Levels of Innovation Systems: competition or complementarity? The case of China

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Abstract: Notwithstanding the popularity of the innovation system (IS) theory, the literature is largely silent on the effects of the relationship between different levels of ISs on innovative activity and the efficacy of public policy. This paper thus sets out to explore the relationship between the national (NIS), regional (RIS), and local (LIS) ISs against the background of China. The result shows that the twenty-nine provinces in China were clustered into five distinct sub-groups. For hinterland regions, it was noticeable that while their science parks generally function better as LISs compared to their host regions, China's NIS still casts the most significant influence, as has been shown in the case of the Optics Valley of China (OVC) within Hubei Province. Overall, it seems a place's economic strength and administrative power and autonomy are among the most crucial factors determining the relative fitness of ISs on different geographical levels.

Key words: local innovation systems, science parks, China, OVC, inter-scalar relations

1. Introduction

Innovation system (IS) theory has emerged strongly as one means of understanding the geography of innovative activities. It also offers important insights into the efficacy of policy in supporting innovation in comparative perspective. The importance of institutional factors in contributing to a nation's competitive advantage and innovation performance was first spelt out in the national innovation system (NIS) theory by the likes of Lundvall (1985), Freeman (1988), and Nelson (1988). A fundamental weakness in earlier studies of NIS, however, lies in their neglect of the diversified economic-institutional settings within a nation. The concepts of regional innovation system (RIS) (Cooke 1992) and local innovation system (LIS) (Rantisi 2002) advanced during the 1990s, therefore, could be seen as an attempt to challenge the former's 'flat-space' assumption. While it is welcome to see space and place being taken seriously by scholars in these RIS and LIS branches of IS theory, one remaining silence in this literature is the relationships between these different levels of ISs. This is to say, the effects of these inter-scalar relationships are far from clear. Scholars have chosen either to debate against each other on the relevance of NIS, RIS, and LIS respectively (Mothe and Paquet 2000), or simply assume that RIS and LIS are sub-systems of a NIS (OECD 1997). Empirically, studies on ISs tend to focus exclusively on one level of the IS, and therefore fail to shed light on the bilateral interactions between them. Given the advantages and increasing popularity of IS theory in studying innovation and its dynamics, the aim of this paper is to explore the relationship between NIS, RIS and LIS, in the case of China.

IS theory provides a territorially circumscribed perspective of the innovation processes when situating firm-level innovation within their surrounding institutional setting. By borrowing from evolutionary economics ideas such as variation, co-evolution, and fitness, the IS theory is capable of providing a temporal profile to a territory's competitiveness. This scale-based perspective can be contrasted to some economic geographical approaches to the study of innovation, which attribute the porosity of NISs, RISs and LISs to international networks of relations (Bunnell and Coe 2001). Such a relational perspective on innovation has emerged as part of broader contrasts in human geography between scalar or territorial perspective on the one hand, and relational perspectives on economic, social and political processes on the other (see for example, Allen and Cochrane 2007; Elden 2010; Jonas 2006). These perspectives have often been presented as mutually exclusive alternatives by many. However, as Jonas (2006) outlines, the contrast between the two approaches has been overdrawn, partly because scalar or territorial perspectives in general, and IS theory in particular, are open to, and are in fact being highly productively used in, addressing issues such as: the 'rescaling' of the state and other institutions; the nesting and 'relativisation' of scales of economic, social and political organization, and; the content and effect of inter-scalar relations. Furthermore, IS theory pays attention to both the institutional actors and their territoriality, which makes it highly applicable when studying the developmental states of the Asia Pasic region (White and Gray 1988), such as China, where governmental forces have been, and remain, significant (Yeung 2002). Therefore, while a relational economic geographical perspective on innovation has much to commend it, this paper instead adopts a territorial perspective when making a contribution to the development of IS theory.

The paper begins by outlining IS theory and identifying its silence on the relationships between NIS, RIS and LIS. What is proposed in section two and three is a relatively independent but also permeated relationship between the different levels or scales of ISs. Section four then outlines the research method used when testing this hypothesized complex system with a case study of China. A highly diversified picture has emerged regarding the fitness of different levels' ISs in section five. Optics Valley of China (OVC) in Hubei Province was examined in detail there, as it represents a LIS that functions better than the wider RIS. The author's original survey and interview data were drawn upon for this analysis.

The main contributions of the paper are summarized in section six, and the wider implications for the development of IS theory are also outlined there.

2. The geography of innovation systems: which scale?

The idea of IS was developed originally on the national level out of the dissatisfaction with neo-classical economic theory (Lundvall 2007a). Inspired by institutional theory and evolutionary economics, the theory of IS takes into account two sides of the innovation process: the micro-level innovative activities and learning process of the companies, and the wider selection environment in which one variety is preferred to others and thus defines the evolutionary path of the community. Following Freeman (1987), the term 'innovation system' refers to a collection of private and public actors, whose interactions would stimulating the processes of initializing, learning and diffusing economically useful knowledge. Its strong emphasis on the institutional environment, which in turn is spatially specified, has underlined the potential contribution of IS theory in studying the geography of innovation. Furthermore, the active debates among NIS, RIS and LIS imply that there is increasing awareness of the multiple geographical scales at which innovative activities can be considered. However, attention to inter-scalar relationships – that is, the relationships between ISs at different local, regional and national scales – has been less in evidence.

As mentioned before, IS theory was proposed to speak to the national level in the first instance. Firms and institutions comprise the basic framework, which have to be located within the boundary of a nation, and directly or indirectly involved in the innovation processes (OECD 1997). Firms in a NIS are the carriers of technology, innovations and processes of diffusion. They are the catalysts of economic growth. The institutions, on the other hand, provide skilled labour (education sector), capital (financial sector), infrastructure, home market advantages, and a generally supportive environment (Lundvall 1992; Nelson 2000). Why NISs evolve and differ in performance is explained by the different dynamics and ‘matching’ between industrial and institutional structures (Nelson 1994). Therefore interaction and co-evolution between these two domains are crucial to the efficacy of NIS (Freeman 2002; Perez and Soete 1988).

Yet, the paradoxical consequences of globalization, which on the one hand, undermines the power of national authorities, and on the other hand, strengthens meso-level governance (Acs et al. 2005), has directed many scholars’ attention towards RIS. This idea was proposed and popularized mainly through the effort of economic geographers, partly as a reflection and partly as a reaction to the growing cross-border activities led by multinational corporations, and the reinforced regional concentration of production and innovation activates. By focusing on the profound interregional innovation disparities, RIS builds on NIS by revising the latter’s assumption of a ‘flat surface’ within nations (Yeung 2009, p210). Firms and institutions are still regarded as the main components of a RIS, but this time, the region or sub-region defines the boundaries for analysis. According to Cooke et al. (2000, p2), regions are ‘meso-level entities operating, in political and administrative terms, between local and national governments with varying degrees of influence over innovation policy’. Speaking from a relational perspective, Oinas and Malecki (2002, p105) defined the meso level as ‘where nonproprietary and intangible higher order industrial capabilities are developed and maintained by the interactions among firms’. Regarding the question of why RISs differ in performance, students in this school pay more attention to regional disparities both in terms of their industrial structures and institutional architectures, the latter of which has gained on momentum particularly (Asheim and Coenen 2005; Mothe and Paquet 1998; Norma M. Rantisi 2000).

Perhaps one of the most challenging issues facing the IS theory is to distinguish the relative contributions of national, regional and local scales in supporting innovation processes. Up till now, scholars have chosen either to debate the salience of NIS, RIS, and

LIS respectively (Mothe and Paquet 2000), or simply assume that RIS and LIS are sub-systems of a NIS (OECD 1997). For example, the RIS strand used to assume that the local level innovation activities could be completely incorporated into the regional level, and it is the interactive mechanism *between* LISs, not *within*, that is worth exploring. The author, on the other hand, believes that this rather coarse-grained perspective neither reflects the real dynamics of innovation activities, nor adequately reflects the widespread governmental decentralization across the world. What has resulted from this simple classification is that studies on the LIS are scarce and fragmented and often display considerable conflation with other concepts, such as industrial districts, clusters and milieu. However, no matter scholars approach the meso-level through a governmental perspective (Cooke et al. 2000), or from a relational perspective (Oinas and Malecki 2002), the coherence of IS at different levels is itself a spatially and temporally specific phenomenon. Therefore the author is tempted to suggest that it is misleading to acclaim one geographical level is superior to others in analyzing innovation activities, i.e., each innovation scale has its advantages and disadvantages in supporting the innovation processes, while at the same time, their interactions could significantly impact the individual performance if viewed alone. Elsewhere a clearer definition of LIS has been offered, which took note of the context in the developmental states of East Asia in particular (Miao, 2012). I return to this definition of a LIS below when considering the important question of the relationships between NIS, RIS and LIS.

3. The relationship between NIS, RIS and LIS: competition or complementarity?

With respect to IS theory, Mytelka (2000, p19) has argued that 'neither the permeability of national frontiers nor the growing autonomy of localities are integrated into the overall framework of analysis'. This criticism strikes at one key development the IS theory needs to made, which is to explore and specify the relationships between different levels of ISs. This section will try to fill the gap by offering a preliminary attempt in spelling out these relationships.

3.1 Relationships between NIS and RIS

Two perspectives are dominant when it comes to the relationship between NIS and RIS. The first and more dominant one is the 'competitive' viewpoint. As introduced earlier, an altered focus on the institutional factor in economic analysis was provoked by variations in the economic performance among countries over time. Thus Freeman (2002) talked about the dominance of the Great Britain in the 18th century, the leaping forward of the United States in the second half of the 19th century, and the more recent catching-up countries in the 20th century. This is a rich literature, ranging from the dominant industrial sectors, education and training systems, to financial and tax arrangements. However, it is also this richness that hampers the details offered by NIS within one country (Kumaresan and Miyazaki 1999). Against this weakness, the development of RIS, to a great extent, could be seen as built upon critiques of the NIS perspective. Mothe and Paquet (2000, p30), for example, argued that the concept of NIS 'suffers in so far as it is itself not so much an explanatory variable as a dependent variable', and that the notion of NIS will 'almost inevitably lead to compulsive centralization and misguided approaches' (Acs et al. 2000, p37). Therefore many advocates for the concept of RIS argue that the national level is too broad to provide meaningful insights into the complex innovation process (Acs et al. 2005; Cooke 2001a).

The second and quickly emerging perspective is the 'embedded' view on different levels of ISs. Lundvall (2007b, 2007a) for example, suggested that RIS does not replace, but complements NIS, because a better understanding of innovation at regional and local levels would make it easier to compare innovation performance across countries. Zeller (2001, p126), by studying three biotech clusters in Germany, pointed out the necessity to take into consideration the overlapping of ISs on the national, subnational, regional, and local levels, as well as their interfaces with sectorial level ISs. Chung (2002, p486), in the same vein, argued that the NIS should be considered as comprised of regional and sectorial ISs, 'as the user–producer relationship of innovation is established in almost every region and industrial sector'. Moreover, he also argued that the concept of RISs is easier to implement than both the sectorial ISs as well as the NIS, as the 'regions should concentrate specific industrial sectors for the effective development of their regional economies.'

Both the competitive and embedded perspectives, however, could find their difficulties in presenting the complicated relationships between NIS and RIS. On the one hand, ISs on different geographical levels or scales do not necessarily act in competition or contradiction with each another. This is because the cross-level flows of labor, capital, and information are bound to link up the various innovation actors that compose different levels' of ISs as well as the innovation processes. There might also be actors and/or interactions that overarch multiple sites of practices, relations, events and processes across these territorial-based ISs, and thus exemplify some characteristics of the relational site-based ontology (Marston et al. 2005). This is why Oinas and Malecki (2002) argued for a 'spatial innovation system'. For them, the spatial IS refers to interlinked subsystems over space, whose connections are established by the necessity of developing particular technologies or technological systems. A variety of regions might be linked up in this technology development chain, whose specialization and technology sophistication will in turn define their roles either as genuine innovators, adapters, or adopters (ibid, p113). Nevertheless, it is arguably over-optimistic to treat the lower level ISs as completely embedded within its higher level ISs. There are parallel interactions and connections among RISs and NISs themselves, and/or 'grey spaces' that are so unique to a lower level IS that cannot be represented by its higher level ones. This holds for the relationship between RIS and LIS, as will be elaborated next.

3.2 Relationships between RIS and LIS

The relationship between LIS and RIS is less elaborated compared to aforementioned discussions on RIS and NIS. This in turn stems from the lack of an adequate definition of a LIS. Thus, Miao (2012) suggested a four-pillar framework which could helped to distinguish a LIS from other spatial-economic patterns, such as Marshallian industrial districts and Porter's clusters. These four pillars include: 1) A network or set of conscious interactions between the system components, which in turn would influence the whole unit's innovation performance; 2) A high level of collectivity as a unit, which distinguishes the community as an entirety; 3) Noticeable coevolution among its industrial structures, institutional components as well as between these two domains and; 4) Substantial administrative autonomy and power when dealing with its external environment. Against the context of developmental states in East Asia, especially in China, the feasibility of science parks as LISs has been discussed as well.

The lack of an adequate definition has also led to the conflations of LIS with other related but different terms, such as cluster and industrial district. Detailed comparisons between these diversified economic-spatial formats have been offered by Miao (2012) elsewhere, while the focus in this section is to draw on lessons learnt from studies that tried to uncover the connections between clusters/industrial districts and RISs. Early on, Cooke (2001b) hinted that at the strategic level, the RIS may encompass many smaller forms of economic agglomerations, such as clusters or even company-towns. However, he didn't touch upon the questions of in what way and how the different spatial forms fit with each other. He also regarded the city as a sub-scale of a RIS, and argued that 'RIS are driven in important ways by their key cities ... the more a city is a regional capital and the region is industrial, the more the city innovation system is integrated with the regional, in some cases more than the national, and much more than the global levels' (Cooke 2004, p8-9). Seo (2006) supported the idea that clusters and RIS were closely related in a way that RISs could contain several clusters. Under the assumption that the presence of an industrial cluster is a key attribute of RISs, Seo further argued for a cluster-based policy in regional economic development, which focuses on the vertical relationships between dissimilar firms and between suppliers, main producers and users. Nevertheless, using a cluster-based approach to study knowledge flows within the NIS has already been practiced in some western countries and recommended by OECD (1997).

In tapping into the relations between clusters and RISs, the extant literature however, tends to assume that both the existence of industrial clusters and ISs are assured, and a spatial overlap between the two is the norm. More recently studies have nevertheless cast doubt on this simple assumption. Muscio (2006), for example, while admitting there was a close relation between the concepts of an industrial district and a RIS, pointed out that these two concepts actually capture different regional development aspects. Industrial districts would be embedded within and supported by a RIS, but they would also stand autonomous as LISs. Similarly, Asheim and Coenen (Forthcoming, p13) also admitted that the regional level is neither necessary nor often sufficient for clustered companies to retain their innovation and competitiveness. In order to explore deeper the fitness between clusters and RISs, these authors have referred to Asheim and Gertler's (2005, p295-6) distinction between 'analytical' and 'synthetic' knowledge base. While the former describes the economic activities where scientific knowledge is fundamental, and where formal models and processes are needed for knowledge creation; the latter annotates the industrial settings where basic R & D activities are less important than other functions, and companies' innovation is approached mainly through applying or combining existing knowledge. Based on this distinction, the authors tentatively suggested that 'clusters drawing on a predominantly synthetic knowledge base are more loosely coupled with the RIS in comparison to clusters which draw on a predominantly analytic knowledge base' (ibid, p14).

Although there seems to be growing awareness that clusters/industrial districts have their independence, and therefore are not uniformly subordinates to RISs, the bulk of effort from the RIS scholars, nevertheless, has been devoted towards how to convert a cluster or clustering systems into a RIS. The consensus among many scholars is that, a RIS is in place as soon as there are firms and knowledge organizations interacting systematically on the regional level. Based on this logic, Asheim and Isaksen (Forthcoming) claimed that RIS is a new way of organizing the working of regional clusters. For them, RIS "denotes regional clusters surrounded by 'supporting' organizations" (ibid. p10). Thus, the development from a cluster to an innovation system may require (i) more formal inter-firm innovation collaboration between firms in the cluster, and (ii) a strengthening of the institutional infrastructure, i.e. more knowledge providers are involved in innovation cooperation. In the same vein, Isaksen and Hauge (2002) argued that while industrial clusters might be seen as a spontaneous phenomenon, RISs needs more organizing and planning. More specifically, they suggested that "to constitute an innovation system, firms in a regional cluster first have to form regional innovative networks involving more organized and formal co-operation between firms in innovation projects" (ibid. p14). These innovation networks, in turn, need attention and support from knowledge creating and diffusing organizations before they could be qualified as 'complete' RISs.

Although plausible, three potential shortcomings of the above viewpoints could be identified. First, it seems that scholars in the broad IS school tend to assume that local innovation activities (a) proceed in a less-structured manner and (b) lack well-defined institutional architecture. The first feature disqualifies 'local' as a proper level to probe the general patterns of innovation mechanisms; whereas the second feature, if true, is an obstacle to an IS formation on the local level, because half of its components are missing. These assumptions in turn lead many to overlook the LIS, or suggest integrating the local up to the regional or national frameworks. The author, however, worries about the potential danger of this theorization, as without a clear understanding of innovation activities from within a local community, studies on the linkages across these communities will also lose their foundation. Second, the concepts of cluster and industrial district have often been misused as substitutes for LISs. This is misleading as the former exhibits different configurations of networks, collectivities, coevolution, and especially the administrative power and autonomy among innovation actors from those exhibited by a LIS. Third, there seems to be an implicit assumption that RISs are superior to clusters/industrial districts in approaching innovation activities, since most studies discussed above have advocated the upgrading of clusters to RISs. However, without a proper understanding of LIS, and without pinning down the relationship between clusters/industrial districts and RISs, one cannot pre-assume that the former is less desirable than the latter, and thus a conversion is needed.

3.3 Interrelationships between NIS, RIS and LIS

Based on the above analysis, the author believes that portraying the relationships between NIS, RIS and LIS should be the foremost task in advancing the IS theory. Miao (2012) suggested a four-pillar framework to distinguish a LIS. Among these pillars, it was the last feature, i.e., a substantial governmental and institutional autonomy, that was highlighted as a distinctive quality for a LIS. Therefore essentially what the author attempts to suggest, is the necessity to look at the three levels of ISs as relatively independent but also permeated systems, as illustrated in figure 1. The fundamental assumption of this relationship is that, beginning at the scale of a LIS, every level of the IS is partly embedded and partly distinguished from its upper level systems: Cross-level resource flows, knowledge exchanges and power readjustments, are some of the mechanisms that bridge ISs on different geographical levels. At the same time, unique resource combination and economic-social endowment distinguish each IS from others. In other words, one could argue that each system is complex in its own right, but they nevertheless complement and/or constrain each other when functioning as a unity. The result of their configuration structures and dynamic relations determines to a large extent their innovation capabilities on the national and international scales.

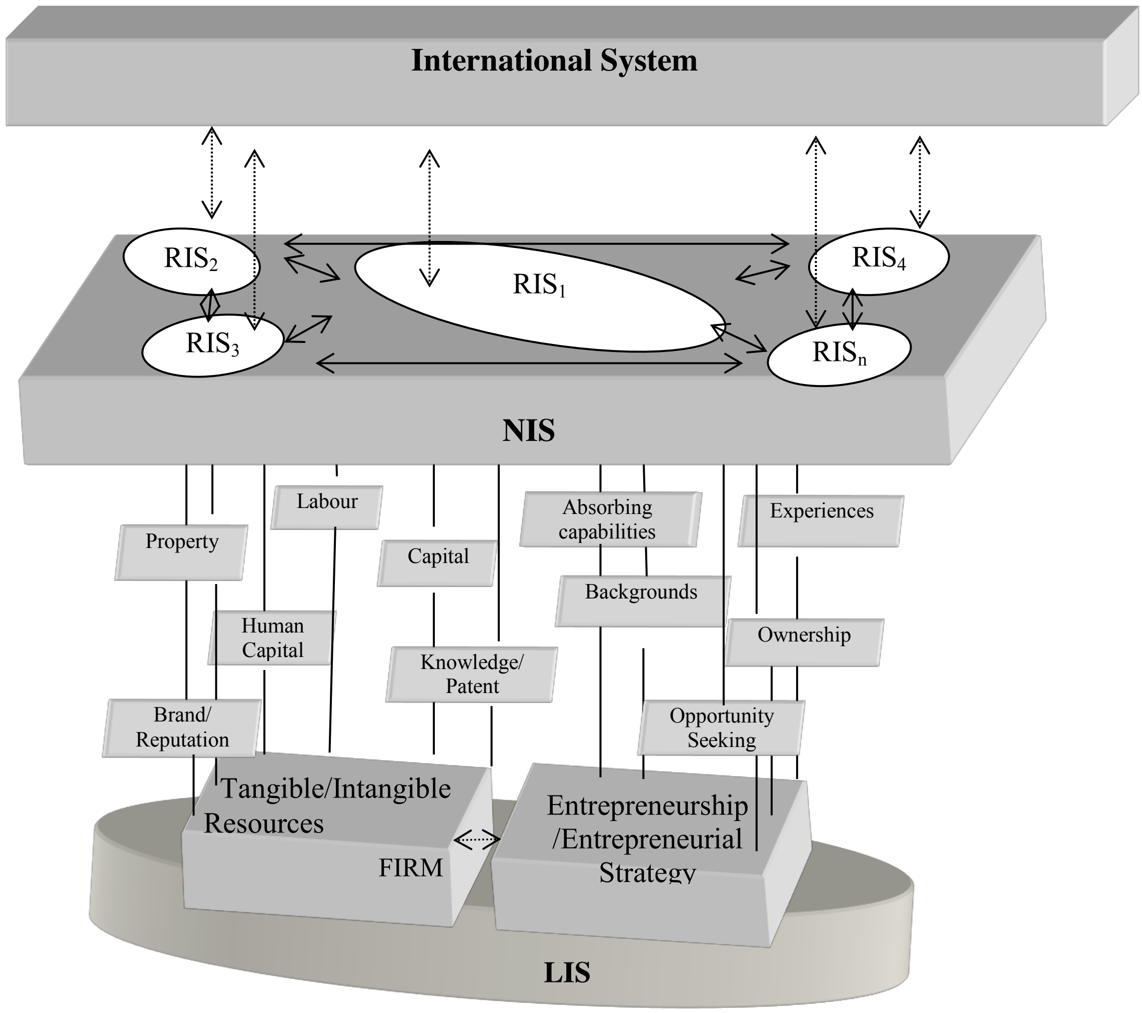

Figure 1 The relationship between NIS, RIS, and LIS

Source: the author

More specifically, the LIS is proposed as the smallest analytical unit for the IS architecture. Firms are placed at the heart of a LIS, whose innovation performance is arguably influenced by two related factors: 1) Its tangible resources, such as labour, capital and property assets; and intangible resources, such as its knowledge stock exemplified by the number of its patent, its latent knowledge that carried by its human capital, as well as its brand and reputation. This hypothesis is supported by the resource-based view of the firms (Wernerfelt 1984), which promotes the idea that firms' behavior is enabled but also constrained by their internal resources. 2) The company's entrepreneurship level, which, among others, would be affected by the company's ownership structure, past experience, and absorbing capability (Freeman and Soete 1997). This is to say that a company's entrepreneurship is partly influenced and party influencing its internal resources (Alvarez and Busenitz 2001). A company's entrepreneurship strategy, in turn, could to a great extent determine how willing the company is to get out of its 'comfort zone', how effective it is in approaching complementary resources, and how likely it is to succeed in knowledge acquisition and learning processes (Yeung 2009).

All these factors are partly supported by the company's local institutional infrastructure, and partly out-sourced by tapping into its wider regional and national systems. Moreover, because of the knowledge flow between LIS and RIS within a nation, especially those embodied in commodities and codified information, a company located in a local innovation community is engaging in and contributing to both the regional and the national innovation frameworks, which underpins the interdependence between different layers' ISs. Having said this, each IS's unique administrative power and autonomy and internal dynamics help to retain their distinctive features and influences. Beyond the national boundary, we also have the international framework, which could include the worldwide trade, investment and intellectual property agreements (Mytelka 2000), which in themselves represent a separate sphere of influence on ISs. This international environment exerts greater and more direct influence on firms now. As a result, the international institutional framework should as well be taken into account when studying the individual ISs and their relationships - though this task is beyond the scope of the present paper.

Taking this argument one step further, it can be suggested that ISs on different geographical levels will have different 'fitness' for supporting companies' innovation activities and meeting their needs, a phenomenon that has not been fully explored before. In this study, the fitness of an IS is defined by the overall innovation performance of its components in both private and public domains. Corresponding to the framework proposed here, three configurations could arguably make an impact on the fitness of an IS. Again, beginning with the case of a LIS and working upwards in the architecture depicted in figure 1, the degree of system-fitness can be described as a function of:

(1) A strong measure of proactivity and a coordinating mechanism among the components within a given level of IS. i.e., coevolution is partly a conscious and endogenous process.

(2) A strong and extensive external focus apparent in the knowledge acquisition scanning activities within a given level of IS.

(3) A high recognition gained from other ISs, being it either on the same geographical level or on different layers. This 'reputation effect' would in turn put an IS on a favorable position when building relationships with other LISs, RISs and NISs.

In order to provide a preliminary exploration of the relationship between local, regional and national level innovation systems, the paper will present China as a case study and compare the system-fitness between the different levels of China's ISs.

4. Research Methods

This paper is one of the very first attempts to investigate the system-fitness of LIS, RIS and NIS empirically against China's background. Without many established methodologies and data to rely on, the author has to make some simplifications in order to precede this investigation further.

To begin with, the fitness of different levels of ISs is going to be approached by their industry productivities but not their overall innovation activities. There are three reasons for this. First of all, the two indexes: 1) the total number of employees in industrial sectors and, 2) industrial output values, are among the few limited indexes that are available on all the three geographical levels in China. Second, the capability of the most widely used innovation indexes, such as patent counts and new product sales, is still under debate regarding their suitability in capturing companies' innovation achievement properly (Feldman 1999; Ratanawaraha and Polenske 2007). Last but not least, scholars have argued that companies' innovation capability could be, and should be, partly reflected by their economic performance (Hendry and Brown 2006). Given that the 'best index' for system-fitness is still unapproachable in China, it is preferable to use a 'good' index instead.

LIS is represented by the national-level science parks (SPs) in this country. As detailed in Miao (2012), SPs in East Asia in particular – though arguably less so in many other regions worldwide - fulfill the four-pillar framework and qualify for candidates as LISs. Specifically, there are normally clearly defined private and public actors involved in SPs' development. Their proactive networks would strengthen the identity of the whole system and lead towards significant collectivity. These closer interactions and co-movements between the various stakeholders in turn, will promote the coevolution of the whole system. Moreover, many SPs nowadays are devolved with self-organizing autonomy and power. In China for example, the SP model itself was a consequence of interactions and power rebalance between entrepreneurs and governments (Cao 2004), whose independence is expanding quickly along with China's emphases on innovation, decentralization, and marketization, (Sutherland 2005; Zhu and Tann 2005).

By 2009, there were fifty-four national-level SPs hosted by twenty-nine provinces, which are used in the following empirical analysis as a proxy for China's LISs. However, in some cases, there are multiple SPs in one province. In order to reduce the burden of data complexity and offer a concise sense of inter-scalar fitness, the data on individual SPs were agglomerated onto their regional level by using their average performance. A word of caution is that some intra-LIS differences might be concealed by these average data. Nonetheless, the purpose of this paper is to highlight the inter-differences between LIS, RIS, and NIS, so an average presentation of SPs could serve the purpose. Furthermore, the disparities between LISs within the same province were not significant statistically.

The provinces or municipalities (major cities) that host these SPs are adopted as approximations of RISs, while the NIS will be analysed by the national average data. The viability of using provinces to define the boundary of the RIS in China could be found in Batisse and Poncet (2004) and in Poncet (2005). Both authors have identified the formidable barriers in inter-provincial trading on the one hand, and the severe duplication of industry structures between provinces on the other. As a result, Poncet (2005) has concluded that China is still fragmented in its domestic market, even though the bureaucratic integration has started to impose constrains (Bai et al. 2008).

The fifty-four SPs' economic performance data in 2010 were mainly approached from China Science & Technology Statistics (STS 2011), while provincial/municipalities data and national data were available from the National Bureau of Statistics (2011). A relatively static picture portraying the system-fitness between LIS, RIS, and NIS will be presented in the next section. The preliminary findings gained from this quantitative exercise will be cross-checked by existing published literature on China's local/regional development and SPs (see for example, Hu 2007; Jon 2004; X. B. Li 2009; Macdonald and Deng 2004; Tan 2006; Zhu and Tann 2005). But more importantly, this broad-brush conclusion will be tested against the author's face-to-face survey of 138 optoelectronic companies registered in OVC[1], as well as 53 semi-structured interviews conducted between June and October 2010. Interviewees included the managers of companies, government officers on the local, regional and national levels, planners and representatives from public institutes. The statistical analysis software of SPSS 15.0 was utilized in arranging and analysing the database, whereas Atlas.ti was relied on to organize and analyse the interview and secondary data.

5. The fit between different levels of innovation systems in China

5.1 LISs, RISs and NIS in China

In order to compare the system-fitness between LISs, RISs and NIS in China, two composite indexes were calculated and plotted in figure 2: (a) Productivity comparison between regional and national level ISs, marked as RIS/NIS on the vertical axis and; (b) Productivity comparison between local and regional level ISs, marked as LIS/RIS on the horizontal axis. The multiplication between these two indexes gave us the productivity comparison between LIS and NIS.

Three reference lines are also added to figure 2 in order to interpret the results and structure the discussion: 1) The vertical line starting on the point of (1.0, 0.0) indicates the position where the LISs have the same productivity as their RIS. Any point falling on the left of this line means this LIS is less productive than its RIS, and vice versa for a point falling on the right of it; 2) The horizontal line starting at the point of (0.0, 1.0) indicates the position where the RIS has the same productivity as the NIS. Any point falling above this line means the RIS is more productive than the NIS, and vice versa for a point falling below this line; 3) The curve indicates the position where the LISs have the same productivity as the NIS. Any point falling on the upper right of this curve means

[1] These were out of the 183 identifiable optoelectronic companies in Hubei Province in 2010.

the LISs are more productive than the NIS, and vice versa for a point falling on the lower left of this curve.

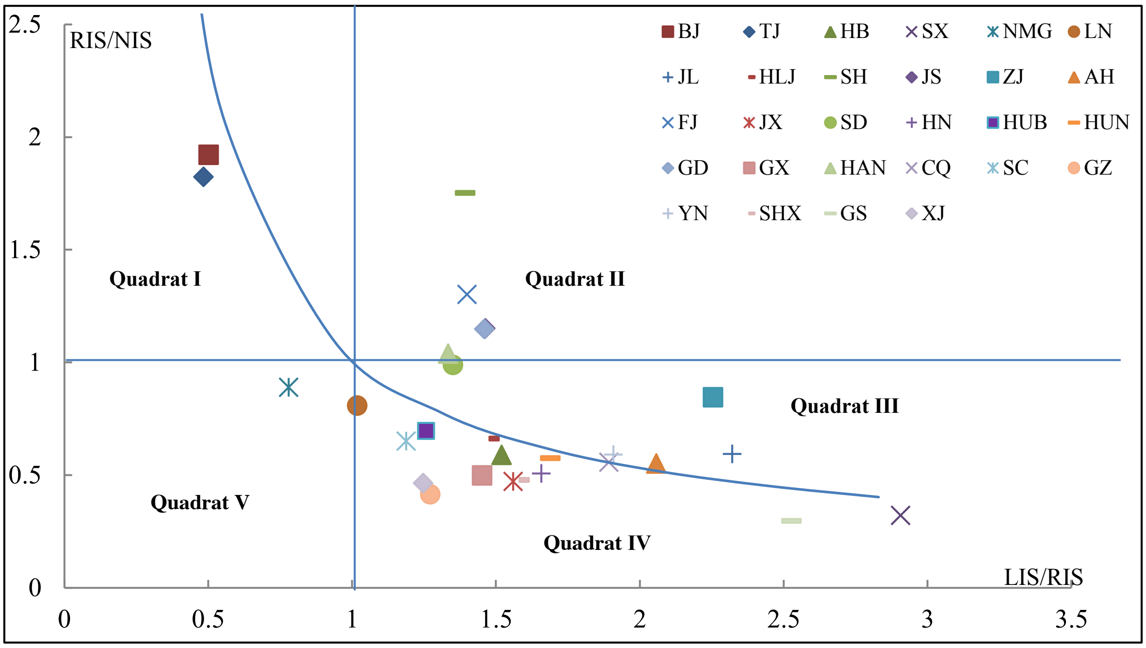

Figure 2 The relation between national, regional, and local innovation systems

Source: China Science & Technology Statistics (STS 2011) and National Bureau of Statistics (2011), compiled by the author

The patterns which emerge suggest that several initial conclusions can be drawn. First, regions falling on the upper left corner (quadrant I) are those where the RIS is more efficient than both the NIS and its LISs. Beijing and Tianjin were in this group. They are termed the 'Metropolitan scale innovative hubs' in this study. The unique feature shown by these two cases is that, their municipal scale is small compared to the typical provinces in China, but they are efficient and independent enough to coordinate the various innovation activities, which lead to a better fitness of RIS than that of their SPs. On the other hand, both cities are easiest reachable by the central government, which enables the latter to exert influence more directly and strongly. As a result, their local SPs even showed inferior productivity to the national innovation framework.

Second regions falling in the upper right corner (quadrant II) have a more efficient RIS compared with the NIS, but their LISs, represented by their hosted SPs, are the best fitted systems. Shanghai, Fujian, Jiangsu, Guangdong, and Hainan were the five regions in this category. The term, 'Bottom-up innovation regions', is coined to describe these places. A closer examination reveals that all these places are the most dynamic leading cities/regions that comprise the Yangtze River Delta and Pearl River Delta. The latter of which are the strongest economic and innovation city-regions in China in their own credit.

Third, falling in the lower right corner of this chart are most of the inland regions. These are regions in which their RIS functions worse than both the NIS and their LISs. Therefore, one could argue that it is this bunch of provinces that illustrate the value of distinguishing LIS from the regional level most strongly. In order to compare the efficiency between NIS and LISs in a region, the third reference line was needed. As it turns out, for provinces that are moving up the economic league, such as Zhejiang and Shandong, their LISs were performing better than the NIS (quadrant III). This is understandable given that these are relative advanced inland hubs in China, which are gaining power and autonomy from the central government. 4) Provinces with a slightly weaker economic base, such as Hubei in Central China, turned out to be influenced more substantially by the NIS (Quadrat IV). The favourable policies and special support given to these provinces are quite often perceived by the local authorities as crucial opportunities for their growth.

Fifth, those cases located on the lower left side of the chart (Quadrant V) are those for which the NIS is the best fitted and the LISs are the worst in generating innovation synergies. Only Inner Mongolia fell into this quadrant, which reflects its 'allocated-growth' position. As traditionally, the Chinese government has been strongly supporting the economic growth of this province, but also closely monitoring its social stability. In this regards, one could hypnotize that the provinces of Tibet and Qinghai will very likely fall into this category as well, if they host national level SPs and their data are available.

Table 1 further groups the raw data plotted in figure 2 into several different relationships between LISs, RISs and NIS. Figure 3 visualizes the emerging patterns in order to give the readers a sense of whether there is a distinctive geography to the system-fitness between ISs across a large country like China.

Table 1 Fitness comparison between national, regional, and local innovation systems

Quadrants	Features (‘>’means better fit)	Provinces
I. Metropolitan scale innovative hubs	RIS > NIS > LIS	Beijing, Tianjin
II. Bottom-up innovation regions	LIS > RIS > NIS	Shanghai, Fujian, Jiangsu, Guangdong, and Hainan
III. Established local innovation spots	LIS >NIS > RIS (upper right of curve)	Jilin, Zhejiang, Anhui, Shandong, Chongqing, Yunnan
IV. Emerging local innovation spots	NIS > LIS > RIS (lower left of curve)	Hebei, Shanxi, Liaoning, Heilongjiang, Jiangxi, Henan, Hubei, Hunan, Guangxi, Sichuan, Guizhou, Shaanxi, Gansu, Xinjiang
V. Allocated growth regions	NIS > RIS > LIS	Inner Mongolia

Source: the author

Figure 3 Fitness comparisons between national, regional, and local innovation systems

Note: 1. : RIS> NIS > LIS; : LIS > RIS > NIS; :NIS > RIS > LIS;

: NIS > LIS > RIS; : LIS > NIS > RIS

2. No data available for Tibet and Qinghai;

3. Source: the author.

Perhaps the most striking feature that emerges from this empirical investigation at the aggregate level is the huge diversity in different parts of China. As figure 3 illustrates, it seems the RISs and LISs along the coastal line were more capable in supporting companies' innovation activities. In contrast, China's NIS has shown stronger influence on inland regions and their SPs. This preliminary analysis and closer observation leads the author to suggest that, at least against China's context, the relative fitness of an IS in supporting companies' innovation activities is related in a significant way to two factors: 1) the region's economic status and, 2) its administrative autonomy or status. Referring back to section three where a more general explanation for system-fitness is offered, one could see that on the one hand, an IS's proactive coordination mechanism among its components and its extensive external linkages in seeking for knowledge could determine its economic status significantly. On the other, this IS's high reputation and recognition gained from others would influence and be influenced by its economic and autonomy status in a substantial way.

Beijing and Tianjin were the only Municipalities that had best fitted RISs. As explained earlier, their smaller size compared to China's provinces might ease the collective actions on the regional level. Regarding the performance of their LISs, if Asheim and Coenen (Forthcoming) are right, then the LISs in Beijing and Tianjin should have embedded tighter within their RISs, and thus exhibited outstanding fitness like their regions. This is because both municipalities are the leading knowledge hubs in China in terms of their basic education and training sectors, as well as their original R & D strength, which qualify them as the 'analytical knowledge bases' in China [interview: Chief Director of OVC Strategic Development Research Centre, on 10th August 2010]. The contradictory result found in this study might have resulted from the strategic position of the two cities, and particularly, their geographical proximity to the Central Government. What this proximity has led to, as pointed out by an officer from the Torch Centre – the national level management authority of SPs in China – are the defects of administrative power and autonomy for these municipal governments, because both municipalities had to bear stricter judicial procedure, lower bureaucratic efficiency, and higher responsibilities for social stability [interview: on 20th August, 2010].

The combined effect of economic and administrative power and status could further explain the opposite patterns found in the Yangtze River Delta and Pearl River Delta to that of Beijing and Tianjin. It was in these regions that the lower level ISs performed better than China's NIS. Moreover, SPs in these areas have surpassed their regions in supporting companies' innovation activities, thanks to their early-mover advantage and greater autonomy in China's reform era. The situation of Inner Mongolia contrasts dramatically with the 'bottom-up innovation regions' both in its economic base and in its administrative power and independence, due to its high reliance on Beijing's economic assistance and significance for China's national security. So the fitness of higher level ISs was found stronger than its lower level ones in this province.

The regions with the worst fitted RISs were those generally located inland, and were mainly second and third-tier regions. This finding is interesting given the aforementioned popularity of RIS argument, especially its insistence on the regional level as the most suitable meso level for organising innovation activities. Among the twenty regions failing into this broad category, two sub-groups emerged in China's context. First of all, it seems that SPs established in the vast hinterland of China have already shown a positive sign of improving the local innovation environment out of their poorly functioned RISs. This is particularly true for regions with better economic foundations, such as Zhejiang and Shandong, and for those with higher power sovereignty, such as Chongqing, the fourth municipal city in China, and Yunnan, which hosts many Minority Autonomous Regions and Districts. On the contrary, those inland regions with less-favoured economic and administrative power and status were still over-shadowed by China's overall economic, political, and institutional environment, since compared with the coastal regions, Central and West China carry more weight in securing the safety of China's heavy industry and primary industry. Therefore Beijing is much more cautious in decentralizing power to these areas (Xinhua News 2006).

5.2 Optics Valley of China, 'star' LIS amidst an innovation desert?

As pointed out earlier, the groups falling in the lower right corner of figure 2 deserve more attention, as their RISs function worse than both the NIS and their LISs and thus sit uneasily with the popular RIS School. In order to explore the features of this sub-group further, a concrete study on OVC is offered in what follows.

RIS vs. NIS

According to figure 2, Hubei was classified within the 'Emerging local innovation spots', which featured a strong NIS but poor RIS in supporting innovation activities. The inland location of Hubei has much to blame for the region's lagging innovation performance. On the one hand, China's 'staged development' strategy since its reform era had agglomerated the much needed capital along its coastal regions, which however, was largely achieved by sacrificing the vast hinterland. In the case of Hubei, it used to occupy a crucial position in China's heavy manufacturing industries during the 1950s and 1960s, when Mao's integrated growth philosophy and 'three-front' construction strategy prioritized Central and West China (Y. Li and Wu 2012). Many large national industrial projects and infrastructures were located in Hubei, especially those related to automobile, shipbuilding, iron and steel making (Si-ming 2000). Since the 1980s, however, its leading position had gradually been challenged, as both the region and its cities have been suffering from the industrial restructuring processes from heavy industries to light industries, and more recently, to service sectors. China's 'one-size-fit-all' reform in state-owned factories between 1980s and 1990s did not do much benefit to Hubei either (Lin et al. 2003), therefore a large number of state-owned factories had gone bankrupt, leaving this region with a higher than the national average unemployment rate for the past decade (National Research Database Center 2011). As recalled by the Director of Wuhan Urban Planning Bureau:

> 'Now the influence of Wuhan as industrial and commercial harbour in China has been replaced by cities like Shenzhen and Shanghai. The traditionally competitive industries in Wuhan used to be automobile, shipbuilding, and mechanical manufacturing. However, the local government arbitrarily changed Wuhan's development strategy in the mid-1980s, concentrating on sectors like services and transport instead of industries…Consequently, many traditional industries in Wuhan collapsed, and many skilled workers were unemployed' [interviewed on 13th August, 2010].

This backward economic profile was reinforced by the biased political treatment of different regions by government in Beijing. An unbalanced regional development strategy was implemented since 1978 and was expanded for the following three decades. One preferential policy – the special economic zones – in particular, has been relied on extensively by Beijing to promote the economic departure of the East. What were often brought by the status of special zones were other power devolutions in areas such as taxation, finance, export, and land usage. Fourteen Coastal Open Cities, for example, were established in 1984 (Jun 2004), followed by three Economic Open Regions (Xu and Li 1990), Hainan Special Economic Zone, and Pudong Economic New Zone. The vast Central and West China, on the other hand, were defined as the energy and agricultural supplying basements to coastal regions (State Council 1986). It was not until 1999 that West China got promoted through the 'West China Exploration Strategy', and until 2003 the Northeast was revitalized (Northeast revitalization leading team 2011). For Central China, where Hubei belongs to, however, concrete development measures were not available until September 2009, when the 'Planning for Central China Up-rising' was announced (The Development & Reform Bureau 2010). In this guideline, eight key tasks were allocated to the six provinces in Central China, such as strengthening agricultural foundation; expanding energy and raw material supply capability; and developing modern equipment manufacturing and high-tech industries. Compared to China's earlier regional development strategies, where 'do it first and test it first' was the principle, this much more concrete Central China Up-rising document could arguably restrict the initiatives of the central regions by leaving them limited leeway.

As a result of Hubei's backward economic competitiveness and impeded political support and hence administrative power autonomy, it is not surprising to find that its RIS was less fitted compared to the NIS.

LIS vs. RIS

OVC in Hubei, nevertheless, stands out as a promising LIS in terms of the proactive networks among its system components, a high level collective awareness, conscious coevolution between private and public sectors as well as substantial administrative power and autonomy (Miao, 2012). Economically, the total core industrial revenue of OVC reached 225.3 billion YMB in 2010, 43.46% of that in Wuhan and 18.15% of Hubei. There were 288 nationally approved high-tech companies, which accounted for 54.65% and 21.67% of the total numbers in Wuhan and Hubei respectively (Statistics Bureau of Hubei 2011). Its most competitive industrial sector, the fibre and optoelectronic sector, for example, contributed to 83.56 billion YMB, or 37.72% of its total revenue in 2009 (OVC 2011). There were approximately 700 companies engaging in this sector by 2010, and some of them had reached international leading positions, such as Yangtze Optical Fibre and Cable Company Ltd. (YOFC), which claimed to be No.1 worldwide in fibre manufacturing capabilities by 2010 (Shangmin 2010). In particular, this SP agglomerated a large proportion of skilled labor. For example, in 2009, there were 43,232 R & D personnel in OVC, counting for 60 per cent of the total number in its host city. In terms of industrial R & D investment, OVC figured 1.857

billion YMB in 2009, amounted to 29 per cent of Wuhan's total amount (OVC 2011; Statistics Bureau of Wuhan 2011). Among the twenty-one higher education institutes (27% of those in Wuhan), fifty-four research institutes (85.7% of those in Wuhan), and ten state key research laboratories in OVC now, Wuhan Posts and Telecommunications Research Institute (WRI) and Huazhong University of Science & Technology (HUST) take the most crucial roles in fostering the development of optoelectronic industry, and paving the knowledge foundation for OVC.

In terms of administrative power and autonomy, although this SP announced its establishment in 1983, it was only in 2000 - when the first National Optoelectronic Industrial Base was assigned to this SP - that OVC gained on attention from both the regional and the national level authorities (Miao and Hall 2013). Taking this title seriously and aiming to turn OVC into the growth pole of the while province, Hubei devoted extensive economic and governance autonomy to this SP ever since. In April 2000, for example, the newly elected Hubei Government set up the 'OVC Construction Leading Team', headed by the Deputy Secretary of Hubei Province and comprised of many top officers from the provincial government (Ying and Li 2000). The power structure of OVC was therefore organized in a way that surpassed the city's level and incorporated directly under the provincial government (fig 4). In other words, this embryonic LIS had been upgraded above the rigid bureaucratic system onto a higher-level management system, which stimulated its economic dynamic and innovation performance significantly [interview: Deputy Director of OVC Economic Development Bureau, 27th July 2010].

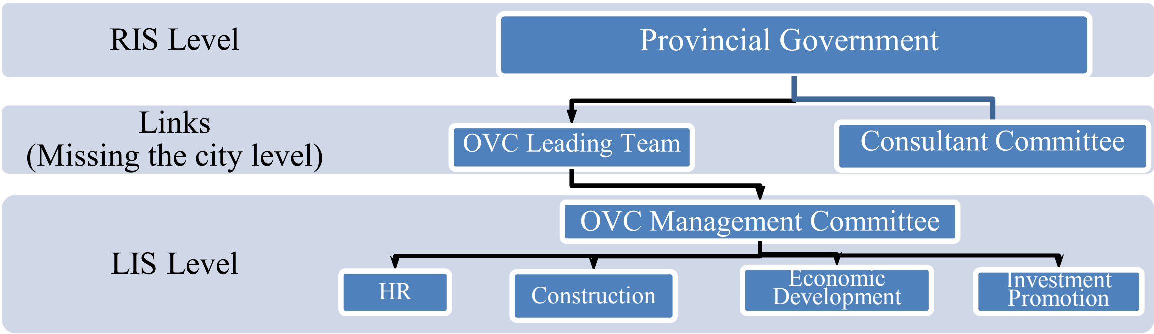

Figure 4 Management structure of OVC since 2000

Source: the author

As a result of OVC's robust economic development and greater administrative autonomy and status, a higher recognition and positive awareness of this LIS, as compared to Hubei's RIS, has become noticeable, which was confirmed by the surveyed companies. Figure 5 below, for example, shows the result of a survey question asking for the consent level of the companies to a series of statements. A five point Likert scale was adopted, and a score of '0' means least agree and '4' means totally agree. The results indicate that the relatively advanced position of OVC as a LIS within China was the most agreed-upon statement (average scored 2.28), which was closely followed by companies' awareness of locally-based cooperation opportunities (average scored 2.12). In comparison to companies' confidence in OVC, many surveyed companies were not convinced by the statement that 'Hubei holds a leading investment environment in China' (average scored 1.72). Nevertheless, there was a wide agreement on the crucial role of the Central Government on completing the function of Hubei's RIS. The strategy of 'Central China Up-rising', in particular, was mentioned by both the R & D Director of YOFC [interview: on 31st June 2010] and the CEO of a laser company [interview: on 9th July 2010] as the cornerstone for Hubei, and especially for OVC's accelerated growth. This persistent influence of China's NIS in Central China also shed light on the relationship between OVC as a LIS and China's NIS, as will be discussed next.

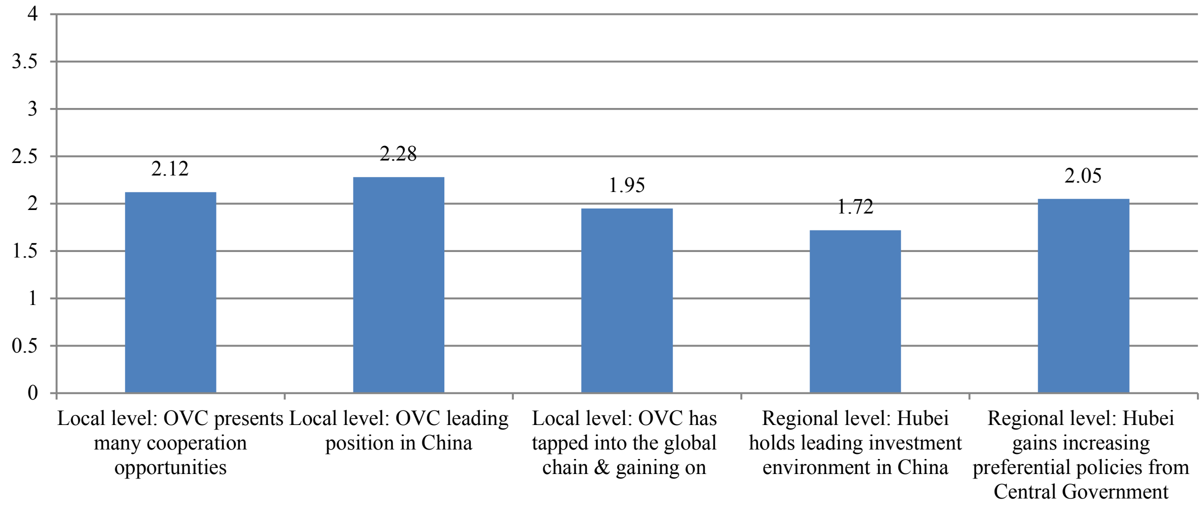

Figure 5 Agreement of companies on the relative system-fitness of LIS and RIS

Note: 1. 0-Not agree at all, 1-Less agree; 2-just so-so, 3-agree a little bit, and 4-totally agree;

2. Source: the author

LIS vs. NIS

Table 2 below summarizes the 2009 economic performance of the 138 optoelectronics companies surveyed by the author with data on: the OVC average; the industrial sectors of Hubei Province on average, and; the industrial sectors of China on average taken from published government statistics. The data for the last two indexes were only available for companies above designated size, which implies the results could be biased towards the upper end. Comparing the five economic indexes, it would be seen that in general, the economic performance of OVC indeed fell behind the national-level science parks and National industrial sectors on average. But its performance was comparable to that of Hubei. Moreover, the surveyed optoelectronic companies in this study surpassed OVC, the national-level science parks, and the national average industrial performance by a substantial margin, which might infer that a dominant industrial structure is emerging in OVC and supported by its wider institutional settings. The CEO from a laser company commented that:

> 'The Management Committee of OVC functions as a powerful umbrella for the local laser companies, which could be perceived as a local advantage....but it might as well hamper the market competitiveness of companies…This is one of the fundamental reasons why the majority of the laser companies in OVC cannot grow big enough and occupy larger market shares as compared to those in Shenzhen and Shanghai, as the latter have to compete fiercely on the market without many protections from the government' [interview: on 9th July 2010].

Table 2 Summary of companies' economic performance in 2009

Index (Million YMB)	Surveyed companies					OVC AVE[1]	Hubei Industry[2]	SP AVE[3]	China industry[4]
	N	Min	Max	Med	AVE				
1.Revenue	138	0.0	10241.	9.28	216.0	103.07	95.19	146.59	123.43
2.Industry product	138	0.0	9211.7	8.74	216.6	90.04	96.65	113.89	126.26
3.Profit	138	-198.16	448.46	0.02	11.16	6.04	6.78	8.32	7.95
4.Added value	138	0.0	1777.4	2.80	50.30	30.41	32.18	28.71	31.14
5.Export (Million	138	0.0	270.96	0.0	5.58	1.15	0.62	3.74	2.62

Note: 1. OVC AVE: the averages performance of OVC companies, from OVC (2011);
2. Hubei industry: average performance of industrial companies in Hubei above designated size, data from National Statistics Bureau (2013)
3. SP AVE: the averages performance of the 54 national science parks, data from STS (2011b);
4. China industry: average performance of industrial companies nationwide above designated size, data from National Statistics Bureau (2013).

Therefore it seems the intervention of the local government does not necessarily move in line with the needs of a functioning LIS, which is partly to blame for the moderate economic success of OVC. This economic performance further reinforced OVC's relatively humble administrative power and status within China. This observation could be justified by comparing Zhongguancun SP in Beijing, Zhangjiang SP in Shanghai and OVC, which are the three Self-Innovation Model Zones in China by now. It was found that for Beijing

Zhongguancun SP, it was hand-picked as the first science and technology reform pilot in 1988, and later promoted as the first Self-Innovation Model Zone of China in 2008. For Zhangjiang SP, its host – Shanghai Pudong New Zone – was promoted as the first Comprehensive Reform Area in 1980, and itself was easily lobbied as the third Model Zone in 2011 [interview: an engineer from National Optoelectronic Lab on 12th August, and Officer from the Torch Center on 20th August 2010]. Their easy upgrading in administrative power and status thus contrasts dramatically with OVC, who had to wait eight years to be acknowledged as a national level SP, and at least two years to prepare and lobby for the title of Self-Innovation Model Zone (refer to Miao and Hall (2013) for a more detailed account). The combined effect of modest economic performance and lower autonomy status has arguably resulted in OVC still under the shadow of China's NIS, although it has shown promise in supporting innovation activities more effectively than its host RIS.

6. Conclusion

This paper sets out to consider the relationship between NIS, RIS and LIS. Previous studies on the relationship between ISs on different geographical levels tend to adopt one of the two assumptions: competitiveness or embeddedness. However, it is argued in this paper that both viewpoints are too simplistic to capture the complex relations between them. A more realistic hypothesis is that, these ISs are neither head-to-head competing with each other, nor perfectly inlaid or nested. What has been presented here is a framework in which different levels of IS are partly independent and partly embedded with each other. What is more, since each layer's IS could function individually to some degree, a following-on hypothesis is that, the systematic fit or synergy between different levels' ISs could vary as well.

This speculation has been tested by comparing the productivities of the different levels' innovation systems in China. As it turns out, provinces in China have clustered into five sub-groups. While the coastal regions generally had a better fitted RISs and LISs, the hinterland regions were largely over-shadowed by the influence of the NIS of China. Nevertheless, the SPs in these hinterland regions have built on their synergy as fertile land for companies' innovation activities, mainly thanks to their greater administrative power and autonomy devolved from the higher level governments. All in all, this study identified that a place's economic strength and administrative power and autonomy are among the most crucial factors that could impact the relative fitness of ISs on different geographical levels. The rule of thumb is that, the stronger a place's economic foundation is, and the greater administrative independence it enjoys, the more likely its lower level ISs are more active and productive.

More thorough studies, however, are needed to explore the role played by the knowledge base in the relations between ISs, and in particular, the interface between knowledge, economics and power on ISs' fitness. Related, more rigorous indicators for evaluating ISs' fitness and their relations are required, if robust findings are to be obtained. In the case of China, it would be very interesting to explore further the different spatial dynamics uncovered in the paper, looking into the underlying reasons for the diverse performance of NIS, RIS and LIS in different parts of China.

Finally, this paper run short of space in exploring the manner in which the efficacy of NIS, RIS and LIS are related to aspects of the international business and regulatory environment. This international environment can hardly be considered as having a sufficient territorial coherence to represent an international IS as such. Yet the patchwork of international and continental business regulation relating to trade and investment, intellectual property, standards and the like clearly impacts the effectiveness of NIS, RIS and LISs. This is a topic that deserves future research within the IS theory tradition.

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