# PATENT LANDSCAPE ANALYSIS FOR UNIVERSITIES IN ASIAN CITIES

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**Summary**

This paper seeks to examine the contributions of university in forming the knowledge structure of city innovation systems of two Asian city states – Hong Kong and Singapore. It reveals the performance of university in knowledge production, networks and features in accordance with: (i) patent portfolio and fields of technology; (ii) patent landscape; and (iii) correlation map between fields and entities that produce patents. This attempt is parallel to the interest of urban scholars and policymakers in the roles of different entities (i.e. firms, universities, public research institutes) in translating their knowledge stocks into high-value added products and services. Findings indicate that private firms dominate the patenting landscape for the selected economies. Scientific activities performed by universities and public research institutions are converging with technological knowledge performed by firms. Hong Kong and Singapore sought to attain a co-evolution process for science-based industrial development.

**Key words:** University incubator, knowledge structure, patents, innovation systems

## 1. Introduction

City spaces are crucial innovation system sites that host the nation's innovation capability for creating and meeting sectoral demands. They accumulate the desired scientific and investment knowledge capabilities of the nation (Cooke et al., 2002). Athey *et al.* (2008) revealed that cities generally tend to provide a specialised and knowledge-based workforce – such as for engineering-based manufacturing, manufacturing, knowledge-intensive services and creative industries – which helps to enable and drive innovation. The role of the university as an innovation engine – rather than merely a learning and research centre – is pivotal to the development of cities, and this relationship is a growing interest in innovation system studies (Dvir and Pasher, 2004). The university is considered the founder of innovation communities (Athey et al., 2008). Universities – together with other non-firm organisations such as financial institutions, government agencies and local authorities – support innovation, technological diffusion and production by firms (Malerba, 2002). Also, the sources of technological opportunities are related to major scientific breakthroughs in universities (Rosenberg, 1982; Malerba, 2002), and this particularly so among the industries.

In this respect, university business incubators – which operate as a tool for entrepreneurial universities to create technology start-ups – seem to be an important platform in forming the linkages between universities and innovation communities in a city innovation system (Barbero et al., 2012). The purpose of this paper is to explore the overall knowledge structure of a city innovation system (CIS) in Hong Kong and Singapore, and determines the role of university in CIS in these two Asian economies. In this respect, the patent portfolios of the two cities are used as the proxy to examine the networks and features of technological knowledge in the city innovation systems.

## 2.0 City Innovation System, University Incubators and Patents

City Innovation System (CIS) is an analytical framework that brings the analysis of innovation down from the national and sectoral levels to the city level (Ratanawaraha, 2012). With reference to the case of Southeast Asia, the notion of city innovation systems denotes structures that contribute to the enhanced liveability, prosperity and equity of the city. In the same vein, Johnson (2008) suggested that the concept of innovation systems is useful to provide understanding of city dynamics (i.e. innovation as a drivers of cities), and assists in the sustainable development of cities – and thereby, society as a whole (i.e. cities as drivers of innovation). According to Cooke *et al.* (2002), the key features of cities with innovation capability involves the interaction of institutions such as the venture capital industry, knowledgeable attorneys, research centres or creative knowledge sources, firms and – to varying degrees – public support services. The balance between technological supply and demand factors is crucial for city innovation. Overall, cities can be useful as conducive spaces for innovation processes (Shearmur, 2012).

Universities are identified in the literature as one of the key actors in innovation systems. In the mainstream innovation studies, universities are often treated as part of the Triple Helix of university-industry-government (Etzkowitz and Leydesdorff, 2000; Ratanawaraha, 2012). Benneworth *et al.* (2010) distinguish three kinds of benefits that universities offer to the competitiveness processes of cities, namely: creation of new knowledge-intensive spaces; improvement in the quality of urban governance; and strengthening of intangible development (such as place branding) of the cities. Together with other education centres, universities build a city's assets foundation through the supply of skilled labour and graduates,

forming a strong base of human capital and granting academic degrees. Within universities, 'star' scientists responsible for major breakthroughs can also impact a city's innovation trajectory and help attract businesses and further talent (see Athey et al., 2008; McCartney, 2005). Besides their significance as knowledge creators, universities are also seen to be vital as consumers of knowledge through their demand for highly skilled workers as part of the education sector, high and medium tech manufacturing, high tech services (communications, computer services and R&D), financial services and business services (Williams et al., 2008).

Besides, universities with research specialisations produce graduates and researchers with high-level expertise that is used by firms (Athey et al., 2008). Innovative university research can also stimulate sector growth through spin-off companies, licences and knowledge exchange. Indeed, entrepreneurs who participate in university incubation programs tend to perform better than matched samples from non-university incubator firms (Lasrado et al., 2015). In other words, it is not enough for universities simply to produce knowledge; they must actively transfer that knowledge to industry, user and community groups (May and Perry, 2006). There is a growing interest in the consistent pattern of the flow of patented knowledge into high-technology production processes from universities. Nonetheless, in order to turn intellectual property into economic wealth, creative communities surrounding the universities must be able to absorb and utilise it within a social structure of creativity. Thus, cities must accommodate the 'creative class' in order to remain competitive (McCartney, 2005). By citing Silicon Valley as the case study, Nataraj *et al.* (2012) provided evidence that university patenting contributed to the development of Silicon Valley. University patenting activities have increased since the introduction of the Patent and Trademark Amendments of 1980 (or better known as the Bayh-Dole Act); the increased industry funding of university research; and an increase in university technology transfer offices.

As cities are seen as the nations' innovation hubs in producing patents and other types of new products and processes in business (Marceau, 2008), a study to explore the significant roles of universities in translating their knowledge stocks into tangible goods and services is at the centre of innovation studies. In fact, this is one of the profound research agendas of entrepreneurial universities. In a broader definition, university entrepreneurship includes any published research pertaining to entrepreneurial activities in which a university could be involved. This includes patenting, licensing, creating new firms, facilitating technology

transfer through incubators and science parks, and facilitating regional economic development (Rothaermel et al., 2007). As one of the key entities of entrepreneurial universities, technological incubators that are closely linked to universities facilitate academic personnel to exploit knowledge-based business ideas, thus reducing the barriers that inhibit direct commercial application of the university research (O'Gorman et al., 2008). In short, the numerous services provided by university incubators to the universities are in the form of accommodation, administrative services, consultancy (e.g. market surveys, financial strategies and legal advices), training, linkages (e.g. financial searching, contact network support, etc.), and creation of an infrastructure that allows access to information on accounting, markets and technology (de la Garza, 1993).

## 3.0 Methodology and Data Source

This paper seeks to draw on literature describing the CIS, as well as various empirical studies of city innovations that have (re)organised and fashioned the socio-economic structure of the city economy. The change in socio-economic structure is understood to have been led by the learning routines of the agents of change in innovation systems (Wong and Goh, 2012; Wong et al., 2015). The routines then led to new configurations of knowledge structures of the city that are productive for knowledge-oriented economic activities. Advanced economies such as Hong Kong and Singapore would certainly mobilise resources to invest in and appropriate intellectual property capital, in order to advance their knowledge-based industries.

Hong Kong and Singapore are the among most acknowledged city states in terms of successful transition from labour intensive to knowledge based economies. They are recognised as the two tiger economies that managed to catch up with the world frontiers in both economy and technology. The two cities are endowed with productive capabilities which have led to massive diversification of industries. Given the acknowledged efforts made for their respective innovation systems (as maintained by the literature), it is expected that their knowledge structures would have been productive and functional for knowledge-based type of economic activities.

We seek to inform the literature of the linkage constructs of city dwellers, particularly those who are endowed with resources and capabilities to create a path for learning and searching

for knowledge-based economic prospects. Patents provide important information and insights into technological progress, impacts of certain technologies on others, fusion of technology, and collaboration patterns for new technology (Wong, 2013). Nonetheless, we acknowledge that patents may not be the perfect indicator for technological knowledge, as innovations or technical change may not necessarily lead to the creation of patents. In addition, the process of attaining tacit knowledge is complex, and one should not quantify it via a set proxies. Instead, one should cautiously examine the process – specifically when adopting an analytical framework that is intended to simplify the complex process of learning – or risk being constrained by certain naïve assumptions.

This study uses the historical series of granted utility patents data from 1st January 1994 to 9th March 2016. The data was extracted from the United States Patent and Trademark Office's (USPTO) database using Patsnap's search engine. We observed that Hong Kong and Singapore attained 5,385 and 9,960 granted patents respectively. We cautiously examined the configuration of knowledge structures of Hong Kong and Singapore in accordance with their respective patenting portfolios. We will highlight those actors (firms, universities or PRIs) which actively performed patenting activities in their respective economies. Patsnap's knowledge landscaping tool is instrumental to this study, as it helps us to cluster common keywords found in the extracted patent documents, and furthermore illustrate them through a computer-generated graphical map. The map provides us with the information on the knowledge landscape of the two cities. We then perform cross-correlation analysis between the assigned International Patent Classification (IPC) patent codes and extracted patents, in order to identify the knowledge ties. Using the Vantage Point system, we will triangulate the ties generated with various innovation system studies on these two cities. What follows would be the cross correlation analysis between the IPC patent codes and the top 30 performing entities in patenting. Additionally, several face-to-face interactions with the top management of university commercialisation centres or university incubators in Hong Kong (i.e. Hong Kong University of Science and Technology, Chinese University of Hong Kong, and City University of Hong Kong) and Singapore (i.e. National University of Singapore) were carried out during the period of 2014-2015.

## 4.0 Results and Discussion

### *4.1 Knowledge Landscape*

Figure 1 and Figure 2 show the knowledge maps for Hong Kong and Singapore respectively. The extracted patents of the two economies for the past five years are categorised based on IPC codes and mapped to the grid nodes that are labelled with different colours. The distances between the nodes inform about how similar the patents are to one another. The distances allow the software learning machine to plot clusters and provide labels (appearing on the centre of the peak of the cluster) based on common keywords that are found in the patent documents. The legend informs about the top 20 stakeholders (categorised according to three entities, namely private firms, universities and PRIs) of patenting activities.

Both figures provide a brief overview of the intensity of patenting activities amongst the three entities (i.e. private firms, universities and PRIs) in the respective cities. It illustrates the areas of technological focus of each city innovation system. We observe that private firms dominate the patenting landscape for the economies, while patents from universities and PRIs are scattered around. This can be a good indication that scientific activities (performed by universities and PRIs) and technology (mainly performed by private firms) are converging in the city innovation system to attain a co-evolution process for science-based industrial development. Relatively speaking, universities in Hong Kong appear to have been endowed with resources and were more active in patenting compared to the PRIs. At the other extreme, Singapore witnessed noteworthy contribution from PRIs, which performed far above the universities.

The private firms were found to be active in ICT related products and processes. Hong Kong performs in children's products such as toys and moulds for seats and strollers. This can be attributed to the design capabilities that Hong Kong firms attained (for foreign firms producing child related products). Universities and PRIs emerged to invest in high risk, science-based sectors that produce drugs and biotechnology related products (with "Protein, Therapeutic, Synthetases, Relate, Fragment" as the label). Singapore on the other hand seems to have mobilised its resources for only few areas that are related to ICT. Semiconductor oriented technologies (with "Integrate, Interconnect, Bump, Encapsulant, Wafer" as the label) created the largest footprint in the landscape.

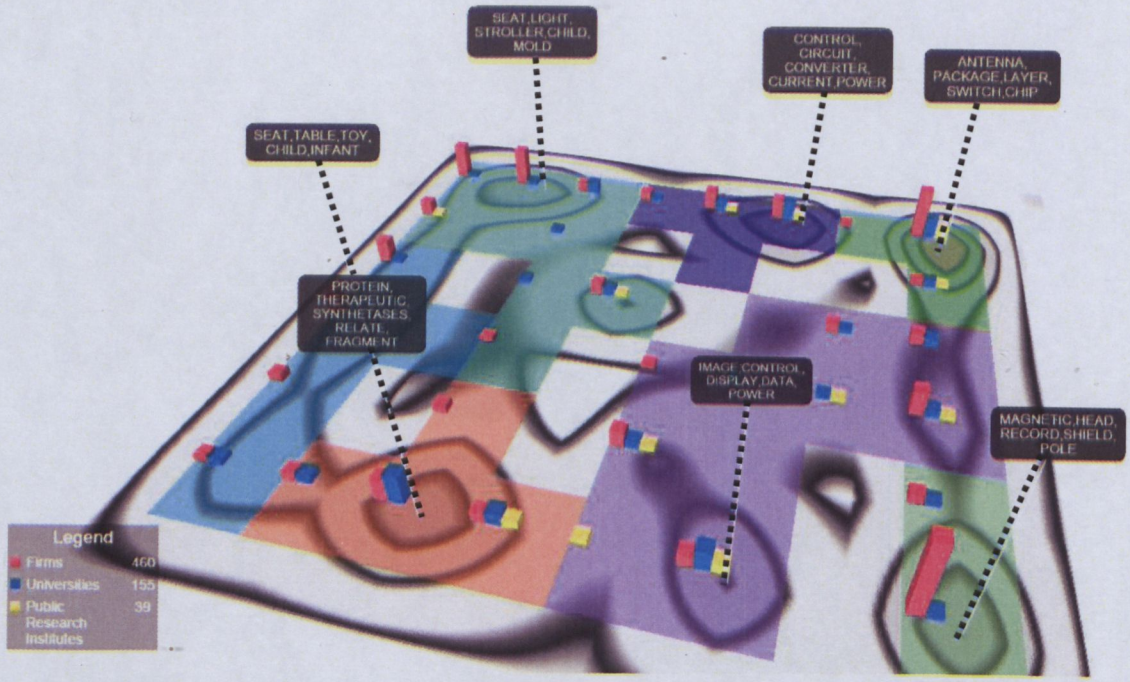


**Figure 1**: Knowledge Cluster Map for Patenting Activities of Hong Kong (2011-2015)

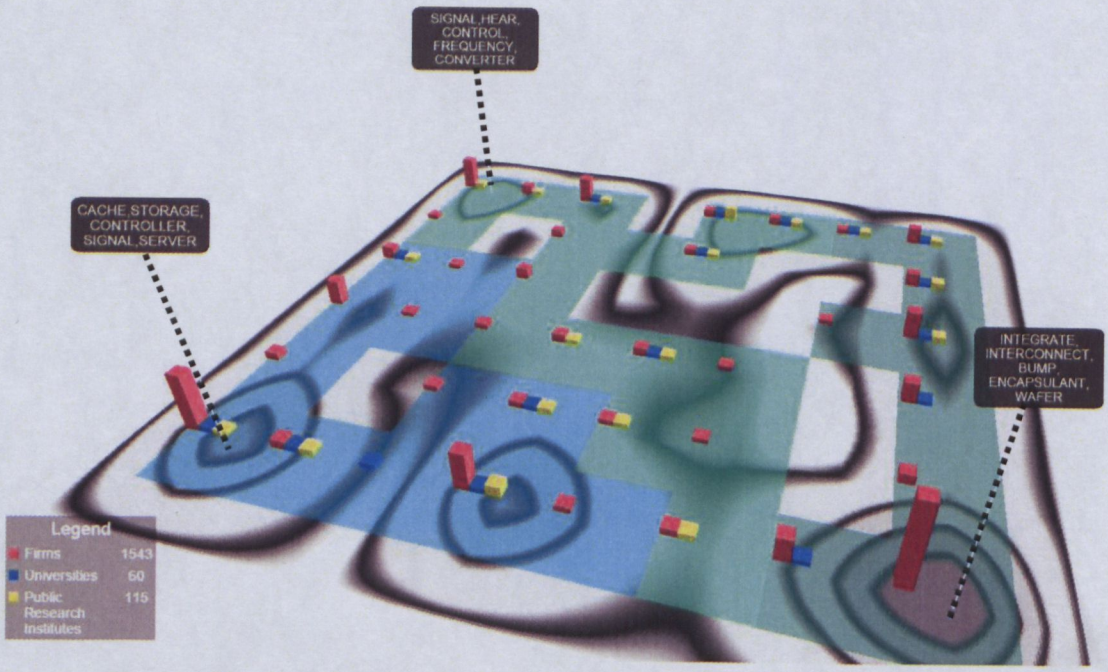


**Figure 2**: Knowledge Cluster Map for Patenting Activities of Singapore (2011-2015)

### *4.2 Knowledge Structure and Network*

Figure 3 and Figure 4 show the auto-correlation links mapped for fields of technology[1] for Hong Kong and Singapore respectively. The maps highlight the highly correlated links between fields, while those links which are less correlated (i.e. with values of 0.75 and below) are hidden. The two maps manifest similar structures for each cluster. There are basically six clusters mapped for each economy, indicating identical fusion of technological innovations in the city innovation system. In other words, active knowledge exchange and networking are exhibited in the cities' technological progress. Nevertheless, there are marginal differences in some clusters.

Figure 5 and Figure 6 map the cross correlation networks between the top 30 assignees and fields of technology for Hong Kong and Singapore respectively. The maps allow us to observe the influence of different technological research orientations that shape and organise networks of different technological actors. From Figure 5, technological research activities of Hong Kong appear to be performed mainly by private entities, with many of them pursuing their research agendas without having a common (or collective) interest with other stakeholders in the market (there being only eight highly correlated links in the map). Hong Kong seems to prefer mobilising its research resources towards several universities (green nodes) to pursue technological innovation. These active universities are the University of Hong Kong, Chinese University of Hong Kong, Hong Kong University of Science and Technology, Hong Kong Polytechnic University, and City University of Hong Kong. Nevertheless, there are no highly correlated links amongst these aforementioned universities. There is only one PRI (red node) – at Hong Kong Applied Science and Technology Research Institute, which is performing as one of the top 30 patent assignees. The figure also illustrates that there is only one network that significantly connects institutions from different entities, i.e. the link between Hong Kong University of Science and Technology (a university) and Hong Kong Applied Science and Technology Research Institute (a PRI).

From Figure 7, Singapore emerged to have organised a strong network, with private firms pursuing similar research agendas. This can be attributed to the research routine that been established for upgrading of semiconductor industries. A Singaporean PRI, Agency for

[1] Note that an innovation reported in patent documents can be classified in more than one IPC field of technology.

Science, Technology and Research (A*STAR) emerged as the bridging institution linking scientific research activities from universities with technological activities performed by private firms. The knowledge networks of Singapore appear to be deliberately structured and more organised compared to those of Hong Kong. This can be attributed to the systemic pursuit for both upstream (exploration for niche positions in the market value chain) and downstream (scaling of production) knowledge production for the economy. National University of Singapore and Nanyang Technological University are the two universities that perform significantly in the network map. They are highly correlated to the private firms through A*STAR.

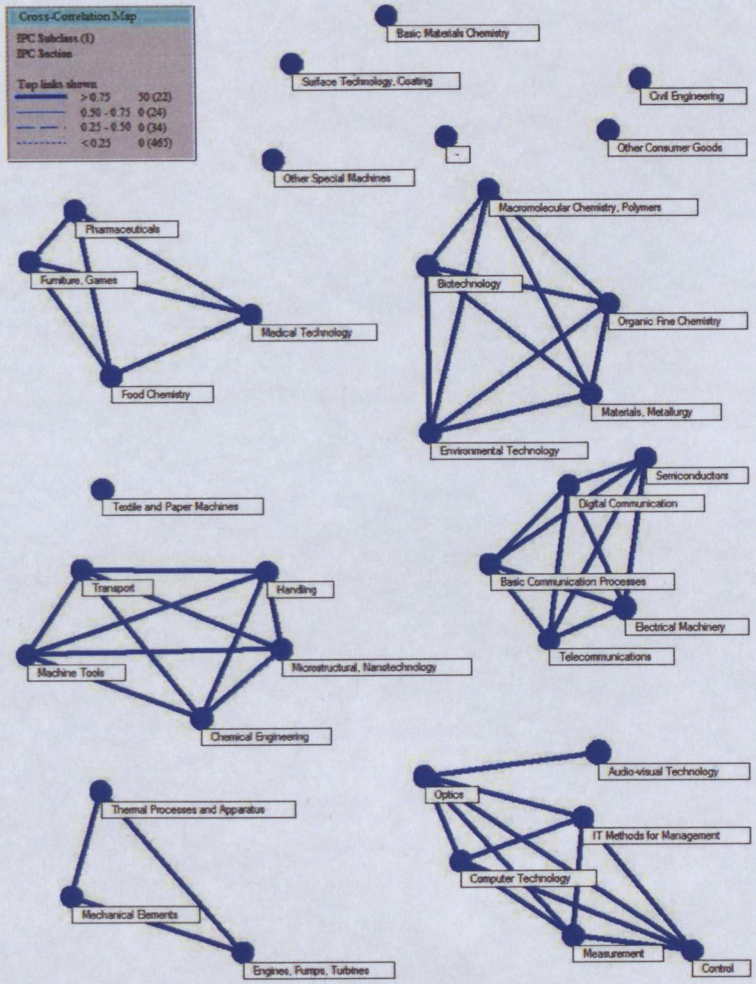


**Figure 4**: Correlation Links Mapped for Fields of Technology - Hong Kong

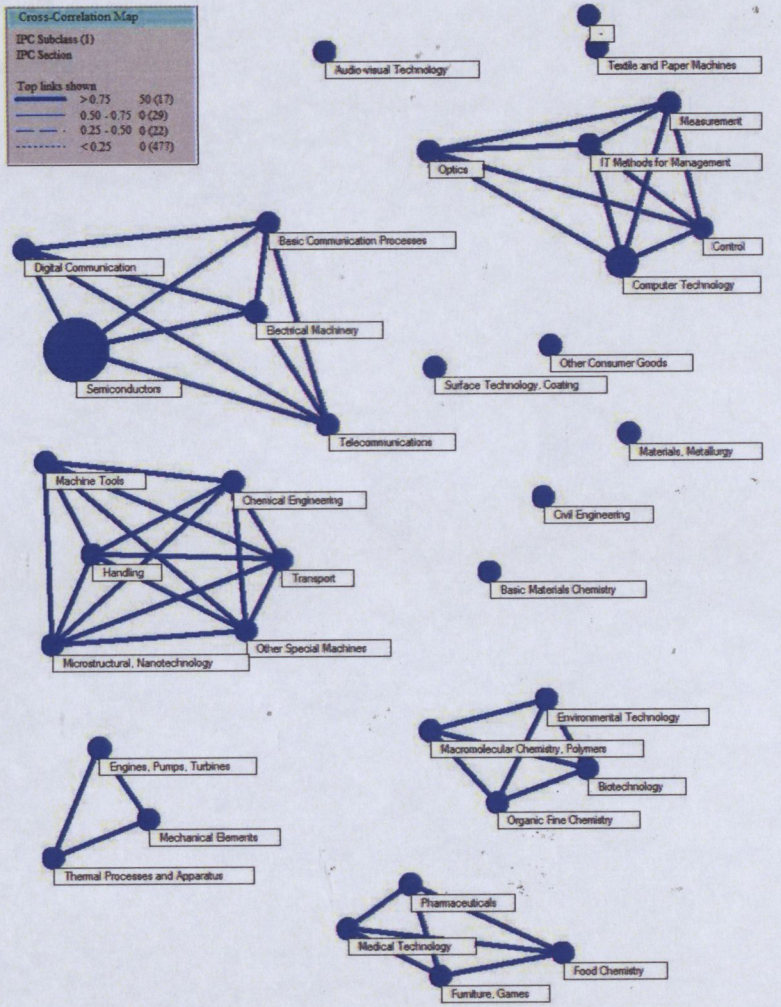


**Figure 5**: Correlation Links Mapped for Fields of Technology - Singapore

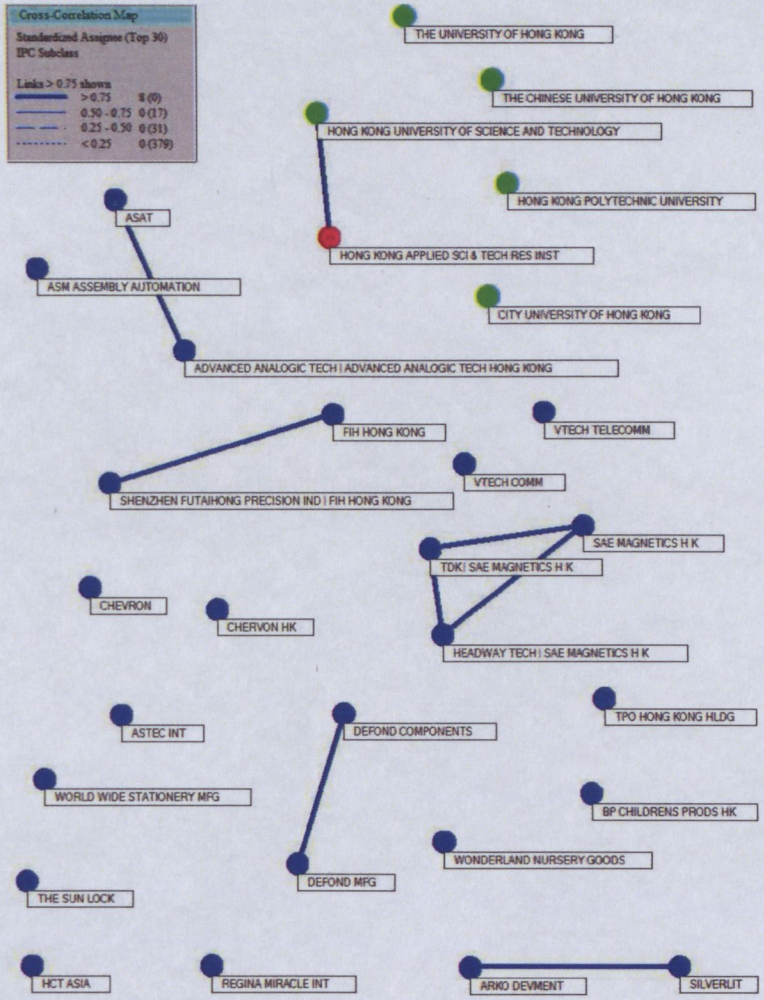


**Figure 6**: Cross correlation network map between Top 30 Assignees and Fields of Technology - Hong Kong

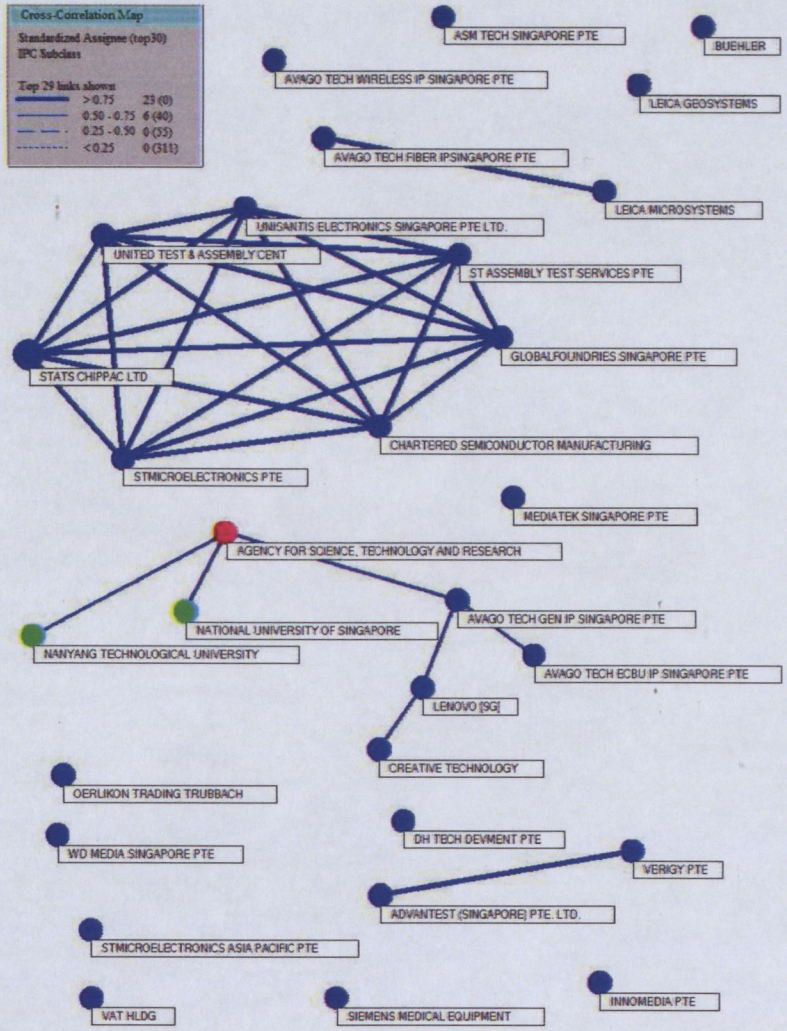


**Figure 7**: Cross Correlation Network Map between Top 30 Assignees and Fields of Technology - Singapore

## 5.0 Conclusion

This paper discusses the knowledge structure of city innovation systems based on two case studies, namely Hong Kong and Singapore. It is explicitly recognised that the knowledge structures differ between cities. Hong Kong and Singapore manifest knowledge structures which have similarities, yet are different in terms of networks organised for research activities. Hong Kong appears to pursue a technological track that is led by many private firms, with universities performing technological research via a forward engineering approach in an environment conducive to exploratory activities. Universities in Hong Kong may anticipate capable firms abroad (particularly firms in mainland China) to codify their innovations and modularise their manufacturing processes to scale up production. By contrast, Singapore pursues a more organised pathway where firms perform on common research agendas, with PRIs performing as bridging institutions to ensure science and technology are aligned for systemic industrial development. Singapore is committed to both upstream (research, prototyping, integration, pilot scale, etc.) and downstream (scaling of production) production. These different pathways in city development may be attributed to government interventions, such as the establishment of specific techno-entrepreneurial capabilities, creation of science parks, and etc.

We have so far explored the knowledge structure of the two economies, as well as the network features that were influenced by the competencies and routes of the economies in productive activities. We believe that this study can be extended to explore the knowledge structures and networks of other city innovation systems. Our preliminary review of the literature (Wong et al. 2015b and Wong 2016) on the knowledge structures of Kuala Lumpur (of Malaysia) and Hsinchu (of Taiwan) seems to suggest a pattern that shares similarities with that of Singapore. Meanwhile, cities like Boston may share a pattern in pursuing technological knowledge and innovations identical to that of Hong Kong (as gleaned from reviewing the pursuit of firms explained by Reynolds et al. 2013). Therefore, our study may suggest interesting comparative applications for future research to highlight knowledge structures and networks.

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