International R&D Alliances and Clustering in East Asia:

Implications for the Multi-Scalar Governance of Science and Innovation

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1. Introduction

There appears to be a growing tendency for innovation to be created within global networks of firms and research organizations (Reddy, 2000), leading to the 'internationalization of innovation systems' (Carlsson, 2006). It has been also noted that internationalisation in R&D is growing, shifting the 'geography of science and innovation' to the Far East (Edler, 2008). In addition to the growing corporate international R&D, increase in patenting and publishing activities involving two or more countries, and rising shares of foreign students in national higher education systems all indicate that knowledge is becoming more internationalised (Schwaag Serger, 2008).

The challenge of *co-ordination of internationalization policies* has been recognised in different parts of the world. In Europe, for instance, a few countries such as Finland, UK and Germany, are beginning to think about the 'formulation and implementation of *comprehensive* policies towards internationalization of industrial – and public- R&D' (Edler, 2008), and also, at local and regional level, along with the European level, the 'internationalisation of clusters' has been on policy agenda, with transnational inter-cluster initiatives being implemented in recent years.[2] In cities and regions throughout East Asia—South Korea, China, Taiwan, Singapore and Japan—competition to establish and maintain information and knowledge activities is becoming fierce. Singapore, for example, referred to as a business hub, is facing intense competition from other nations. While competition is intensifying among East Asia's

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[2] e.g. http://www.proinno-europe.eu/index.cfm?fuseaction=page.display&topicID=395&parentID=0&CFID=615201&CFTOKEN=37088135

economic agglomerations, however, inter-linkages between these regions are also growing (e.g. Kitagawa, 2005).

Globalization of the economy provides new opportunities for latecomers such as China to enter international trade, which is shaping and conditioning the processes of trade patterns and production networks in Asia, with implications for future Asian regional integration and moderation of international trade imbalances (see Gaulier et al., 2004; Ernst, 2003). One factor encouraging inter-agglomerative linkages within East Asian regions has been the movement of multinational corporations into East Asia, including those of Japan. In recent years, a number of East Asian countries, and China, in particular, have emerged as the 'world's factory' seizing top world production shares for many products. The offshore shift of Japanese firms prompted changes in Japan's local economic structure which has been characterized as the 'hollowing out' of the Japanese economy(Bailey and Sugden 2008). With the so-called 'hollowing out' of Japanese manufacturing sector, East Asian production and R&D networks are changing (Ernst, 2003). This paper examines these organisational and spatial transformations and policy challenges through internationalisation in R&D activities by identifying recent trends in network relationships between firms and other organizations, and the spatiality of their knowledge creation set in East Asia.

This exploratory paper has three different aims: Firstly, different conditions and pathways for Open and International Science and Innovation are discussed by referring to some theoretical literature. Secondly, the paper highlights the recent emergence of some city-regions in East Asia as new potential 'centre of excellence' for new technology and new product creation, and points to the increased importance of 'regional learning' (Dodgson, et al. 2006) through strategic governance of science and innovation at regional and local level. Some empirical examples of new forms of research alliances between firms, and between universities and firms in East Asian countries are identified as exemplars of new inter-organisational local capacity formation which further condition intra-country spatial dynamics. Thirdly, the paper sketches strategic roles played by public policy in constructing international R&D networks across East Asia, both industrial and public, pointing to emerging transnational systems of innovation in the region.

The broad research questions asked in this paper are as follows:

- What can we find about the *internationalization* of the R&D with firms in East Asia, and their *strategic alliance formation* and their R&D *location*?
- In what ways does *local, national and trans-national governance* make the impact on the relationship between the firms, universities and their regions?
- What are the lessons for Europe from Asia and *vice versa* for Asia from Europe in terms of *constructing 'international regional advantage'*?

This paper is principally based on the broad secondary literature survey synthesising different areas of literature such as economic geography, regional studies, strategic management and organizational studies, political sciences and international business; and it draws on analysis of policy and academic documents, and an empirical case of trans-national R&D collaboration encompassing different East Asian countries. Through the examination of evolution of different types of 'research alliances' developed in countries in East Asia, the paper aims to highlight the different roles played by the government, and the changing relationships between firms, universities and public research in different national contexts with different levels of economic development and different types of international linkages.

The rest of the paper is structured as follows. Section 2 gives review of the literature highlighting the historical evolution of the models of 'research alliances' as a strategic policy tool, and highlights different models of open innovation and science in terms of university-industry linkages. Section 3 turns to look at geography of collaborative knowledge production set within the multi-spatiality of the science and innovation governance in the East Asian 'region' with implications for the new roles of research alliances at different spatial levels including the roles of sub-national governance in constructing spaces of science and innovation. Section 4 gives specific case study by focusing on *Fukuoka Silicon Seabelt Project*, an initiative taken at sub-national level to construct System LSI R&D networks in East Asia. The final section sums up earlier discussion and identifies future research agendas concerning data collection, combining different theoretical perspectives, policy implications and challenges comparing Europe and East Asia as new *transnational spaces* of research and innovation.

2. Literature Review: Evolution of 'Cross-boundary Research Alliances', University-Industry Linkages, and Internationalisation of Knowledge Collaboration

There is a large body of literature on 'strategic research partnership', 'R&D consortia' and 'strategic alliance' (Hagedoorn, et al. 2003), and some of the terms are used in an interchangeable way. The focus of this paper is a special case of strategic alliance, what can be called 'a strategic technical alliance' or 'an innovation-based relationship that involves…a significant effort in research and development (R&D)' (Hagedoorn et al. 2000). In a similar vein, Teece (1992) defines a strategic alliance as 'a web of agreements whereby two or more partners share the commitment to reach a common goal by *pooling* their resources and *coordinating* their activities' (cited by Hagedoorn et al. 2000; emphasis added). Such strategic alliances can be found at different levels, encompassing actors at sub-national, national and trans-national levels.

R&D alliances augment and extend firms' internal efforts to achieve strategic objectives, providing access to specialized knowledge that may be difficult, if not impossible, to bring into the firm (Bercovitz and Feldman, 2007). Recent literature on "open innovation" has further emphasized the importance of inter-organizational relationships in the innovation process. Organisations increasingly rely on external sources of innovation via inter-organisational network relationships (Perkmann and Walsh, 2007). According to Chesbrough (2003), the role of internal R&D is to identify, understand, select from, and connect to the wealth of available external knowledge, and to fill in the missing pieces of knowledge that are not being externally developed. In this light, as Bercovitz and Feldman (2007) argue, the 'university-firm dyad' is a particularly unique mechanism for 'cross-boundary learning', increasingly with Mode 2 production of knowledge (Gibbons et al 1994). Recent studies suggest that institutions that bridge the gap between the science base and industry can have a significant effect on the extent and speed of knowledge transfer and innovation (Frenz and Oughton, 2005).

The recognition of different types and motives of 'cross-boundary research alliances' (Bercovitz and Feldman, 2007) (e.g. between firms, between university and firm, between government laboratory and firm), the analysis of external knowledge acquisition on the level of individual interactions (e.g. Weck and Blomqvist, 2008) and detailed study on strategic technology management at a firm level (e.g. Jones and Smith 1997) question some of the basic conceptualisations of innovation, firm strategies and policy assumptions.[3] A micro study of firm innovation strategy and the process of building 'research alliances' would reveal how they develop 'multifaceted relationships' (Bercovitz and Feldman, 2007) with their research partners, including firms, universities and public research institutes.

The question regarding the appropriate role for any government in promoting industrial growth remains vexed (see Fransman and Tanaka, 1995). This may be done through encouraging interactions of the so-called triple helix linkages between firms, academic institutions and the government (Etzkowitz, 1998) as part of any national innovation systems. According to Sanz-Menendez and Cruz-Castro (2005), broadly speaking, two 'ideal types'[4] of policy approaches to science and innovation can be distinguished. The first is the *academic approach*, which is 'geared towards fostering academic research and mainly towards universities and public research centres'. The second is the *business approach*, which attaches greater emphasis to applied research and technological innovation processes in business. While both approaches seek to increase and foster the production of new knowledge and skills, 'one aims to finance academic activities, without direct connection to short-term results, the other aims to foster private investment and raise companies' level of technology, and to tie public research to the transfer of results to the private sector' (Sanz-Menendez and Cruz-Castro, 2005, p.942).

It is pointed out by a US researcher that the dramatic increase of 'strategic research partnerships' in the past two decades is attributed to the following three factors: 'large increase in public-private partnerships', 'policies promoting the transfer of

[3] In this light, the interactive co-production of knowledge between universities and companies make a conceptualization in terms of a one-directional "knowledge transfer processes" problematic. As Bercovitz and Feldman (2007) argue, the 'university-firm dyad' is a particularly unique mechanism for 'cross-boundary learning'. This is in contrast to the earlier conceptualization of linear model of innovation, and the focus on start-ups from universities. In this light, Bercovitz and Feldman (2007) examine how innovation strategy of firms influences their level of involvement with university based research, forming 'cross boundary research alliances'.

[4] In practice these tend to appear together, although one predominates over the other in a specific policy context.

technology from universities to firms', and 'relaxation of antitrust enforcement related to collaborative research' (Siegel, 2003). However, the development of such forms of collaboration is very much defined by the characteristics and evolution of each national system of science, research and innovation over time. Sakakibara and Dodgson (2003), for example, explain the specific institutional setting in Japan as reasons of the importance of 'strategic research partnerships', and argue that many of the institutional setting found in Japan are common throughout industrialized Asia, particularly regarding the following features in the national innovation system: *weak university research*, a *preference for organic rather than acquired diversification*, and *limited labour market mobility*. However, as some of the recent literature implies and as this paper demonstrates later, these institutional characteristics are rapidly changing in each national innovation system, [5] with growing linkages developing between universities and firms, and increasing flows of knowledge and production networks across countries.

The first step towards characterising and identifying the different roles of policies concerning 'research alliances' entails answering the question: *'Who gets what, when and how?'* (Laswell, 1936). There seems to be a large number of literatures on 'strategic technical alliances' in the fields of semiconductor, electronics and ICT developed in East Asia. This partly reflects earlier policy interests from the US and Europe in Japanese 'government-funded Consortia' (e.g. Hane, 1993; Ray, 1998). The promotion of cooperative R&D by the Japanese government started in 1959, which led to the formation of Technological Research Associations (TRAs) (Sakakibara and Dodgson, 2003). Throughout 1960s and 1980s, Japan was regarded as a forerunner in the practice of

[5] Research in Japan has been concentrated traditionally in-house within large *keiretsu* companies. Furthermore, Grandstrand (1999) pointed out that R&D intensive large Japanese corporations relied on collaborations with US universities rather than Japanese universities, except in-house R&D (cited in Kneller, 2003). The 'relative impoverishment of Japanese academic science' (Nakayama and Low, 1997) had begun to be addressed by the government rather recently in response to the growing significance of Science-based Industries. Consequently, combined with the relative decline of in-house R&D at Japanese firms throughout the slow economic growth period, there is new expectation on university-based research as a driver of innovation and economic growth. Furthermore, rising competition with other Asian nations and their universities has also forced the Japanese government to place higher education high on the national policy agenda in order to maintain strategic competitiveness. Recent university reforms and new competition have changed the landscape of Japanese higher education. Hicks (1993) argues that the system has been evolving in directions more favorable for university *research excellence*. New types of budgetary funds and project-based research funds established during the 1990s served to strengthen competition among universities by creating a mechanism for 'differentiated financial allocation' which is justifiable to both universities and society (Asonuma, 2002).

'government-led R&D alliances' and has been studied most extensively (e.g. Sakakibara, 1997, 2001; Hane, 1993). Japan's earlier joint R&D projects aimed at catching up with the leading technological leaders such as those in the US. Based on a *business approach* led by MITI, Japanese R&D consortia depended heavily on government funds for their support, whereas US consortia depended mostly on member dues. Unlike the US, national institutional support appears to provide a strong central source for the diffusion of knowledge and Japanese consortia had weak linkage to university-based R&D (Aldrich and Sasaki, 1995; Sakakibara, 1997). Throughout the 1980s, policy makers on both sides of the Atlantic had become very enthusiastic about 'Japanese-style' collaborative research and the perceived success of *keiretsu* (Georghiou, 1999; Ray, 1998; Sakakibara, 1997; Sakakibara and Dodgson, 2003). Other earlier studies on R&D consortia was dominated by accounts of a few 'highly publicized' (Sakakibara, 1997) projects in different regions, such as MCC (e.g. Gibson and Rogers 1994), SEMATECH in the US, ESPRIT in Europe, or the VLSI Project and the Fifth Generation Computer Project in Japan (e.g. Odagiri et al. 1997). (see also Georghiou and Rossener, 2000).

This model of government-led large R&D consortia had been seen effective in Japan throughout the 1960 to mid 1980s for diffusing technology as part of the 'catching-up model' of the economy.[6] However, by the beginning of 1990s, with changing industrial and social structures of the national economy along with the globalisation and growing competition with neighbouring Asian countries, fundamental change in the national industrial and R&D policy and strategies were required (Bailey and Sugden 2008). The increasing importance of 'science-based industries' (Goto and Odagiri, 1997) such as the life sciences, IT and nanotechnology with strong linkages with scientific research activities as their main feature reflects the increased contribution of academic research to industrial innovation. The development of a new research system in Japan throughout the 1990s is seemingly leading to the emergence of new relationships and

[6] The promotion of Korea cooperative R&D started in 1982. The government introduced the Industrial Research Association (IRA) system, which was modeled after the Japanese TRA system (Sakakibara and Dodgson, 2003). In South Korea, co-operative R&D started in 1982, and the government introduced the industrial research association system modeled after the Japanese TRA system. Throughout 1980s and 1990s, R&D consortia developed mainly in the electronics, information and machinery areas (Sakakibara and Chou 2002).

systems of innovation in which universities play more significant roles based on *academic approach* of science and technology policy.

In this respect, R&D location, allocation, and alliance strategies of firms, which might be called an 'alliance-driven model' (Birch, 2008) of the knowledge-based sectors is of particular interest, and in recent years, many studies have been conducted in North America and in Europe taking inter-organisational networks in life sciences as entrance point (e.g. Powell et al, 1996, 2005; Feldman and Ronzio, 2001; Cooke, 2004; McKelvey, 2004). Many of these studies focus on 'a stylised representation of biotechnology' with 'collective, systematic and social processes' (Birch, 2008) that are produced through networks of actors, creating locally and globally constituted 'clusters'(Cooke, 2004).

Studies of 'high-tech clusters' in the US and countries in Europe indicate that research universities, networks among firms, between firms and research institutes and universities, and a pool of skilled labor forces are several important location factors that provide bases for knowledge spillovers which can be transformed into economic advantage. The large biotechnology cluster surrounding Washington, DC, for example, is a direct outgrowth of the major Federal Government investment in life science research and the wealth of manpower it drew to the DC area (Feldman & Francis, 2003).These areas of research informed the basis on cluster policies in many countries whereby academic researchers and consultants 'translate' successful regional development *concepts* and sometimes advice to governments and development agencies on *how* to set up regional clusters (Lagendijk and Cornford, 2000). In the UK, for example, clusters were initially linked to policies to increase the foreign investments and in more recent years has become a 'vehicle to indigenous development' (Lagendijk and Cornford, 2000). Biotechnology clusters in UK policy focuses 'public expenditure on encouraging local interaction and infrastructure that are oriented to facilitating such relationships' (Birch, 2008; Cooke et el, 2007).

In more recent years, a growing body of literature in economic geography and regional studies has begun to criticise cluster concept (e.g. Malmberg and Power, 2005; Asheim et al. 2006), arguing that despite an important consideration of global connections, such research has not addressed the multi-scalar (local, national and international) linkages in innovation processes (Birch, 2008). National and regional debates about the local cluster formations, regional science and innovation paradigm and the role of HEIs in it, and forms of spatially constructed strategic research alliances are intrinsically linked to these wider issues over governance and devolution, which constitute Multi-level governance (MLG) structure of science and innovation policy (Perry and May, 2007). In parallel to this argument, Etzkowitz (2002) has argued that 'the triple helix' interaction between university-industry-government moves towards a 'new global model for the management of knowledge and technology', where an internationalisation strategy emerges within domestic policy structures. Therefore, any 'triple helix systems' needs to be seen as part of the 'co-evolution' process between 'global and national structures' and 'global-national-regional interactions' (Sotarauna and Kautonen, 2007). This area would open up another set of literature which concerns internationalsiation of knowledge collaboration, or 'global techno-scientific collaborations' (Archibugi and Iammarino, 1999).

Globalization processes are interconnected with a growing interdependence and deepening of the interaction between frontier scientific research and industrial innovation. "Internationalization of R&D" encompasses different activities as part of such processes. According to Carlsson, the literature on '*internationalization of corporate R&D*' seems to show that the *degree of internationalization* has indeed increased over the last couple of decades and that the nature of R&D activity abroad has changed in the following ways: 1) it is largely conducted within corporate networks (i.e. it is inter-national and intra-firm); 2) it tends to 'augment home-base technological competence' rather than simply exploiting it abroad, it tends to be less science-based than the R&D conducted at home, and 3) in the cases when it does involve science-based activities it tends to be in fields 'outside the companies' core competencies' (Carlsson, 2006). Another possible dimension of "internationalization of R&D" is more specifically concerned about 'global techno-scientific collaborations' (Archibugi and Iammarino, 1999) through which each individual R&D-unit (be it in a company, a university or public research institute) is increasing its cooperation with R&D-units abroad (see Edler 2008). Along with this process, arguably, both universities, as the prime producers of scientific knowledge, and companies as the main locus of innovation, are subject to growing pressures to be competitive on a global scale, each in their own domain. [7]

Archibugi and Iammarino (1999) made a taxonomy of the 'globalisation of innovation': *International exploitation of nationally produced innovations; Global generation of innovations;* and *Global techno-scientific collaborations*. They argue that different and separate strategies are needed for both firms and governments. A major challenge for national, as well as regional-level, policies seeking to strategically promote closer interaction between universities, public research institutes(PRIs) and industry for economic benefits in the respective territories is to accomplish this while being sensitive to the needs of both universities, PRIs and companies to actively seek innovation and research partners on a global scale with the most appropriate complementary assets in terms of innovation and research capabilities respectively.

This paper next turns to examine the evolution of strategic research alliances, set in the East Asian political economy. R&D collaboration in different forms have played an important role in each national economic success of East Asian countries, such as Japan, Taiwan, South Korea, Singapore and China, whereby various forms of collaboration is increasingly seen as 'a strategic tool' (Dodgson, et al. 2006) as the globalisation of corporate R&D proceeds. Recently, there is also an emerging literature on university-industry relationships in East Asian countries, reflecting the evolution of new 'cross-boundary alliances', with different contexts of economic development in East Asia (*for China,* e.g., Kroll and Leifner 2008, Wu 2007; *for Korea,* e.g. Sohn and Kenny, 2007; *for Taiwan*, e.g. Mathews and Hu, 2007; *for Singapore*, e.g. Wong et al 2006; *for Japan*, e.g. Kodama, 2008).

At the same time, at the sub-national level, the critical role that *regions* play in determining national economic success has been increasingly highlighted in national policy arenas in recent years (*for China* Chun and Kenny 2007; Wu, 2007; *for Japan*, Kitagawa and Woolgar, 2008). Policy makers have sought to promote university-industry links as a means to stimulate regional economic growth through local cluster initiatives. Consequently, new mechanisms of university-industry linkages are being forged and

[7] This has to be further empirically examined by also looking at firms' collaborative R&D activities with universities and other organizations, and how 'the competence' of the firm is geographically constituted.

various institutional strategies of universities are emerging to enhance regional innovation-based growth (*for Japan*, Kitagawa, 2009). Furthermore, different forms of 'globalisation of innovation' take place in East Asia, affecting multi-scalar (local, national and international) linkages in innovation processes, to which the following section turns to.

3. Globalisation and Regionalisation of Innovation in East Asia: Towards East Asian Innovation Networks?

Countries in East Asia are diverse and very different in terms of their scientific capabilities, resources, and the characteristics of economic growth. In East Asia, New Industiralising Economies (NIEs) such as South Korea, Taiwan, Singapore, and Hong Kong, and emerging countries such as China, have put more emphasis than ever on building innovation capability to compete in the globalising economy. Singapore is an exemplar, which, after its economic growth based on the electronics, envisioned itself as the 'premier global R&D hub of biomedical science' (Biomed-Singapore, 2003), attracting foreign Multinational Enterprises (MNEs) with 'world-class capacities across the entire value chain, from basic research to clinical trials, product/process development, full-scale manufacturing, and healthcare delivery' (Finegold et al. 2004) (see also, Wong et al. 2005).

Recent years have witnessed rapidly growing interests in 'catching up' strategies of emerging economies such as China (e.g. Liu and White, 2001) and Taiwan (e.g. Chang and Tsai, 2000). During the 1970s and 1980s, Taiwanese government agencies and policy makers in their efforts to improve its position in the international economy, created a technology park (i.e., the Hsinchu Science-based Industrial Park) and a venture capital industry. Taiwanese firms benefit from highly-developed networks of institutions for collaboration, such as universities and state-sponsored research institutes, most notably the Industrial Technology Research Institute (ITRI). Taiwan also has developed many industry/cluster based trade associations. The case of Taiwan is an exemplar of combining multi-scalar R&D collaboration with regional development (Dodgson et al., 2006). Of Taiwan's manufacturing industries, 98% are small and medium-sized enterprises (SMEs). To survive and to thrive, SMEs have developed unique parallel/open collaborative networks in order to provide the collaboration channels for them to form partnerships within multiple networks (Chan and Hsu, 2002). Moreover, they recruited Taiwanese and Chinese engineers and entrepreneurs working in the USA to return to Taiwan and they promoted the development of connections to the US market (Saxenian, 2004). The Taiwanese case suggests that regions need to pay attention 'not only to the creation of an infrastructure of institutions that funds and supports new firms but also to the facilitation and promotion of financial, technical and technology connections among Taiwanese firms and also between Taiwanese firms and institutions in other regional communities like Silicon Valley' (Castilla, 2003).

Governments in emerging countries, such as China, have transformed the national systems of innovation and used technology policies to promote indigenous R&D and foreign technology transfer (Motohashi and Yun, 2007; Lundin and Schwaag Serger, 2007). [8] International knowledge transfer has been extensively studied, but has been mostly concerned with 'formal mechanisms' such as foreign direct investment (FDI) and foreign licensing (FL), and limited in 'informal mechanisms' (Ernst and Kim, 2002) of knowledge transfer and 'cross-border learning'. Growing area of research is found in international business literature on R&D internationalization strategies of the MNEs in Asian emerging economies as the agglomeration of a wide spectrum of MNEs' R&D activities continues as part of the Global Innovation Networks (GINs). The rise of China as 'a global export production base, as a sophisticated growth market, especially for mobile communications and digital consumer devices, and as a new source of R&D and innovation' (Ernst, 2003) has drawn policy, business and academic attention. As Sigurdson (2004) points out, technological innovation will take place in a number of regions and clusters constituting 'spatial innovation systems' in any country.[9] It is vital for countries like China to create stronger links between local clusters, foreign technology sources and national programmes. In the last decade, three IT industry based clusters, Beijing, Shanghai and Shenzen have emerged in China (Chen, 2007). While

[8] Official figure show that 750 MNC R&D centers were established in Beijing, Shanghai, Guangzhou, Chengdu, etc by mid-2005. (For the discussion about R&D activities of MNEs in China, see: Amsden and Tschang, 2003; Fan, 2006; Chen, 2007; Chen and Vang 2008; Li and Zhong, 2003; von Zedtwitz, and Gassmann, 2002; Lundin and Schwaag Serger, 2007; Sigurdson, 2004; Walsh, 2003).
[9] Sigurdson (2004) discusses the concept of 'competence block' (Eliasson and Eliasson, 1996) to explain this process.

Beijing, and to a lesser extent Shanghai, do represent the greatest concentration of technical manpower, research institutes, and universities, a number of other cities (e.g. Guangzhou, Nanjing, Hefei, Wuhan, Chongqing, Chengdu, Xian, Tianjin, Shenyang, Dalian, Changchun, Harbin) are also growing as centers of research and innovation activities (Suttmeier, 2002) along with the decentralisation of R&D centres of Multi National Enterprises (MNEs) (Chen and Vang 2008).

In recent years, local governments have become more active in developing these resources. Expenditures on science and technology by local governments have grown more rapidly than that of the central government, over the course of the 1990s albeit from a much smaller base (Suttmeier, 2002). [10] These constitute 'intra-country spatial dynamics' of China (Chen and Vang 2008) which conditions the location decisions of MNEs and innovative capabilities of the regions. Segal (2003) points to the growing importance of 'local officials' in the process of decentralization and devolution in China, creating space for localities to experiment with different organizational structures and policy approaches. There seems to be a process of constructing Regional Innovation Systems (Sigurdson, 2004) in China with both indigenous and exogenous actors. There is also an 'inherent conflict' between regional or localised development on one hand and the rapid concentration of industrial and technological activities on the other.

In recent years, growing number of Japanese, South Korean and Taiwanese firms have established R&D-units in China (and, to a lesser extent, in India). As Ernst states, 'competition between distinct national business models' is no longer so distinctive, as in recent years, firms of diverse nationality compete and collaborate within 'multi-layered global networks of networks' of marketing, production and innovation , which is particularly getting a dominant feature of East Asian 'regionalization' (Ernst, 2003). The concept of Chinese Economic Area (CEA) has been used widely referring to the economic integration of a geographic area encompassing China Mainland, Hong Kong, Macao and Taiwan. The process has been driven by the 'entrepreneurship and self-interests of business sector' rather than promoted by political initiatives and intergovernmental coordination (Sigurdson, 2004).

[10] By1999, local governments had accounted for almost 37 percent of the national expenditure on science and technology, up from 28 percent in 1991(Suttmeier, 2002).

> Globalisation of the electronics industry over the past couple of decades has facilitated the interaction and cooperation between Taiwan and China despite a lack of political understanding and the result is a high tech network in which capital, technology and human resources are flooding onto the Mainland (Sigurdson, 2004: p.34).

China's economic relations with neighbouring South Korea, and Japan have been also developing rapidly through growing FDI, not only through manufacturing sites but also with increasing shift of R&D functions. Before the mid 1990s, Japanese electronic firms undertook little R&D in their subsidiaries in East Asia while leading competitors in the US, Europe and Korea 'have aggressively moved ahead with R&D outsourcing to tap into the region's vast lower-cost pool of human resources and specialized skills' (Ernst, 2003). [11]

> Some Japanese firms are belatedly following the partnering strategies pioneered by global industry leaders like Motorola, Intel, IBM, Cisco, Alcatel, Philips, Siemens, Infineon, but also by Korea's "Big Four" (Samsung, LG, SK Telecom and KT), Singapore's Temasek, and Taiwan's industry leaders.

He further points out that the key to 'successful alliances' with Asian partners is "hybridization" of business organization including both intra-firm and inter-firm transactions and forms of coordination beyond national models, where firms adopt 'successful features of East Asian firms', as part of 'East Asian Production Networks' (EAPN). This would involve constructing strategic space of innovation building value chain into a variety of 'discrete functions' with locations wherever 'they can be carried out most effectively, where they improve the firm's access to resources, capabilities and knowledge, and where they are needed to facilitate the penetration of important growth markets'(Ernst, 2003).

Such Global Production Networks (GPNs) encompass 'all stages of the value chain', not just production, but also sales, procurement, outsourcing, and R&D. Therefore, such networks are seen as Global Innovation Networks (GINs) where the sharing of knowledge is the necessary 'glue that keeps these networks growing' (Ernst and Kim, 2002), which then provides new opportunities for the sharing and joint creation of

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[11] The number of Japanese R&D affiliates in China increased from 13 (FY 2000) to 28 (FY 2002).

knowledge. Existing literature in international business studies shows that the focus of research needs to move from the industry and the individual firm to the international dimension of business networks (Ernst and Kim, 2002; Ghoshal and Barlett, 1990). Ernst (2003) also points out the asymmetric process of such networks whereby 'global network flagships' dominate control over network resources and decision-making.

Issues remain as to a) how to make *global*, *regional* (trans-national), *national* and *regional* (sub-national) innovation networks meet; b) how to link such networks to the 'local capability formation' (Ernst and Kim, 2002); c) how *intra* and *inter*-organisational cross-boundary learning happens as part of such multi-scalar innovation networks; and d) how to make institutional mechanisms to make *East Asian* innovation networks as *transnational space for innovation* and what the expected roles of *public policy*.

4. R&D Alliances and International Clustering in East Asia: A Case of Fukuoka Seabelt Development in Japan

Having identified these conceptual backgrounds in international business literature with some of the existing empirical studies on 'cross-boundary alliances' and innovation systems being conducted in East Asia, it is now of interest of this paper to identify the roles to be played by public policy in forming such Global Innovation Networks set within the multi-scalar settings in East Asia. The example of the Fukuoka Silicon Sea-belt Project (Kitagawa, 2005), a recent development in a sub-national region of Japan, is used to illustrate the development of such transnational regional innovation networks.

Japan has been suffering from the so-called 'hollowing out' of its economy (see, Bailey and Sugden 2008). [12] Following the bursting of its bubble economy in 1991, Japan experienced macro-economic stagnation (Shapira, 2008), which contributed to weak home demand for manufactured products. This, combined with growing competition from nearby Asian countries led to an ongoing restructuring and internationalization of the Japanese economy, with large firms moving production overseas and cutting domestic

[12] The concept of industrial hollowing-out can be narrowly defined as 'a shift of production sites to foreign countries in line with increasing direct foreign investment and a decline in domestic employment' (Horaguchi, 2004).

SMEs out of their supply chains. [13] In the post 'bubble' era of the 1990s and 2000s, increasing global competition has put pressure on all segments of the Japanese national innovation system to be more productive. Research in Japan has been concentrated traditionally in-house within large *keiretsu* groups, and this feature has declined throughout the slow growth period as 'hollowing out' process went on (Schaede, 2008). It would be relevant to point out that there has been little expansion of foreign firms R&D-labs in Japan. [14]

Consequently, throughout the 1990s and 2000s, the Japanese innovation system went through widespread reform, and one the distinctive features of this change is 'regionalisation of innovation policies' (Kitagawa, 2007; Kitagawa and Woolgar, 2008). In Japan, throughout the 1990s, the central government and local governments have actively promoted various types of *cluster initiatives*. The *Knowledge Cluster Initiative* supported by MEXT, based on the so-called 'academic approach' (Sanz-Menendz and Cruz-Castro, 2005) to innovation policies, was developed from existing policies for the promotion of S&T activities in regions. The *Industrial Cluster Initiative* implemented by METI, based on the so-called 'business approach' (Sanz-Menendz and Cruz-Castro, 2005) to innovation policies, aims at revitalising regional economies and promoting industrial accumulation through promoting networks between industry, university and public research institutes (e.g., Regional R&D Consortium), and through supporting the creation of new businesses and new industries. In 2007, MEXT decided to nominate six regions for its 2nd stage Knowledge Cluster. One of the main aims for the second phase of the Knowledge Cluster programme is to promote '*internationalisation*' as well as connecting local clusters to wider areas. [15]

Recent Chinese development has centred on those industries located in nearby Japanese cities, imposing challenges to the development of Japanese local and regional

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[13] The government has also taken protective measures to keep jobs at home with the fear of 'hollowing out' of manufacturing industry since the 1980s due to offshoring to Asia (Schaede, 2005).

[14] In Japan there has recently even been some retrenchment of foreign companies in terms of R&D. Pfizer shut its drug discovery operations in Japan in 2007, for example.

[15] As of June 2008, nine initiatives have been selected in total: Sapporo Biocluster, Sendai Cluster for Creating an Advanced Preventive Health Society, Nagano area for smart devices based on nanotechnology materials, Hamamatsu Optronic Cluster, Tokai Wide area manufacturing technology cluster, Hokuriku Health Creation Cluster, Kyoto Environment-related nanocluster, Kansai Wide area biomedical cluster, and Fukuoka advanced systems LSI development cluster. There is an earmarked fund more than 50 m JPY pa /region for connecting the region to wider area including overseas partners.

innovation systems. As far as Japanese firms are concerned, manufacturing and sales clearly comprise the bulk of offshore operations, while in the R&D sector, companies have only just began to shift their operations abroad (METI, 2002). However, this landscape may change as the Chinese strategy for translocation of global information and communication technology (ICT) production and R&D into the Beijing, Huamgdong (Shanghai) and Guangzhou (Shenzen-Guangdong) regions has borne fruit, significantly on the back of an investment in engineering talent (Cooke, 2004). Nevertheless, having been the most economically advanced nation in East Asia, city-regions in Japan may find themselves in a strategic position to develop ties, especially in terms of creating further 'knowledge value chain' links with East Asian economic agglomerations in terms not only of geographical location but also of distinctive stages of development (see METI, 2002).

Fukuoka Silicon Sea-belt Project, a recent development in a sub-national region of Japan, can be an exemplar. This project aims at promoting R&D exchange activities with South Korea, Taiwan, Singapore, and other semiconductor development hubs in East Asia, and reflects rapid technological growth and innovation in this region. Fukuoka Prefecture in Kyushu region has been characterized by the strong leadership of local authorities to promote regional innovation with growing trans-national R&D links with other regions in Asia. The rationale behind the establishment of the Silicon Sea-Belt Project is an acute recognition that broader alliances are required in market expansion, technology development, and human resources enhancement both nationally and internationally. The area constitutes world's biggest supplier of engineers in this area. To facilitate the project, the Promotion Committee for the Fukuoka System LSI Technology Development Hub was organized in 2001 with the cooperation of industries, academia and government agencies. The committee has been engaged in five tasks: R&D support, human resources development, venture creation and support, promotion of networking and collaboration, and cluster promotion. [16] Asian regions including Gyeonggi in Korea, Kyushu in Japan, Shinchu in Taiwan, Shanghai, Beijing in China, Hong Kong, Singapore and Bangalore in India (Figure 1) collectively form a vital centre of excellence

[16] http://www2.lab-ist.jp/english/114.html#p1

characterized by strong partnership among industry–government–academia and industries for semiconductor design through manufacturing.

This project aims at promoting R&D exchange activities with South Korea, Taiwan, Singapore, and other semiconductor development hubs in East Asia, and reflects rapid technological growth and innovation in this region. The trans-national R&D alliance, with multi-scalar innovation system governance model represented in the Silicon Sea-belt strategy, marks a new phase in the evolution of technological globalization whereby local nodes of excellence link in *inter-cluster networks* animated by large firms, university research, smaller specialist firms and government support across space to recover and enhance global competitiveness in specific advanced technologies. [17]

The Kyushu region stretches over an area with a radius of about 200 kilometers with population of 13 million as of 2005. The establishment of semiconductor plants started in the late 1960s in Kyushu region. The production of semiconductor industry came to account for more than 10 percent of the global semiconductor market in the late 1980s, and Kyushu came to be known as a 'Silicon Island', but the R&D function was not so strong, being referred to as 'brainless silicon island' (Tamura, 2004). Taiwan also came to be called as silicon island during the 1990s as its semiconductor industry developed rapidly during the decade. It was in the mid 1990s that Kyushu started to upgrade its R&D functions. Today many of the semiconductor plants have certain R&D and design functions and they are engaged with joint research with local universities. Some firms have recently set up their R&D headquarters in Fukuoka city, aiming to build a world class comprehensive operational system based in Kyushu. (e.g. Sony Semiconductor Kyushu Co., JM NET Inc.) (Tamura, 2004).

With regular daily flights to major cities in other Asian countries, Fukuoka is located in an ideal and strategic place for promoting business with Asian manufacturers. Accordingly, in recent decades the semiconductor industry in Kyushu has developed links with other Asian economies. Mass production facilities have been leaving Kyushu for other Asian nations providing cheaper labour, while R&D functions have

[17] The Kyushu region has strong auto industry, which has been expanding recently. There are some possible connections between System LSI design and embedded electronic systems for vehicles. Another strong area is environmental technology.

strengthened in Kyushu. Nevertheless, in recent years, other Asian nations have advanced their technologies and countries such as Taiwan, Korea, Singapore and China are strengthening their positions as bases of semiconductor technology development and manufacturing. More than 50% of world production in the semiconductor industry occurs in this area. [18] Fukuoka Airport can be one of the major hubs in the Asian network and can facilitate such networks. Professor Yamazaki of Kyushu University points out that Fukuoka Airport now ranks third among international trading airports in Japan, reflecting the rapid increase in semiconductor exports (Tamura, 2004).

Fukuoka is now home to a semiconductor cluster comprised of R&D divisions of major semiconductor manufacturers such as Sony, NEC Electronics, Toshiba, Hitachi and Panasonic, as well as start-up companies with groundbreaking technologies. As of 2008, 156 system LSI companies are operating in Fukuoka.[19] The University of Kyushu had developed a critical mass of research excellence in the field of System LSI. In order to strengthen this feature, System LSI Research Center (SLRC) was founded in 2001 to develop the design and application technologies of system LSI's. There is also a growing number of spin-off venture firms from universities. Fukuoka also provides additional LSI market through a strong automotive industry in Kyushu region and the growing percentage of electronics used in cars. It is expected that alliances with semiconductor firms will be vital to the production of next-generation cars.[20] Kyushu Silicon Cluster Project has made a strategy for 'building a wider range of related industries based on thirty years of semiconductor manufacturing in the area, in order to enhance international competence for the entire industrial area' (Tamura, 2004).

The first Silicon Sea-belt summit was held in January 2003 in Fukuoka with over

[18] According to World Semiconductor Trade Statistics (WSTS), the global semiconductor market in 2005 reached a record high of USD 227.5 billion, and is expected to exceed USD 245 billion in 2006.
Invest in Fuluoka http://www.investfk.jp/industry_02.html

[19] Prefecture of Fukuoka, http://www.pref.fukuoka.lg.jp/somu/multilingual/english/flash.html

[20] Automobile industry is bigger than semiconductor industry in Kyushu. There is a great accumulation of automotive companies in the area, but auto plants are not equipped with decision-making functions (Tamura, 2004). Nissan Motor and Toyota Motor Kyushu factories are operating at full capacity and, with the addition of production at the neighboring Daihatsu Motor Kyushu plant, production output reached over one million in 2006. Meanwhile, following Toyota Motor Kyushu's construction of an engine factory, Daihatsu Motor Kyushu has also decided to construct a new engine factory.
Invest in Fukuoka http://www.investfk.jp/industry_02.html

500 opinion leaders in the area participating, whereby ideas on industry–academy collaboration, human resource development, market creation, and technology development were exchanged. Recognizing the importance of information sharing in establishing and maintaining stronger regional alliances in technology development and market expansion within the Silicon Sea-belt, a second summit was held in Fukuoka in March 2004, whereby discussions centred on issues and strategies of industry–government–academia alliances in the semiconductor industry, and the possibility for region-to-region alliances. Hosting of future summits will rotate among the participating regions. In February 2007, in the Silicon Sea Belt Summit in Fukuoka 2007, Wataru Aso, Governor of Fukuoka Prefecture, emphasized that 'the prefecture will create a dynamic economic engine for the future through the combined power of the semiconductor industry supported by the prefecture and the automobile industry'. [21]

These developments must be seen in relation to the number of policy initiatives at both national, regional and sub-regional levels. The recent 'Silicon Cluster Initiative', designated by the METI Kyushu regional bureau, builds on the semiconductor industrial agglomeration which has been growing in the region over the last three decades, aiming at enhancing the international competitiveness and R&D functions of the sector. There are a number of financial, technological and operational support schemes to System LSI-related venture companies, and other related R&D firms to create frontier businesses. Moreover, the national government has invested 3.5 billion yen (31.5 million USD) in establishing the Fukuoka System LSI Total Development Centre (Tamura, 2004).

Universities, firms and the government have been making collective efforts to promote R&D for System LSI, using a variety of human and economic resources. Thirty universities are concentrated in Fukuoka, 11 of which have science and engineering faculties providing graduates majoring in these disciplines. Another local advantage is that due to geographical proximity, it is possible for firms to conduct joint research and other cooperative activities with leading System LSI design researchers at Kyushu University, Kyushu Institute of Technology, and other post-secondary institutions located in Fukuoka. The scale of academic concentration in System LSI design in Fukuoka is

[21] Fukuoka Prefecture http://www.pref.fukuoka.lg.jp/somu/multilingual/english/flash06.html#070221 Access 20/12/08

second only to that found in the Tokyo metropolitan area.

In 2001, using Scotland's Alba Centre as a model,1 a joint initiative between the prefectural government, universities and industry produced the 'Fukuoka System LSI College', opened to serve as a training facility for the continuing professional development of LSI engineers. The aim of the college is to retain well-experienced LSI engineers in Fukuoka and provide them with the state-of-the-art technology. A professor of Kyushu University, serving as a nodal point due to linkages to a number of innovation support organizations in Kyushu, serves as principal of this College.

In 2002, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) initiated the 'Knowledge Cluster Initiative' through which the neighbouring cities of Fukuoka-Kitakyushu region were designated 'knowledge clusters' based on research related to System LSI, micro-nanotechnology and environmental technologies. Major R&D hubs, such as the Kitakyushu Academic Research District with research institutes of international standard and prominent university faculties, constitute the critical mass of research and innovation.[22] In the last 5 years, at least JPY 10 billion has been invested from the national budget in Fukuoka through various schemes such as the Knowledge Cluster Initiative, which has promoted building infrastructure, organizations, and attracting experts to create a local innovation cluster. In 2007, Fukuoka was designated as one of the six MEXT 2nd stage Knowledge Cluster initiatives aiming to promote '*internationalisation*' as well as connecting local clusters to wider areas. The project aims to conduct 20 joint R&D projects with overseas organizations between 2007 and 2011.[23] (see also Figure 2). In November 2008, for example, the Fukuoka Cluster Initiative made a Memorandum of Understanding (MOU) with FhG IZM and FhG ENAS in Germany for future R&D collaboration.

Development of the local semiconductor R&D cluster in Fukuoka has been successful due to the presence and proximity of leading companies in the semiconductor industry and entrepreneurial individuals who have acted as nodal points connecting firms, local governments and academic sector synthesizing provisions and projects at multiple

[22] In Iizuka city, which is adjacent to Kitakyushu, with a large number of scientists engaging in research activities, internationalization of R&D has been prompted with the opening of a research centre jointly operated by Henkel, Germany and Kinki University, and the Iizuka Office of the Centre for the Study to Language and Information (CSLI), Stanford University.

[23] http://www2.lab-ist.jp/english/139.html

levels. Concentration of research universities supplemented by international research institutes and new training provisions such as Fukuoka System LSI College, and a new business school at Kyushu University provide the region with human resources and professional skills which serve as prime regional assets in Fukuoka, Kyushu. In the private sector, most of the large firms' R&D headquarters are concentrated in the Tokyo metropolitan area. Regional and prefectural government and support organizations consider creating further incentives to attract large R&D firms as well as encouraging venture capital firms which supplement the activities of large firms.

Intra- and Inter-regional collaboration is imperative in building regional innovation networks robust enough to survive in the global knowledge economies as part of Global Innovation Network. Semiconductor firms and universities are collaborating across prefectures in Kyushu through regionwide innovation support organizations, supported by the METI regional bureau. Fukuoka provides research capacity for the whole region linking Asian markets and networks. Through the human and institutional inter-linkages created by the Silicon Sea-belt Project, Fukuoka might be able to serve as a 'Silicon Valley in Asia' attracting talent and skills from overseas. The case of the Fukuoka Silicon Sea-belt illustrates the transnational process of 'constructing regional advantage' (Foray & Freeman, 1993).

A new model of university–government–industry alliances and entrepreneurship in Asia may be constructed. Innovation support and technology transfer organizations will need to be designed so as to strategically link science and industry; as well as foster knowledge exploration and exploitation systems, which create spaces for innovation extending beyond the national framework. This multi-level innovation system governance model represented in the Silicon Sea-belt strategy, marks a new phase in the evolution of technological globalization whereby local nodes of excellence link in inter-cluster networks animated by large firms, university research, smaller specialist firms and government support across space to recover and enhance global competitiveness in specific advanced technologies. According to Professor Yamazaki, remaining issues include: 1) the need for 'total coordination across a broader area of policy measures', 2) the 'accumulation and vitalistion of brainpower in industries' (Tamura, 2004).

4. Concluding remarks

This paper painted a broad brushed picture of 'internationalisation of innovation systems' in East Asia by focusing on the evolution of different forms of strategic 'research alliances' set in different national contexts. An attempt was made to highlight different and changing roles played by the government, and the changing relationships between firms, universities and public research organizations in different national contexts with different levels of economic development and different types of international linkages. In other wards, the evolution of 'cross-boundary alliances' needs to be seen as part of the 'co-evolution' process between 'global and national structures' on one hand, and 'global-national-regional interactions' on the other. As Freeman puts it, "innovation at all levels—the global level, the continental and sub-continental levels, the national level and the sub-national level" (Freeman, 2002) is important with growing inter-linkages between them. By reflecting the evolution of 'cross-boundary alliances', the paper emphasised the 'networked relationship' of firms and outsourcing of R&D activities, which is a growing feature of certain firms in the so-called 'open innovation' paradigm. The review of the literature confirmed that 'the triple helix' interaction between university-industry-government moves towards a new global model for the management of knowledge and technology, where an 'internationalisation' strategy emerges within domestic policy structures.

The transformation of Japan's innovation systems needs to be investigated in relation to emerging transnational innovation systems in East Asia, with growing inter-cluster competition and partnerships. The Japanese national innovation system has been highly centred upon the Tokyo metropolitan region. In order for regions to compete with growing economic powers in Asia such as Taiwan and Korea, public support for human resource and skill development and financial provisions underlying regional innovation are needed. The national government may take a more strategic and integrated approach to enhance regional innovation capacities of regions to make them meet international standards.

Such a multi-level perspective to science and innovation governance was applied to the case of Japan, in particular, highlighting the two simultaneous processes: 'regionalisation' of science and innovation policies, especially through cluster initiatives funded by the central government, and 'internationalisation of R&D and production' with the corporate R&D shifting to East Asian countries (mainly China) as 'hollowing out' of the Japanese economy continues. Spatial dynamics within the East Asian *region* with linkages developing between Mainland China and Taiwan, China and Korea, and also *intra spatial dynamics* between city-regions in China were illustrated, illuminating the diverse nature of East Asia as an emerging *space of innovation*. As Sigurdson (2004) points out, these regional inter-linkages have been driven by the entrepreneurship and self-interests of business sector, rather than promoted by political initiatives and intergovernmental coordination. This is one of the main features of internationalization of innovation systems in East Asia, arguably, making a stark and dynamic contrast to that in Europe.

The paper highlighted efforts made by local public initiative in a city region in Japan in order to construct regional advantage by building international R&D hubs and networks through international triple helix linkages. From a public policy perspective, constructing 'knowledge hubs' set within a wider framework of transnational regional innovation systems is of key importance. After the 'lost decade' of the 1990s when the Japanese semiconductor industry lost market share, with Asia's chip industry shifting toward Taiwan and China, Japanese companies are now once again investing heavily in semiconductors. Japan is a late 'globalizer' as a nation. However, as globalization of its economy continues, the Japanese national innovation system, with its technology and science bases, has been transformed along lines similar to other industrialized countries (Fransman, 1999).

Fukuoka Silicon Seabelt Project illustrates efforts to connect sub-national cluster building to emerging Global Production Network (GNP) of semiconductor industry encompassing different city-regions in East Asia. It remains to be seen if the new strategic alliances between firms and universities and the local government with close collaboration with national government would lead into new Global Innovation Networks (GIN) and Global Production Network (GPN) in a wider East Asian region. A closer investigation is needed to see if the internationalization of R&D activities would lead to 'local capability formation' in Kyushu region and also, other city-regions in the emerging and developing economies in East Asia. As Ernst and Kim point out:

> Network participation may provide new opportunities for effective knowledge diffusion to local firms and industrial districts…., *provided* appropriate policies and support institutions are in place that enable local suppliers to exploit the opportunities and pressures that result from network participation(Ernst and Kim, 2002, p.1428).

The nature of these policies, institutions and strategic alliance formation at multi-scalar level as part of the process needs to be studied further.

One of the inherent problems of studying this area is lack of data at both national and international level. In general, existing studies of research alliances suffer from data limitations (Siegel, 2003). Better indicators and data sets for both public and private R&D activities, and STI policy measures are required. Unlike Europe, where there are public mechanisms and governance structure of STI at transnational level, East Asia lacks basic transnational infrastructure and resources, let alone consensus in measurement methodologies. Lessons need to be drawn from the experiences of governance of international research alliances – e.g. EU Framework programmes as *tranasnational R&D netoworks* (see Paier and Scherngell, 2008; Scherngell and Barbar, 2008) as well as inter-cluster linkages. At the same time, policy makers promoting the public driven R&D alliances might need to learn more from experiences of more entrepreneurship-driven business approach to alliances, for example, those emerging in East Asia.

Despite an important consideration of global connections, many of the existing research has not addressed the multi-scalar (local, national and international) linkages in innovation processes, both from business perspective and policy perspective. There are different approaches to organizational learning and knowledge production by firms, through network participation and through cross-boundary alliances between firms and universities. The spatiality of these activities and intra and inter-organisational relationships is dynamic and inter-linked. More empirical studies are needed in these fields and there are a number of policy and theoretical lessons to be learnt cross-nationally.

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Figure 1 Fukuoka Silicon Seabelt
Source http://www.investfk.jp/industry_02.html

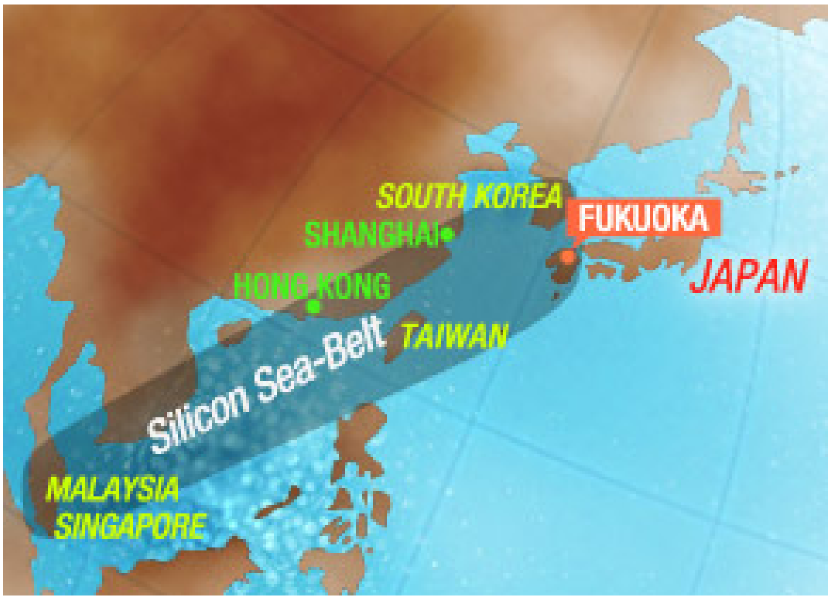

Figure 2
Source Fukuoka IST http://www2.lab-ist.jp/english/139.html