies, which created the Taiwan Engine Company to produce the product; but this was not successful. Thus, the R&D consortium is an interfirm organizational form that Taiwan has adapted to its own purposes as a vehicle for catch-up industry creation and technological upgrading, through both successes and failures. The microdynamics of the operation of these alliances or consortia, is therefore a matter of some substantial interest.

Some of these consortia have been more successful than others - but all seem to have learned organizational lessons from the early cases where government contributed all the funds, and research tasks were formulated in generic and overly ambitious terms for the companies to take advantage of them. The more recent R&D alliances formed in the 1990s have been more focused, more tightly organized and managed, and have involved participant firms much more directly in co-developing a core technology or new technological standard which can be incorporated by the companies, through adoption and adaptation, in their own products.

The basic model of the Taiwanese alliances is the construction of a process in which R&D costs can be shared, and risks reduced, through bringing many small firms into a collaborative alliance with each other and with ITRI (i.e. with one its operating laboratories). It is ITRI which provides the anchor for the alliance and the principal vehicle of technology leverage. Thus, the Taiwan R&D alliances are similar to their counterparts in North America, Europe and Japan in their reliance on public sector laboratories to provide the core institutional vehicle for R&D cooperation. But they differ from their counterparts in the Triad countries in that their goal is *rapid adoption* of new technological standards, products or processes developed elsewhere, and their *rapid diffusion* to as many firms as possible – rather than extending the envelope of R&D. The organizational form of the Taiwan alliances evolved over the course of the two decades in the 1980s and 1990s. It owed much to the R&D collaborative vehicles developed in the leading industrial centers, particularly in the way that Japan structured many relatively short-lived collaborative R&D alliances with clear technological learning goals which in turn drew on earlier European examples. Taiwan's ability to fashion these consortia, and utilize them to accelerate technological catchup and learning, is testament to the country's institutional capacity. The initiative for the formation of early alliances came from the public agencies (largely ITRI or the Ministry of Economic Affairs), but the private sector has been taking an increasingly active role as the institutional form of the consortia has evolved, to the point where private firms were taking the initiative in forming alliances by the end of the 1990s (as in the case of electronic commerce). Thus the Taiwan R&D consortia pose an interesting case for the study of government-business

relations and their evolution as an economy moves through phases of technological imitation to innovation.³⁸

The Taiwan consortia were created to accelerate the diffusion of technological capabilities across industries. In other words they are instruments of economic learning, like their predecessors in Japan. While costs were a consideration, they were marginal compared with the learning benefits conferred on participant firms. This is demonstrated in the impact of consortium membership on firms' R&D expenditures. Far from firms electing to economize on R&D expenditure through joining R&D consortia (a common assumption in the economics literature) the experience in Taiwan indicates that firms rapidly acquire a taste for R&D and an appreciation of its competitive benefits through participating in alliances. They thereby tended to increase the scale of their own R&D activities, even as they participated in the alliances, thereby enhancing their own absorptive capacity (Cohen and Levinthal 1990). This is what may be termed the *innovation effect* of the alliances.³⁹ It is enhanced as firms conduct more and more of the development work within their own facilities -- which is one of the reasons why this trend is encouraged in Taiwan by ITRI, and underpins the networks and clusters that populate the Hsinchu park.

Thus Taiwan's R&D consortia have indeed made a positive contribution to Taiwan's industry development and upgrading – along with other institutional innovations and of course the contributions of private firms themselves. They have contributed to the development of Taiwan's social capital insofar as they established a replicable organizational form adapted to the purposes of technological learning and diffusion. Of course, not all the Taiwan R&D alliances have been successful. Some have been failures in terms of their own goals and targets. Some have been unsuccessful, not because of lack of effort or coordination on the part of the member firms, but because the world did not behave as expected, or a market did not develop as expected (as in the case of the HDTV consortium, and the graphics terminal consortium). In other cases, consortia have been unsuccessful because of lack of supporting infrastructure: for example in the case of efforts to launch laser fax machines and hard disc drives. Here the problem was not so much the alliance itself as the lack of a rich network of precision engineering and machinery firms needed to sustain such industries, i.e. the lack of a sufficiently sophisticated process platform. Sometimes efforts to mount them have been unsuccessful because of opposition from Taiwan's own incumbents – as in the case of early efforts to kickstart Taiwan's optoelectronics industry, or in efforts to create an automotive engine industry.

Yet even where R&D alliances in Taiwan have been less than successful, they have contributed their experience and this has been absorbed and applied in the design and implementation of future alliances. Thus, the Laptop PC consortium was recognized as clearly having too many participants with too little experience - but this was corrected in subsequent consortia. Likewise the trade association was not involved in earlier consortia --

³⁸ Breznitz (2007) devotes a chapter to Taiwan's institutional innovations in promoting diffusion of technology, underlining the successes achieved by ITRI and contrasting these with the lack of such successes on the part of its parallel organization, Institute for Information Industry (III). What ITRI was able to do in the hardware sector of the IT industry III was signally unable to achieve in the software sector. Clearly the Taiwan government has itself recognized this problem, and is taking steps to put III under new management and new terms of reference.

³⁹ Sakakibara (1993; 1997) demonstrated such an effect in the case of Japanese consortia; she later quantified it as one of the demonstrable benefits of firms' participation in R&D consortia (Branstetter and Sakakibara 1997).

but its involvement has been found to be so beneficial, in terms of expanding the scope of the potential participation by firms and in securing the legitimacy of the alliances, that its involvement was seen as important in later alliances. Thus, the alliances represent a form of advanced *economic learning* in two senses: in the sense that there is an underlying improvement from one generation of alliance to the next; and in the sense that the knowledge generated is held by a number of firms and agencies in the “space” that exists between firms and agencies, i.e. in inter-organizational space. It is the capability to organize this space, through various forms of consortia, alliances, trade associations and *keiretsu*, that can be expected to have an increasingly decisive bearing on international competitiveness.

7. Emulation of Hsinchu – in China and elsewhere

China has clearly studied the Taiwan experience closely, and is drawing numerous lessons – through emulation. Many of the Chinese SEZs and High-Tech park initiatives are clearly modelled in some sense on Hsinchu, if without attribution. But one such cluster is explicit – the Zhangjiang Hi-Tech Park (ZJHP) located in the new Pudong region of Shanghai, close to several national R&D institutes and universities such as JiaoTong university. The ZJHP was established in 1992 by the Shanghai municipal government as a showcase for Chinese-made technology, with strong policy support to accelerate the park’s growth – including one-stop shopping for incoming enterprises, venture capital and financial support, tax and other incentives and human capital initiatives such as special schools.⁴⁰ In 1999 the Shanghai municipal government issued its ‘Focus on Zhangjiang’ policy and identified the IC, software and biomedicine industries as lead sectors for the park; in the 2000s it has added photonics, creative industries and bank card industries to this list (focused on multinational park entrants such as Citibank, Asia Pacific Software and SAP. The central cluster in the park has been semiconductors, with SMIC as the flagship chip foundry – but SMIC’s lack of profitability has retarded development. A major investment in a new 300-mm wafer fabrication facility at ZJHP by the Chinese companies Grace Semiconductor and Shanghai Hua Hong (known as *Hua Lei*) in 2010 is expected to revive the IC cluster. However other clusters have moved to fill the vacuum. In photonics, for example, an entire production chain, encompassing upstream producers of LEDs, mid-stream producers of chips and appliances to downstream producers of applications (such as traffic and public lighting) has been established in the park, building on strong synergies with the IC cluster. The establishment of the Shanghai Synchrotron Radiation Facility (one of the most powerful third-generation facilities in the world) is also having a synergetic effect on associated activities in the park. By the end of 2005, the Park had attracted a total of 4297 new enterprises, attracted foreign investment US\$13.7 billion and Chinese investment of 69.5 billion RMB; it had registered 91 R&D centers of transnational enterprises; and firms within the park had applied for 4,032 patents (833 of which were granted).⁴¹

⁴⁰ It is worth noting that ‘one stop shopping’ is a major organizational advance that involves extensive inter-agency negotiation, in that Ministries and established licensing bureaux are cajoled to transfer their powers to the Park administration for the particular group of firms intending to locate in the Park. Such one-stop shopping was also a feature of Hsinchu from the very beginning – and in itself represents a form of economic learning and advanced institutional capacity – a higher-order capability.

⁴¹ By contrast, Hsinchu had by 2005 attracted 382 enterprises, employing 114,863 staff, and NT\$98.8 billion (around US\$3 billion). No less than a sum amounting to 6.8% of these revenues was being reinvested as R&D. A breakdown of investments made by Hsinchu firms is apparently not available.

Elsewhere in China the influence of the Hsinchu model is unmistakable. All the Chinese high-tech industrial parks – from Suzhou to Tianjin – treat the Hsinchu approach to collocation of flagship firms, plus complementary suppliers and design firms, with national R&D institutes and leading universities, combined with access to venture capital and various kinds of government-mandated subsidies, tax concessions and inducements, as a template. Of course they are not always successful. In some cases they reach a ‘limit’ to their technological upgrading, conditioned by the strategic calculations made by the flagship firms that drive cluster formation. In China, for example, it appears that Taiwanese flagship firms are shifting their operations from the Pearl River Delta (Shenzhen, Dongguan et al) to the Shanghai-anchored Yangtze River Delta (Suzhou et al) because the latter economic zones behave more like Hsinchu. The Yangtze River Delta, centred on Shanghai and extending west through Suzhou and into Jiangsu and Zhejiang provinces, is a region with a population now approaching 80 million, comparable in GDP and population to a mid-range country, and is rapidly developing industrial clusters at a higher level of value-adding than those in the PRD.⁴² Suzhou in the YRD is now the world’s most concentrated cluster of production of laptop PCs – whereas production in the PRD, and in the city of Dongguan in particular, has remained focused on desktop computers, and has not made the leap to laptop PCs.⁴³

Indeed the entire industrial system of Hsinchu – involving the IT supply chain including flagship firms like HonHai and BenQ – has been transferred across to the Chinese mainland in the Yangtze River Delta, and specifically to the city of Suzhou and its satellite towns like Kunshan, almost entirely through private sector initiative on the part of Taiwan firms. As described by Taiwan scholar Chuan-Kai Lee, the initiative was taken by Taiwan firms like BenQ because of increasing dis-satisfaction with conditions obtaining in Shenzhen and surrounding towns like Dongguan in the Pearl River Delta, while the high-tech parks of Suzhou and co-located towns like Kunshan and Wujiang provided conditions much closer to those found in Hsinchu. By the end of 2001 more than 1000 Taiwanese firms had set up operations in the greater Suzhou area, contributing more than half of total foreign direct investment into the area (and in the case of Kunshan and Wujiang, no less than 80% and 95% of FDI respectively). This is replication of the Hsinchu model on a grand scale – by Taiwan firms themselves, acting in partnership with local city authorities who were sympathetic to their requirements and prepared to set up the kind of infrastructure and incentives that had been pioneered and tested by the original Hsinchu model.⁴⁴

Beyond China, the Hsinchu model is less easily recognizable – but no less relevant. It is more accessible for developing countries like those in the Middle East, in South and Southeast Asia

⁴² The World Bank scholars Yusuf and Nabeshima (2010) provide the most recent and authoritative account of the transformation of the Shanghai region, contrasting it with the area around Beijing, in their study *Two Dragon Heads*.

⁴³ Industrial sociology studies informed by both regional perspective and global value chains reveal the details of this industrial upgrading dynamic being played out between the industrial clusters in the PRD and those in the YRD – such as the studies by Chen (2007) and by Yang (2009). Chen opened up the topic by focusing on the two main attractors – Shanghai and Hong Kong – and then on important hubs of clusters such as Dongguan in the PRD and Suzhou in the YRD. Yang followed up with analysis based on a series of interviews on the ground in both the PRD and YRD, bringing out the strategic interaction between the flagship firms, particularly Taiwan IT firms, and the cluster participants.

⁴⁴ On the replication of the Hsinchu model in the greater Suzhou area in China, see Lee (2009) as well as Lee and Saxenian (2008) for a more general treatment of the Taiwan IT industrial system and its coevolution according to technological and global competitive pressures.

and in Central and Latin America (not to mention Africa) than the ‘Silicon Valley’ model which is really only applicable to a handful of countries at the technological leading edge. Everywhere else that aspires to high-technology involvement in the global economy needs to study Taiwan’s progress carefully, from labour-intensive manufacturing activities based on low-cost labour inserted into global value chains, to skills and technology upgrading combined with openness to flows of capital, technology and people (particularly exchanges between Hsinchu and Silicon Valley). The steady hand of government as collective entrepreneur is needed to make the breakthroughs necessary, and to provide the ‘new shoots’ (*hsin chu*) of industrial development to maintain the pressure in the long process of change from imitation to innovation, and from contract manufacturing to full-branded enterprise.⁴⁵

Taiwan has created in Hsinchu a model for the rest of the developing world – and for that matter, for the developed world as well. Everyone wants to create the next Silicon Valley – and yet as stressed by historians such as O’Mara (2010), it is not easily done. Indeed, ‘Don’t try this at home’ is a strong warning. But Hsinchu is more accessible and more transparent. It has sparked numerous emulators in China, amongst which can be counted the Zhangjiang High-Tech Park and the Suzhou science-based industry park and its surrounding areas, and provides a model that is accessible and achievable for the rest of the world.

8. Next steps for Hsinchu and Taiwan

If the 1980s was the founding decade for Taiwan’s move up the value-added ladder to encompass industries such as electronics, IT and semiconductors, and the 1990s was the decade when the IC industry flourished in the Hsinchu park, followed by the flat-panel display industry flourishing in the following decade, then what of the 2010s? There are already clues as to the new direction to be taken in Taiwan – in the form of new R&D alliances and industry promotion efforts in such sectors as solar photovoltaic cells (PVs) and concentrated solar power (CSP) systems⁴⁶, in Electric Vehicles (EVs) and associated energy storage (e.g. lithium-ion batteries), in energy-efficient lighting (e.g. LEDs) and other energy-efficient optoelectronic systems. (PVs and LEDs are perfect complements: one converts light into electric current, the other converts electricity to light; they also share several manufacturing steps.) What is common to all these sectors is a new focus on renewable energy and energy efficiency, combined with new industries for a low-carbon emissions future. So far there are promising signs of ‘new shoots’ in these directions – but not yet any sense of a comprehensive commitment on the part of the MoEA and its IDB to launch a new industrial revolution in Taiwan, one that will take the island’s industries beyond the 20th century and into a new low-carbon emitting, energy-efficient and renewable energy system – or ‘green business’ for the new century.

For what the new industrial paradigm would require is not just promotion of new industries (as being done for solar PVs, LEDs and EVs) but promotion of a domestic market as test-bed for the new products and services, and as test bed for a new Circular Economy design of the

⁴⁵ The shift up the value curve from OEM to ODM to OBM has stalled at several junctures in Taiwan, and this remains the single biggest obstacle to further industrial advance on the island. Chinese firms are able to utilize their global reach to build (or acquire) global brands, but this avenue has not been available to Taiwan firms, as yet. For a discussion of the issues involved, see Chu (2009).

⁴⁶ On the emergence of Taiwan’s solar photovoltaic (PV) industry, in comparison with what is happening in China, see Mathews, Hu and Wu (in press).

island's industrial system. Here it has to be said that Taiwan is lagging behind its giant neighbour, China, in the formulation of the conceptual tools needed for such an industrial revolution.⁴⁷ China is forging ahead with plans for a closed-cycle 'Circular Economy' even as it continues to pollute with old-style industrial waste; it is forging ahead with plans for new renewable energy industries even as it builds new coal-fired power plants; and it forges ahead with new Supersmart grid projects and super high-speed rail systems that will provide new sources of low-carbon power and transport services. There is still the opportunity for Taiwan to seize the initiative and demonstrate what can be done in this regard on a small island. Such a comprehensive approach would encompass plans for a SuperSmart grid in Taiwan by 2020 together with incentives for distributed power generation from a variety of renewable sources (including indigenizing production of the chips needed for Advanced Metering Infrastructure (AMI)); for a comprehensive fast-rail transport system by 2020, building on the newly-completed Taiwan High Speed Rail system that now runs up and down the west coast, and extending it to modern light-rail urban transit systems in the capital and the science parks, especially Hsinchu itself (and associated industrial development of locomotive and rolling stock enterprises); a comprehensive infrastructure for charging of electric vehicles (cars, bicycles, vans) in cities throughout the island by 2020; and a drastic scaling up in use of renewable energy sources by 2020, as a means both of cushioning Taiwan against wild swings in fossil fuel supplies but also in setting the pace for modernizing the electric power system overall. Such plans would need to be complemented by promotion of eco-industrial initiatives in the chemical and petrochemical industries, providing incentives for linking the wastes of one process with the inputs to another, for sharing of heat and energy, and the building of common platforms for eco-efficiency as well as swinging producers behind energy- and resource-saving design strategies. All of this would encourage entrepreneurial initiative and creativity in the service of building a new industrial system for the 21st century, one that is expanding in terms of opportunity while maintaining a sustainable relationship with its natural setting – an economy of sustainable enterprise. Here is a grand project for Hsinchu and the new Science-based industry parks to focus on for the next decade, and the following century.⁴⁸

As it approaches its fourth decade, Hsinchu needs a new 'Big Idea' to take it forward and maintain its momentum – and I would like to propose one such idea as candidate. Taiwan and Hsinchu has proven itself to be the world's most successful producer of electronic devices, particularly portable devices and their components – PDAs, GPS systems, e-readers, iPods, laptops, netbooks, mobile phones etc etc. But it remains the case that all these devices remain tied to electric mains and batteries – even advanced lithium-ion batteries – as their power sources. Now Taiwan and Hsinchu is also building a new industry in solar PVs, and is just starting to build an industry in new generation 'thin film' solar PVs, which is where the future of solar power lies. So why not blend these two developments, in a new kind of 'solar-powered' portable electronic device. The goal could be to make every electronic portable device produced in Taiwan to be solar-powered – as calculators were, before they were

⁴⁷ On China's plans for development of a Circular Economy, and on its eco-initiatives generally, see Mathews and Tan (in press).

⁴⁸ The Ministry of Economic Affairs has announced substantial programs for support of low-carbon industrial initiatives (e.g. MoEA Green Energy Industry Promotion program) and new Greenhouse Gas emissions reduction targets. But the targets for renewable energies (e.g. 3 GW for wind power by 2015) are puny compared with comparable targets being set in China, and Taiwan remains dependent on fossil fuels for over 99% of its primary energy requirements. One major obstacle to modernization and decentralization of the grid appears to be the monopoly position of the State-owned power company Taipower.

ousted by laptop computers.⁴⁹ This is a new idea because hardly any portable electronic devices currently carry their own solar power generating module embedded within the system; indeed more and more functions keep being added to mobile devices without any corresponding increase in power storage – making them paradoxically less portable and mobile, and more tied to recharging facilities than before.⁵⁰ So there is a strong case for providing them with an independent power source from the sun. It is a ‘big idea’ in that if solar-powered electronic devices become ubiquitous (as they should, if marketed in a smart way) then their contribution to lowering carbon emissions would be very substantial. Hundreds of millions of new devices that would otherwise demand power from an over-stretched grid utilizing coal-fired electricity generation would be able to produce their own power (a form of ‘energy harvesting’ from ambient sunlight) and at the same time through their mass production help to drive down the price of solar cells themselves, bringing them closer to grid parity. It is a big challenge because it involves substantial re-engineering of the electronic devices to make them both solar-powered and resistant to sunlight which currently damages their operation. New kinds of thin-film solar cells (probably printed on polymer) would be utilized in the devices, and new kinds of casing that would let the sunlight be captured but not overheat the devices. And it is an entrepreneurial challenge, which Taiwan’s hundreds of nimble small and medium-sized firms would be quick to take up if government provided the market incentives and the basic R&D in ITRI’s labs to set the standards for solar-powered electronic devices (SPEDs). Indeed, Hsinchu could promote a new nomenclature for these devices, giving them the ‘s-’ prefix to read s-PDA (solar-powered PDA), s-netbook and so on. Here is a promising ‘new shoot’ for Hsinchu to pursue, both for its own benefit and for the benefit of the world, giving Hsinchu new sources of recognition.

9. Concluding remarks: the ‘Hsinchu Model’

Anniversaries are times for reflection. This 30th anniversary of the founding of the Hsinchu Science-based industry park provides Taiwan with an opportunity to reflect on just how far it has come in the last 30 years. At the time of Hsinchu’s founding, Taiwan was a marginal player in advanced technology industries. It was moving up the value curve, certainly – but without a clear sense of trajectory or strategy for penetrating industries where low labour costs would not provide sufficient competitive advantage. It was the combination of Hsinchu with ITRI and the determination of government agencies to build a new science-based industry in the form of the semiconductor industrial cluster located within the park that made all the difference. While there were earlier attempts to create cross-firm linkages, it was the founding of TSMC in 1986 and the ecosystem it built with IC design firms that flocked to work with it on new chips at the technological frontier, fuelled by venture capital that was also a part of the Hsinchu phenomenon, that set in motion the processes of circular and cumulative causation that characterize all the best industrial clusters. The silicon foundries acted as the specialized intermediaries that expanded the output of ICs in Taiwan, and as the output expanded, so the opportunities for new, even more specialized IC design houses were

⁴⁹ Calculators have such low power requirements that they were commonly produced as solar-powered stand-alone devices, e.g. Casio calculators. Very recently AU Optronics exhibited a new 14-inch solar-powered touch keyboard for a notebook PC at the 2010 FPD International Exhibition in Chiba, Japan. Thus we can be sure that the concept of solar-powered portable electronic devices is feasible. For details of the AUO product, see: <http://computernetworktechnology.net/news-tech/auo-presents-14-inch-solar-powered-touch-keyboard-notebook-solution.html>

⁵⁰ To the best of my knowledge, the idea of making all electronic portable devices energy self-sufficient through embedded solar cells was first voiced by Hermann Scheer in his classic text *The Solar Economy* (2002).

created – and seized by eager entrepreneurs. The process was then repeated in the case of flat panel displays, where again a series of new firms were founded and quickly attracted a whole eco-system – or value chain – of suppliers and users; as the value chain grew, the output of FPDs grew, and created further opportunities for formation of small, specialized firms, some of whom were absorbed by the leading panel producers. Now the process seems to be replicating itself again in the case of solar PV systems and other instances of low-carbon technology and renewable energy (or what is being called ‘green energy’ in Taiwan). With each iteration, the collective efficiency of the firms involved is raised, as they draw on the inter-firm linkages and complementarities created by clustering, first in Hsinchu, and now along the east coast of Taiwan. Each episode is an instance of technological learning, while the process as a whole, with its improving inter-firm routines and governance, may aptly be characterized as economic learning.

The visionaries who created the Hsinchu park had a clear goal in mind – to create a system that would lift Taiwan’s economic activities from low- and medium-technology activities to high-technology activities encompassing IT, electronics, semiconductors and their various applications. You could say that they were obsessed with bringing Taiwan’s economic activities as fast as possible to the product mix found in more advanced countries, in order to benefit from the same kinds of knowledge spillovers enjoyed by advanced countries.⁵¹ The tools they used were relatively simple and straightforward. They passed legislation that created the Hsinchu park as a new category of ‘science-based industry park’ differentiating it from the export processing zones and other labour-intensive agglomerations available in the 1970s; they created incentives for firms locating in the park (such as tax concessions on industrial upgrading investments) as well as obligations, such as the requirement that Hsinchu firms reinvest revenues in R&D at a higher level than prevailed amongst firms in Taiwan generally. They provided advanced infrastructure, including land for high-tech activities, shared utilities and services, and one-stop shop for firms needing regulatory clearance to locate and upgrade their activities. They made sure that there were complementary institutions co-located with the park, including the leading technical universities Tsinghua and Chiaotung, and the large public sector R&D facility, ITRI; these generated the knowledge spillovers enjoyed by firms in the park. They even made sure that there were adequate housing, recreational, health and education services available to Hsinchu park employees – including Taiwan’s first English-language secondary school for children of Taiwan expatriates returning home from the US. These were all the initial conditions – the origins of the park’s success.

But as firms located in the park, they were encouraged to invest in ‘new shoots’ of industrial activities, either new products or new processes, and as they interacted with each other they sparked a cluster dynamic that generated increasing returns – to the level of 50% value-added observed today, compared with 30% value-added by firms outside the park. State initiatives sparked diffusion of technologies as well as venture capital needed by the firms to maintain the pace of new activities creation. The visionaries foresaw that such state initiatives would be needed initially (to make up for the gap between Hsinchu as an industrial latecomer and the incumbent leaders) but that as the clusters within the park matured and evolved, the

⁵¹ In important recent work, Hausmann, Hwang and Rodrik (2007) find that while at the macro level convergence between advanced and less advanced economies may be slow, at an individual product level convergence can be unconditional and relatively quick, i.e. less advanced countries can quickly reach the global best practice frontier, provided they deploy strategies to close the gap. The implication for policy is: export the same sorts of products as rich countries. This is exactly what Taiwan seems to have set out to do through creation of the Hsinchu park.

private sector would play more and more of a role – as has indeed happened. Thus the dynamics of the park's success involve a process of 'economic learning' where close attention to technological trends observed around the world and the building of local Taiwanese capabilities in these new technologies, initially in ITRI and then through structured R&D alliances and eventually within the private sector firms themselves. We observe in these dynamics a process of circular and cumulative causation at work, generating the sustained increasing returns enjoyed by firms in the Hsinchu park.

This is the Hsinchu model – as clear, accessible and transparent a model as could be created, and accessible by any country prepared to make the same kind of initial investments in hard and soft infrastructure, and to apply the same kind of strategic and economic learning investments as have been evidenced in Taiwan.

Now this process is sparking emulation around the world, in China and beyond. Taiwan has much to celebrate in its successes. But the men and women in its institutions are only too aware of how fragile are these gains, and how quickly they could be swept away by adverse business developments. Taiwan, not a member of the IMF, has guarded itself admirably from financial speculation and bubbles, even during the 1997 financial crisis. Technologically it has mounted one peak after another. Now perhaps it is time for Taiwan to display these achievements to the rest of the world even more openly, by inviting scholars and students, for example from Africa, and the Middle East and Latin America and South Asia, to see for themselves the scale of the accomplishments and to learn the secrets of their success. Such might be a smart way of enhancing Taiwan's prestige in the world – and a suitable way to celebrate this 30th anniversary.

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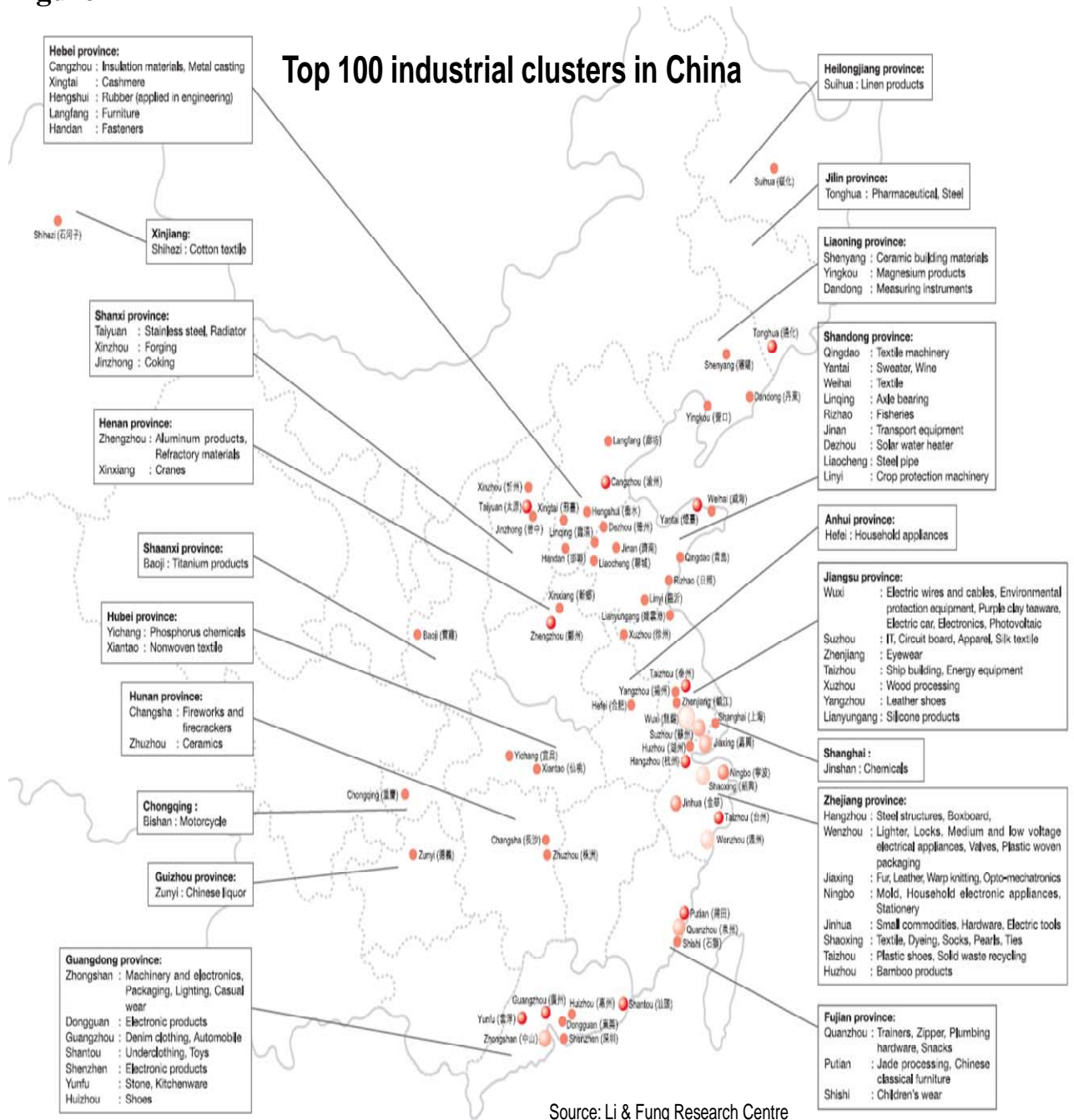
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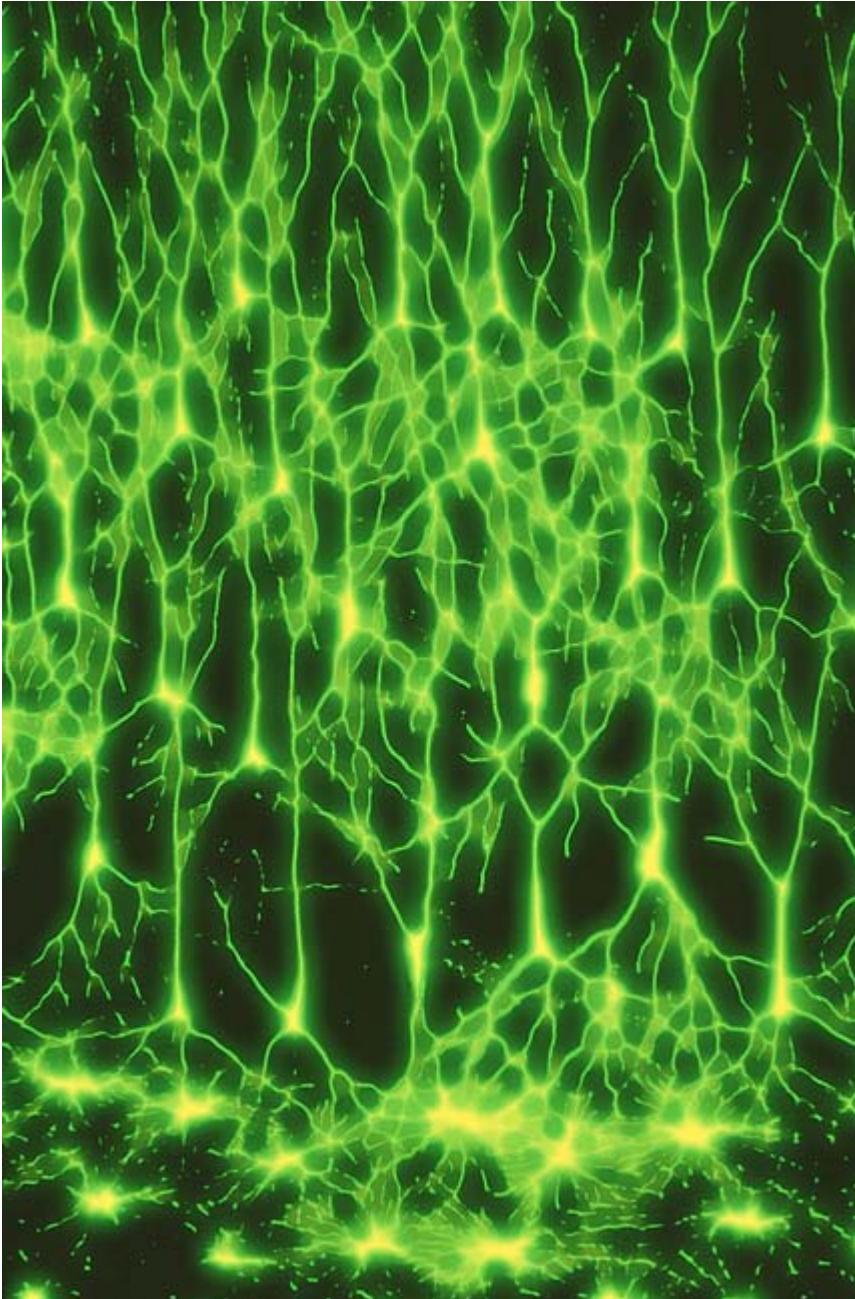
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Figure 1



Source: Li & Fung Research Centre

Fig. 2 -- Neuronal interconnections



Source: <http://www.sciencephoto.com/>

Figure 3 Clusters along Taiwan's east coast

 **Well-established Industrial Clusters in Taiwan**

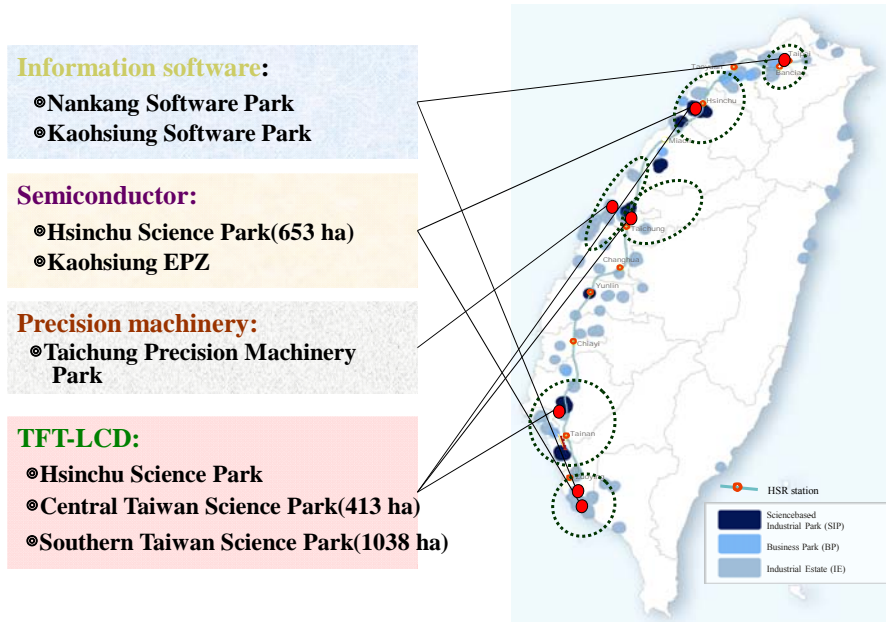
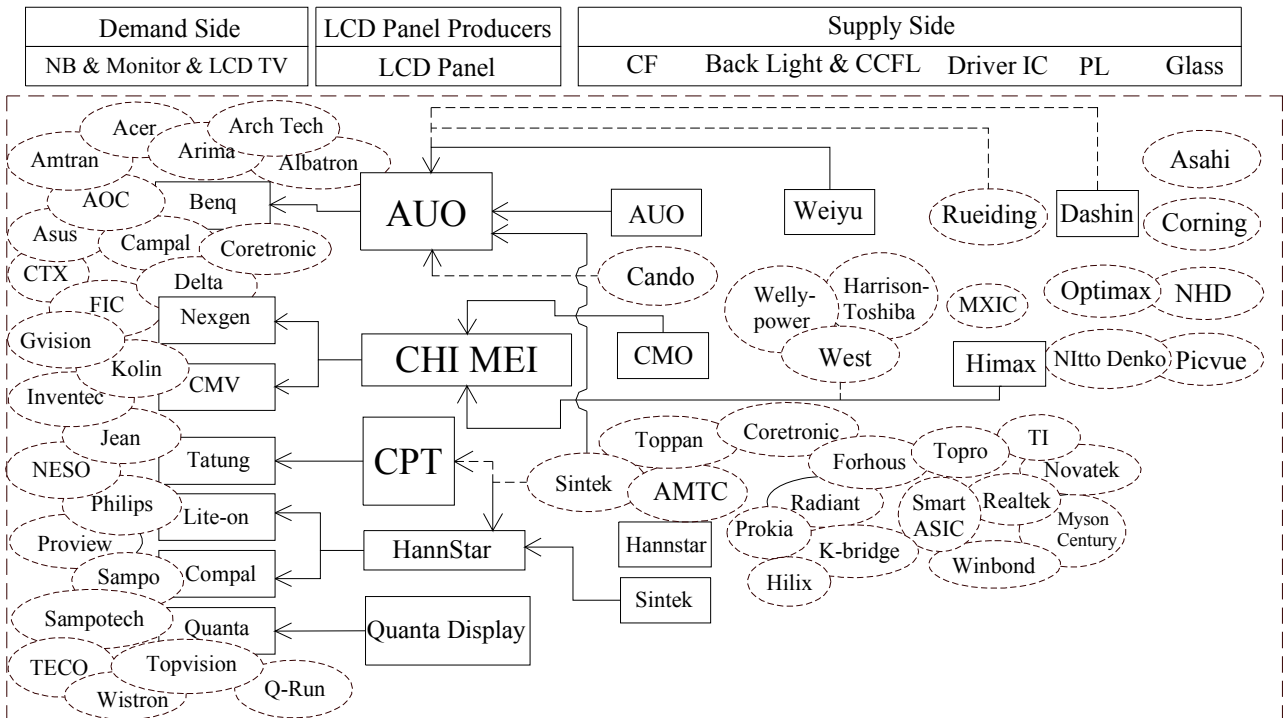


Figure 4

Taiwan FPDs: Rapid buildup of supply-side and demand-side firms



Source: MIC

Note: represents ownership affiliate companies.