

Knowledge workers and regional innovation in China's ICT sector

Introduction:

China's growing influence in the world of commodity markets marks the most important development in international business over the last decade. Yet a central issue concerns whether China is on course to match the levels of technical sophistication of the world's strongest economies, as optimistically signalled by the Chinese government's target to become a global economic power by 2049, or if the economic power-house that has been China will run out of steam. The debate is intriguing, for highly authoritative and respected academic and practitioner literatures appear to hold very different views on the subject.

There is an optimistic view that points to enormous S&T infrastructure, with over one million people employed in R&D (China High-Tech Industry Data Book, 2004). By 2015, 90m people studying diplomas or degree subjects, probably 20m of these engineering graduates. Zhou and Leydesdorff (2005) through their study of research citations argue resolutely that China may be achieving the transition to a knowledge-based economy more quickly than Western counterparts. They point out that more than 4400 science and technology journals were published in China 2001 with particular strength in areas such as nano-technology.

There is also a view that, as a newly industrialising country, China has the ability to leapfrog the advanced capitalist countries (ACCs), because there are no vested interests to protect and no existing businesses to cannibalise. In the words of Laurence Lau of Stanford University there will be 'creation without destruction' due to the IT revolution. (Nolan, 2001, p212). Indeed, there does seem to have been some significant success stories in China's economic development, with the growth of a strong, internationally competitive information and communication technology (ICT) sector. A study of Lenovo, Stone and Founder, three leading Chinese ICT firms, found that they not only imitated Western technology but successfully innovated new products and processes. Their approach was a reverse of the conventional model of technology acquisition by developing countries, where technology acquisition often starts from labour intensive assembly and only much later, if ever, reaches a point of indigenous design (Lu, 2001, Leonard-Barton, 1995).

Nevertheless, important question marks have also been raised about the Chinese model of high technology. Although the size of the S&T base is impressive, with the possible exception of integrated circuit design and semiconductor fabrication, the productivity of the ICT sector lags far behind the advanced capitalist countries (*China Economic Review*, 2005). Moreover, although high tech exports expanded 15 times in dollar terms between 1991-2001, and have continued to expand since, most of these exports have been from multi-national corporations with local operations. Furthermore, many of China's high tech products do not possess independent intellectual property rights, especially in critical technologies (Cao, 2002). According to Nicholas Lardy of the US Institute of International Economics, only 15% of the value of China's exported electronic products are domestic value added, suggesting that the country remains a mere assembler of high-tech products. Although gaming

software is more advanced than in the West, capable of supporting hundreds of thousands of players simultaneously, there is an acute shortage of software engineers available to commercialise this advantage. (*China Economic Review*, 2005). High-tech development has made a significant contribution to Chinese trade. However, these products are located at the bottom end of the high tech value chain, and firms are negatively impacted by upstream changes in standards, specifications etc, beyond their control.

Although it may be somewhat injudicious to compare China's current level of economic development with the richest countries, an analytical approach that investigates the degree of specialisation, diversification and in particular learning in the Chinese innovation system is called for. To this end we begin the discussion by highlighting three inter-related and distinguishing features of the Chinese innovation system that will play a key role in its development and may suggest a particular analytical focus. Firstly there is the size and particular history of the science and technology infrastructure of China, including the importance of high-class universities and the Chinese Academy of Science as a source of knowledge¹. In 2000, China became the world's eighth largest contributor to academic journals in science and technology, with nearly 50000 papers listed in *Science Citation Index, Engineering Index and Index to Science and Technology Proceedings*. This totalled 3.5% of world output, a 7.5% increase on the previous year. In basic science output, China was ranked 8th in the world by *Science Citation Index*, up from 15th five years previously.

Secondly, there is the role of regional parks in China's innovation industry. In 2000, industrial products from high tech parks accounted for 25% of China's value added output and total income from them in 2001 was 13% of GDP. (*Keji ribao*, January 22, 2002, quoted in Cao, op cit). According to official figures, the science parks that the government has been creating contains three quarters of all high tech firms in China, employing close to 4 million people. Given the dominant position they have achieved, understanding how the internal dynamics of science parks have influenced the development of the ICT sector is clearly important.

Finally, in the context of the knowledge economy, China's comparative advantage surely rests on its vast pool of skills and talent for the growth of its creative industries and as a source of disruptive innovation. In terms of its S&T skills, the number of scientists and technologists in China ranks only after the USA, Japan and Russia, with 2 million listed, nearly half of whom were working in R&D (China Statistical Yearbook on Science and Technology, 2001). Florida (1995) argues that those cities and regions that are able to attract talent, skills and creative occupations through strong educational institutions and/or immigration will have greatest potential for growth. The historical example of the US is the prime example of a country that has been able to regenerate its economy through waves of new talent.

This paper discusses the evolution of Chinese innovation system by discussing the changing relationship between the labour markets of knowledge workers, the regional innovation systems and the science and technology infrastructure. The paper is developed along the following lines. Firstly, the debate around regional innovation clusters is discussed, particularly in relation to the role of knowledge workers as key agents of knowledge transfer. The following section suggests that while China's innovation capability has developed extraordinarily quickly, further growth in some areas will require "new economy" advantages that rely on greater levels of flexibility, diversity and responsiveness to innovation trends. This will be followed by a

¹ Tsinghua university alone has been home to some 160 businesses.

discussion of the evolution of scientific labour market structures in China and the degree to which they are influencing the ability of firms to develop innovation breakthroughs in the context of Chinese regional parks. As part of this discussion, results from five case studies of high technology firms in the Zhongguancun park are discussed.

Regional agglomeration effects and epistemic communities

The optimistic premise upon which the Chinese authorities set up innovation parks through all of China's regions was inspired by Silicon Valley, although the literature commenting on regional agglomerations goes back at least to Marshall (1920) who identified four advantages to localized clusters, including hereditary skill and growth of subsidiary trades. Contemporary explanations for the existence of positive relationships between firm performance and sector dynamics tend to fall between market led explanations and non-led market explanations.

In terms of the former, when accounting for the wealth of nations Porter argued "competitive advantage is created and sustained through a highly localized process" (1990, p19). The systemic character of production and knowledge generation often means that the most sophisticated buyer of wholesale products and services creates a range of other sophisticated suppliers, which in turn help to create a competitive cluster. As groups of firms invest in related technology, information resources and human resources, so spillovers occur and the competitive industry becomes more than the sum of the parts.

The argument that specifically geographical concentrations of firms accelerate the development of knowledge generation is more contentious, partly because of the sharp differences that exist across industries and regions in how and how well clusters actually work. Where successful regional clusters exist, it is argued that these regions become a hub for suppliers, often sophisticated customers and information flows Porter (1990) while a concentration of rivals, customers and suppliers will promote specialization (O'Sullivan 1981). The main effect of proximity is that firms and institutions notice each others rivals, universities and firms and this will encourage a response and transmission of information is maximised. The geographic concentration attracts talented people while spin-offs tend to locate near to mother companies, further reinforcing the cluster. These points are largely uncontroversial, more controversial is the argument that regional clusters can encourage greater firm level efficiencies through agglomeration economies.

Here authors have been forced to seek essentially non-market explanations that seek to find the mechanisms by which learning takes place. Breschi and Malerba (1997) for example argue that the more knowledge in a system is ever changing, tacit, complex and part of a larger system, the more relevant are informal means of knowledge transmission and the more sensitive to distance among agents. Maskel and Malmberg (1999) similarly argue that the existence of dynamic clusters strengthens the competitiveness of firms inside the cluster through interactive learning and that knowledge creation is supported by the institutional embodiment of tacit knowledge. In other words, the formal and informal institutions that can be created where there is physical proximity allow transfer of tacit knowledge to be facilitated and there is evidence that a certain interchange of tacit knowledge does take place at local level (Nelson 1987).

Recent literature focussing on organisational performance in clusters have however begun to question the assumption that organizations located in a cluster can in some way "learn" from others by having access to their tacit knowledge. This critique

is borne, not least by the fact that some empirical evidence in the developed capitalist shows there is little correlation between location and firm performance. Hakanson, (2005) in particular argues that the outstanding performance of some clusters occur not as a consequence of superior access by organizations to tacit knowledge, but fundamentally because of the existence of new firm formation from spin-offs and “epistemic communities”, with the access and exploitation of key information by members of these communities that this entails. Most new firms are set up by people who have gained experience working in the same or related industries. It follows, according to this argument, that the activity of most new firms will be related in some way to that of existing ones and the process of new firm formation can be seen as one of gradual specialisation, the rate of which is determined by the growth of the market and by perceived technological opportunities. The result of this process is the emergence of regional production networks characterised by vertical and horizontal disintegration for a region, which avoids the dangers of lock-in and asset specificity (Storper, 1992). This, it is argued, rather than the higher than average performance of firms is key. It is further hypothesised that this argument is especially valid for high tech clusters, where rapid technological change and uncertainty drive spin-off formation. Spin-offs, which are often set up to introduce innovations, can be seen as a ‘bet’ on a particular technology (Audretsch, 1995), and regions with more ‘bets’ will be more resilient than those dominated by vertically integrated firms.

These views have quite different policy implications. The former argument suggests encouraging the formation of high technology clusters with opportunities for networking, from which it follows that successful and efficient firms will emerge, the latter argument will encourage entrepreneurs and epistemic communities and “old economy” economies, with less emphasis on location and firm networking.

Bringing labour into the regional innovation analysis

Our understanding of the relative validity of both arguments can be understood better if the mechanisms by which knowledge transfer and learning take place are further developed. In both arguments that were presented above, the key agents of learning are the individuals that live and work in the cluster, acting not so much as discrete individuals, but by undertaking problem solving activities within firms and/or within epistemic communities more generally.

Surprisingly few models, frameworks or methodologies exist that specifically operationalise how the labour markets of knowledge workers can impact learning capability of individual firms. Perhaps the most cited contribution is Saxenian’s (1994) detailed discussion of the success of Silicon Valley and Route 128 in Massachusetts that focuses to a great extent on the distinctiveness of clusters, as expressed by the culture of openness in the region, a diverse industrial structure including the existence of specialised services and a specific form of firm organisation based on horizontal coordination. The strength of Silicon Valley, argues Saxenian, was initially based around its professional network rather than any specific firm. Key dimensions here include high labour mobility and professional links that are underlined by cultural factors such as loyalty to a network and craft rather a firm (ibid). Arthur and Rousseau (1996) furthermore argue that during the late 1980s and 1990’s, as industrial structures came under pressure to change so greater emphasis was placed upon “boundaryless careers” and “open labour markets”, where regional learning is underpinned by high rates of labour mobility and career paths are built around participation in local networks (Best, 2001). Indeed, breaking down traditional corporate career trajectories,

it is argued, has been a key element in creating a regional entrepreneurial drive (Saxenian 1996).

Closely interrelated with mobility, skills and career institutions of knowledge workers, lie the existence of networks of knowledge workers as a central plank of knowledge transfer. Building on Granovetter's (1973) dense networks, Grabher (2004) in particular develops a typology of individual networks (communal, sociality connectivity) that are judged according to variables such as experience and reputation that can straddle different intensities of relationships, levels of trust and modes of interaction. Approaches of this nature promise to help understand the mechanisms by which communities in clusters can impact firm level performance, although as yet very little empirical work has been undertaken to established relationships between formal and informal labour institutions and innovation performance outcomes. The case of Silicon Valley is of course very specific to the US ICT sector, and there are a number of highly successful clusters that do not demonstrate such levels of openness. The more general point here is that an analysis of different aspects of labour market structures of knowledge workers underpins regional agglomerations.

Following Carlsson (2002), we argue here that the key elements of a system of innovation are its dynamic properties. These consist of its diversity (as a measure of robustness), its flexibility, that we will interpret as a measure of the ability of entrepreneurial firms in the system to develop dynamic rather than static capabilities (largely a function of core capability) and the system's responsiveness i.e. the ability to generate and respond to change. In table 1 below a series of specific labour market dimensions that have been discussed are listed, the first three focussing on new economy features of learning, the final variable to more firm specific elements of learning. We mark where each labour dimension may be of particular relevance to a region's dynamic capabilities.

Table 1: The influence of labour markets of knowledge workers on cluster dynamics

	Inter-firm mobility of labour	Open labour markets to encourage different career routes, ex specialised services	Existence of networks of knowledge workers and epistemic communities, especially with universities	Firm level learning through team work, training and inter departmental knowledge sharing
Ability to generate and respond to change in environment	X		X	X
Flexibility		X		X
Diversity (robustness)	X	X	X	

Inter-firm mobility of labour is associated with the existence of opportunities for individuals to move in search of new employment openings as they arise. At a system level, the existence of occupational type labour market institutions, such as recognised industry qualifications is most likely to encourage the matching of new jobs with relevant skills OECD (2001), thereby improving the ability of a system to respond to

new challenges or indeed generate a change in the environment. Mobility may also be an essential element in attaining diversity of knowledge sources. Often the existence of intermediary institutions, such as specialised contractors and employment agencies can facilitate the mobility process.

Open labour markets refers to the ability of individuals to develop alternative career options and experiment with different career options that derive from their participation in networks (Saxenian, 1996). These are essential for underpinning networks, spin-offs and the creation of new service functions and other entrepreneurial activities that are increasingly important for achieving diversity of knowledge sources. Open labour markets, we argue, will be essential to establish diverse sources of knowledge within a region, thereby increasing the attractiveness of movement into new career opportunities. Similarly they will be essential in underpinning new firm formation.

The existence of networks and how professional and inter-personal networks function have been referred to as key sources of information. As search mechanisms for the firm, the involvement of staff in external networks can be essential for finding out about new technological threats and opportunities. Similarly, the ability to tap into networks can increase the range of sources of knowledge, allowing a more diverse range of knowledge sources.

Finally, internal firm specific routines that rely on training, internal mobility and horizontal type structures have been well documented in the literature as increasing the innovative potential of the firm and dynamic capabilities of organisations. Similarly, we argue that responsiveness to the environment is partly a function of the achievement of flexible competencies within the individual firms of a system. In the following section we develop the discussion with respect to innovation in the Chinese system of innovation and more specifically the Zhongguancun Science Park.

Universities, science parks and the development of the ICT sector in China

The process of change in the Chinese S&T structures began in 1985 with the publication by the Central Committee of the Communist Party of the resolution on structural reform of the science and technology management system. These market orientated changes have continued, empirically driven, ever since and are summarised in Table 2

Table 1 S&T sector policy development 1985-present.

Period	Policy aim	Policy actions
1985-1991	Establish links between S&T sector and enterprises	<ul style="list-style-type: none"> • Introduction of competition between bodies for R&D funding • Reduction of government grants to encourage co-operation with industry • Creation of a technology market for S&T body outputs • Promotion of institutional autonomy and mobility of staff. • Beginning of merging of R&D institutions into enterprises • Promotion of spin-off enterprises
1992-1998	Establish industrial R&D institutions as commercial bodies	<ul style="list-style-type: none"> • Granting of comprehensive economic autonomy to R&D institutions • Promotion of spin-offs by creating science parks and incubators • Continuation of merging strategy
1999-present	Complete transformation of industrial R&D institutions	<ul style="list-style-type: none"> • Completion either of merging of industrial R&D bodies into enterprises, or transformation into non-profit organisations or incorporation into HEIs.

Sources: Gu (1995), Suttmeier and Cao (1999), Liu and White (2001), Liu and Jiang (2001), Cao (2002).

Of the priorities that have endured from the transformation programme, the most important is placing the enterprise at the centre of the innovation process. The others are promoting links between industry and academia and encouraging mobility of staff between the bodies concerned with innovation. Some initiatives such as creating a market for technological outputs proved difficult to implement (Lu, 2001).

According to figures from the Ministry of Science and Technology in 2004, enterprises account for 61% of GERD (Gross Expenditure on R&D), the remainder taken up by S&T institutes and universities. This therefore appears to represent a big step to achieving enterprise based innovation, although there is some doubt about the reliability of the statistics. The merging process was slow partly because the new merged body had to meet very heavy social costs linked to pensions, housing etc. (Suttmeier, 1997). In the period 1998-2003, patent applications increased 10 times, although this explosive growth was unbalanced, focussed in three regions only, Guangdong, Jiangsu and Tianjin. This may be significant since patent data could give an indication of innovative activity in firms (Ernst, 2001).

After more than 20 years of reform there is little doubt that some indigenous Chinese companies have been highly successful. Chinese ICT companies such as Huawei and Great Dragon have captured more than half of the telecom market in direct competition with NEC, Motorola and Alcatel. Lenovo (formerly Legend) has been the PC market leader since 1996, also in competition with international companies such as IBM and Compaq. Stone, a software manufacturer, has 80% of the local word processing market and Founder has become one of the world's leading developers of colour high-resolution electronic publishing systems. There are other anecdotal indications of competence in specific areas. Michael Walker, the head of research at

Vodafone, the world's biggest mobile phone company, stated at a recent meeting organised by the DEMOS thinktank in London that despite a weakness in basic research and highly suspect claims of R&D activity from indigenous companies, Chinese ICT companies had shorter lead times in terms of bringing innovations to market compared with their Western counterparts and that the skills of Chinese engineers were no inferior than those of their Western counterparts.

However, despite the early explosive growth of indigenous Chinese ICT enterprises, question marks have increasingly begun to appear over the ability of indigenous Chinese enterprises to sustain high levels of growth and in particular to achieve world leadership in definable areas. For example, a study of the software industry by Saxenian (2005) claimed that it was still in its infancy, characterised by a lack of technical skills, experience, management know-how, functioning capital markets, transparency and legal protection. In this sector it was concluded that the goal of the Chinese Communist Party (CPC) since 1978, to shift from a planned to a market economy, had only been partly realised. Two non-market factors, government and *guanxi* (literally translated as connections) continue to affect most aspects of the software industry, with firms dependent on government for contracts and other connections necessary to conduct business. How far this status quo will withstand WTO accession it is still too soon to judge. The discussion however suggests that at least in the more developed regions that border the Pacific Ocean, the achievement of sustained growth requires the adoption of systemic characteristics that go beyond one-off breakthroughs that may have been achieved when China's ICT economy was still in its infancy. For the latter, dynamism, responsiveness and entrepreneurial firms that show flexible capabilities are required. In this context we turn to attention towards the nature of regional systems and the evolution of labour markets.

Regional innovation and the development of the Zhongguancun science park

When it launched its programme to harness S&T using market methods in the 1980s, the CPC sent a delegation to the USA to study Western approaches to commercialising R&D. As part of this fact-finding mission, officials visited Silicon Valley in California and the high-tech area in Massachusetts based around Route 128, where explosive growth was driven by a rapid proliferation of spin-off companies.

In an attempt to emulate the perceived success of the Silicon Valley model, in 1988 the State Council designated China's first national high technology development zone in Beijing and encouraged other cities to prepare to develop their own zones. The area was called the Beijing Experimental Zone (BEZ) for new technology industries in the north west of the city, near Zhongguancun street, known commonly as the Zhongguancun (ZGC) Science Park, where there is a very high concentration of Universities and research institutions. Since then, spin-off companies in the Park have become some of the best known in China, such as the Founder Group of Beijing University, the Tongfang group of Tsinghua University and Lenovo (formerly Legend) spin off from the Institute of Computer Technology of the Chinese Academy of Science. There are now 14,000 companies, employing nearly 500,000 knowledge workers (Interview with ZGC Administrative Commission, June 2005). ICT is the dominant industrial sector in ZGC (70%), but there are also other significant players in bio-tech, advanced materials including optics and nano-technology (Wang, 2000). The Commission is the prime regulatory framework for the Park and is responsible for licensing, taxation, international trade, finance and investment, employment and intellectual property rights, as specified by national policy (Gu,1996).

In 1991, 26 zones in other cities were selected and designated as national high technology zones (Wang et al, 1998). The prime catalysts of growth in these areas were high-tech spin-off ventures, sometimes called New Technology Enterprises (NTEs), which grew rapidly to 900 by the mid-nineties, if the companies linked to the Chinese Academy of Science (CAS) are included. The NTEs were strongly promoted by the state because they served four of the objectives of the S&T sector changes that had not been significantly achieved by other policy initiatives. These were to find new sources of revenue for research institutes, to reduce manpower in the state R&D system and to find ways to commercialise research results and innovate new products. The fourth objective was to promote staff mobility and by implication create a flexible labour market for knowledge workers. For their part, research institutes and higher education institutions had a strong incentive to establish profitable spin-offs to finance their core activities, because their budgets were being progressively squeezed as a result of the new government S&T policies. The success rate of these high-tech start-ups was reported in the late 1990s as 10%, which is comparable to the figure found for similar Western ventures. The NTEs typically were established and owned by public sector research institutes, often linked to the CAS, or by universities (Suttmeier, 1997), which although owned by public sector bodies they were run as private companies (Lu, 2001).

If we focus more specifically on the distinctive characteristic of the ZGC science park in Beijing, firstly there is a preponderance of a highly skilled community both in the academic and non-academic field. Within ZGC there are 68 key universities and 213 scientific research institutes, including the Chinese academy of sciences (academics of the Chinese Academy of Sciences and Chinese academy of engineering comprise 36% of all academics in China (Wang 2000)). Approximately 25% of the population in the region, some 360,000 people, have higher education qualifications. Moreover, the so-called “electronic street” in Zhongguancun is the largest collection and distributing centre of electronic products in Northern China and in 1998 the area accounted for 43% of total software sales in the country (ibid). Firms also have a direct financial incentive to set up in the park, they pay 15% tax, just under half of normal, and newly certified entrants get their first three taxes waived and get half tax reduction for the subsequent three years. This provides incentives for firms to stay for at least six years. There are also requirements for companies that want to set up in the park. At least half of all revenue must derive from high technology products and R&D expenditure must account for no less than 3% of total revenue.

The explosive growth that occurred in the park during the 1980s and early 1990s coincided with a period in which the Chinese government liberalised the economy, but kept foreign companies from directly selling and serving their products in China. Chinese companies therefore took advantage to establish their own sales and service networks and brands, as well as acting as platforms for the sales of overseas products. The recent years however have forced firms in ZGC to face new challenges. Firstly, with the entry of China into the WTO and the general policy to attract FDI, Chinese enterprises compete directly with overseas companies in the consumer market. Official government statistics for the whole country show that 15% of firms in science parks are overseas owned, but they make up 42% of value added, while the 46% of “share holding firms” i.e. indigenous public listed companies contribute only 40% to valued added. Of concern is the fact that the recent surge of economic growth in the late 1990s and early part of the new century appears to have largely by-passed Beijing and focussed largely in Guandong, Jiangsu and now Tianjin. Although it still has the

highest R&D expenditure, Beijing is now only the 5th biggest exporting region for high tech goods and the increase in valued added in high tech industries also completely by-passed Beijing in the early part of the decade beginning in 2000 (China High-Tech Industry Data Book, 2004)

Clearly all geographical clusters pass through different stages of development and it is particularly relevant to underline the point that founding a firm in a new cluster is a very different activity than founding a firm in a mature cluster (Bresnahan, 2001). The argument is made that external effects only tend to come in the mature stages of a cluster. The driving force for the success of ZGC in the past undoubtedly were the spin-off ventures from the academic institutions. Beijing University, Tsinghua University and the Chinese Academy of Sciences have been central in launching the most important firms in the park. Lenovo was established by the Institute of Computing Technology of the Chinese Academy of Sciences and Founder's original capital was provided by Beijing University. Many of the leading Chinese telecom companies were similarly spun-off from state R&D institutes (Gao and Xu, 2001). This would suggest that the existence of scientific entrepreneurs, the "star scientists" that Zucker (1995) refers to that combine scientific and entrepreneurial knowledge were the key agents of entrepreneurial drive in the region. The existence of high skilled labour provided the necessary impetus, although, unlike most ICT based clusters that exist in the West, the main demand was not from US multinationals but the burgeoning domestic consumer demand from the State and the burgeoning domestic market.

However, both interviews with science park officials and with directors from companies in the park carried out in 2005, suggest that the high level of reliance on universities is now declining and there is a move to distance commercial companies from university ownership. This is no doubt an attempt to establish managerial autonomy for commercial enterprises and break the reliance of universities on income from commercial activities. Furthermore, a speech in 2005 by Liu Zhihua, Vice-Mayor of Beijing, further suggested that the emphasis now is less creating new firms, than linking up with overseas ventures, enhancing a greater culture of cooperation for the commercialisation and development scientific ideas, developing managerial competence in existing firms and encouraging returning overseas postgraduate students to set up in the park (www.zgc.cn).

This would suggest that there is a realization that a diversification of knowledge sources is required, with greater attention paid to inter-firm learning and management skills, which can be facilitated by the existence of specialised expertise, such as knowledge intensive business firms and learning from overseas experience. The ability to mobilise tacit knowledge has been noted as an important factor in the success of Chinese knowledge intensive firms. (Marcotte and Niosi, 2000, Gao and Xu, 2001, Chen and Qu, 2003). However, what underpinned this success was not studied, so it is difficult to draw any conclusions about agglomeration effects, because learning by mobilising tacit knowledge can be linked to 'old economy' firm behaviour (internal training, closed labour markets etc), as well as to informal horizontal networking, diversity etc., more associated with the 'knowledge economy' (Lam and Lundvall, 2005). The following section therefore, focuses on the development of the knowledge workers labour markets and discusses the extent to which they have evolved to encourage greater diversity and growth in the context of regional innovation in China.

Emerging knowledge workers in China

The evolution of the scientific labour market in China since the introduction of the market reforms is closely tied in with the growth of new technology enterprises, the

growth of high technology multinational enterprises and the reforms associated to the Chinese higher education (HE) system. China's S&T structures were traditionally modelled closely on those of the Soviet Union in the 1950s. The Soviet innovation model was of a simple linear nature, with some similarities to the early generation demand-pull model proposed for Western societies (OECD 1969, Holloway, 1982). Of course, consumer/producer relations were entirely different to a market system, the consumer in the command system was the planning body and its demands were transmitted by administrative *fiat* through industrial ministries to S&T bodies. Each ministry was responsible for a particular industrial sector, e.g. telecoms, and had production enterprises, R&D institutes and often higher education bodies under its control.

The system was vertically integrated with very few if any formal horizontal linkages between production units on the one hand, and the R&D institutes responsible for innovation and HE bodies with industrial ministry affiliation. The role of such HE bodies was to provide a pool of highly specialised knowledge workers for the production units and R&D institutes. Other organisations existed outside the industrial ministries that had S&T functions, such as the institutes of the various academies of science and universities under non-industrial ministries, but they played little role, if any, in industrial innovation. Labour mobility was very limited and labour markets for knowledge workers did not exist, since jobs were allocated administratively, and were usually for life. In China the structures for innovation were extensive, with 800 industry branch R&D institutes existing before the market orientated changes began in the mid 1980s (Suttmeier, 1997).

The 1985 policy initiative concerning the S&T sector was accompanied by similar measures concerning higher education, since the HE sector was seen as the main driver in Chinese high-tech development (Yin and White, 1994). Its role in the formation of NTEs has already been mentioned. The aims of the HE changes were to expand the autonomy, financial and otherwise, of institutions, to strengthen links with production organisations and to develop a labour market for HE workers. The greater financial autonomy was to be achieved in two ways. Firstly by charging students for their tuition fees and secondly by developing commercial structures to sell expertise or to invest in spin-off ventures of various kinds. The main vehicles for the new approach were the new vocational universities, which first appeared in the 1980s. All students paid fees, in one form or another, to attend these bodies and the curriculum was flexible and market driven, with a strong vocational content (Fang 1991).

One of the reasons for the 1985 policy change in HE was that the then system was thought to be too academically focused to serve business needs. Although science and engineering subjects with a vocational bias dominated in the curriculum they were taught without regard for the needs of the production organisations. This was even true of the industry-branch universities. As a result, there was seen to be a need for less academic, vocational skills training and to provide this new structures were developed. The first vocational university, Jinling, was established in 1980 and the sector expanded rapidly, so that by 1986 there were 128 with a total student enrolment of 67,000. The curricula of the new institutions were market driven and encompassed 'non-academic' subjects, for example, dress making. (Fang, 1991). As state budgets were cut, vocational universities and other HE institutions also turned to providing training courses for firms, on a commercial basis (Yin and White 1994). There is also some evidence from case studies that firms have started to develop in-house training programmes, possibly driven by insufficiently developed state training structures. For example, the approach of ZDZK, a leading control systems firm, owned by Zhejiang

University, includes formal training ‘for transferring explicit knowledge’ and apprenticeship based learning programmes for all new employees. (Chen and Qu, 2003).

Dramatic changes in the make-up of R&D labour markets appears in the growing mobility of employees. There is evidence from the business and professional press that Chinese high-tech firms are experiencing double digit labour turnover and difficulty in retaining qualified staff, leading to the need to concede high salary rises (Raatikainen, 2003, Leininger, 2004), indicating that there is an active and mobile labour market in this sector. The new state HE policy discussed above could have facilitated this, because as well as trying to promote labour mobility in universities it also had an aim of developing a labour market in the S&T sector. A key feature of the new policy was that the system where jobs for graduates were allocated by the state was replaced in 1990 by the “two way selection” process. As the term implies, the prospective employer and employee both had a say in the transaction (Lewin and Xu, 1993).

The development of spin-off ventures may however have been the main driver in creating a high-tech labour market in China. The growth of this sector has been explosive, as revealed by the figures in the previous section that there are now 23,000 NTEs in the ‘Torch’ programme (Huang et al., 2006). These firms were spun-off both by research institutes affiliated to the academy of sciences or former industrial branch ministries and by HEIs. By the early 1990s in some HEIs, most of the staff held concurrent jobs in spin-offs from their own institutions. For example, 80% of the teachers in Jiamusi Technology Institute were also working in its 12 affiliated ventures (Yin and White 1994). The same study also reported that there was pressure on staff to leave the HE sector completely for business. The state actively encouraged this trend through financial mechanisms, i.e. budget cuts, on HEIs and has continued to do so.

Another driver of labour market mobility was the transformation of research institutes into private companies, where the ability to hire/fire staff was seen as a factor influencing the change (Suttmeier, 1997). A study of one of the leading ICT firms, Stone, noted that all the R&D team had acquired their skills in the state R&D sector. The same paper also concluded that mobility of key researchers from state institutes to the new spin-offs was a factor in accounting for their success (Lu, 2001).

Learning on the high technology parks

As has been commented, there is strong evidence to suggest that the institutions of labour markets have adapted to encourage greater mobility from the academic sector to the new emerging market sector. However, direct evidence of a link between labour mobility or indeed other features of labour markets and the innovation capability of firms (or dynamism of regions) is sparse.

It has for example been claimed that: “engineers’ behaviour in spin off activitiesin the case of Silicon Valley, is similar in the ZGC” and “..when engineers move between firms in the same industry, they take with them the knowledge skills and experience acquired at their previous jobs. In a cluster such as ZGC, short tenure often becomes a norm. This further facilitates the exchange of employees (and information) across organisational boundaries” (both quoted from Tan, op cit.). Since no details are given of the sources for this information it is hard to judge what weight to give to these quotes. Some information sharing between competitors is reported by the same author, but quite limited in scope and having a formal, codified character. Further on though, and significantly, the point is made that informal communications have not significantly promoted co-operative innovation, partly

because many spin-offs from different state owned institutions have maintained strong ties with their parent organisations (Tan, op cit).

In order to further investigate these issues, interviews were conducted with managers in the following four ICT firms in ZGC in 2005. For reasons of confidentiality, the real company names are omitted and shall be replaced with fictitious names.

- *Telecom A*: A small and medium sized enterprise spin off from Tsinghua University, manufacturing software and hardware for manufacturing companies. Licensee of Autodesk, the US market leader in CAD/CAM software.
- *Software B*: A small and medium sized enterprise spin-off from Tsinghua University, manufacturing ASIC computer chips plus some bespoke software.
- *Hardware C*: Mainly manufacturer of hardware, 1700 workers. Not a spin off.
- *Data D*: A small and medium sized networking technology company. Spin off Tsinghua University, manufacturer of data switching hardware and software.
- *IT E*: Employing more than 1000 people producer of IT software service.

A summary of the findings are presented in table 3. All companies have a large proportion of staff involved in R&D, they are all in ICT sectors, although their area of expertise varies for example software, hardware, telecoms and in the degree of specialisation and size. This study is not meant to be representative of the ZGC park. However, exploratory work in this field over a range of different firms can gauge the nature of internal and external learning and the mechanisms by which they take place. Furthermore, they play an important role in directing future quantitative studies in setting up relevant hypotheses. The interviewees in the different firms combined human resource directors, R&D managers and R&D employees. The authors plan to re-visit the firms to complete the data analysis.

Table 3: Summary interviews of 5 ICT firms in the ZGC park

Name	Sector and size	Inter-firm mobility of Labour (total not just R&D)	Open labour markets: specialised services, diverse recruitment	Inter firm networks	Internal training, promotion and vertical disintegration
<i>Telecom A</i>	IT software and hardware, SME, Tsinghua spin-off.	7-10%. Highest mobility for sales rather than non-R&D staff.	Little diversification, although recruitment is predominantly using the Internet	In ZGC mainly with Tsinghua. Other formal links with overseas MNCs.	Internal promotion and training prioritised
<i>Software B</i>	IT hardware, SME Tsinghua major shareholder	10%	Recruitment from Internet and local universities. Rely on few services from the park	In ZGC only with universities, very little formal network with other firms in park.	Internal promotion and training prioritised. No evidence of vertical disintegration.
<i>Hardware C</i>	IT hardware, LME, >1000 staff.	15%	Very limited use of specialised services	Not in ZGC. Yes, with universities/ Research institutes	Internal promotion and training was prioritised
<i>Data D</i>	Communications hardware and software, SME	No data	Preferred to recruit from other firms	Attendance at international conferences encouraged	No data
<i>IT E Focus group</i>	IT Software and services, LME >1000 staff	No data	Very limited use of specialised services.	Close networks with founder firm and founder universities/ research institutes	No data

Telecoms A

This was set up as a private shareholder company affiliated to Tsinghua. Half of the staff work in R&D, including before and after sales services. It has also become the agent for a number of foreign multinationals. The origins of the company lie in a group of professionals from Tsinghua university and their Msc students who spun-off to form the company. Previously the profits of the company would be distributed to the university. However, formal links with Tsinghua have been receding with exception of internships. This reflects a more general strive towards separation of ownership between universities and companies in China. Having said this, it is clear that strong relationships still exist. Its President, in the company's website, makes explicit the reliance on the intellectual and technical resources from Tsinghua. The main customers are SMEs, who are not so technologically demanding, therefore change is not too sudden.

In terms of recruitment, main areas of recruitment are personal contacts of employees and the Internet. Less emphasis is placed on academic qualifications for medium and lower skilled positions, these are trained internally. However, for more complex positions, such as systems analysts, the company has to headhunt because of the difficulty of finding the top skills. In terms of knowledge workers the most important priority appears to be promotion, followed by being assigned challenging projects and thirdly their social status in the company, such as recognition. Employees tend to stay 5 years on average with biggest turnover in sales. Advantages of the park are primarily financial to the skills of residents with urban status. Little knowledge sharing is undertaken since most products are standardised.

Software B

The R&D manager highlighted a number problems confronting the firm. The first is that customers are unwilling to pay for a standardised technology, instead wishing to pay only for that part that they use. The result is high levels of complexity rather than a generic product. The lack of sophistication of users makes the development of greater functionality and innovation difficult.

In terms of the organisation of the company, strong and continuing close links with universities were reported, both in terms of its finance (previously all investment had to be funded through retained profits, a new Tsinghua shareholder has allowed growth to speed up) but also in terms of the sources of its recruitment and assistance in dealing with technical problems. However, one of the main challenges is the management of complexity. By this is meant that greater number of interfaces, demand for be-spoke support requiring more complex management methods. Yet, the head of R&D commented... "the universities are good at managing difficulty, not complexity, this is a management problem".

In terms of networking, *Software B* reported that little formal networking occurred in the ZGC park. This was because its main customers were outside of the cluster, also that part of the reason for not collaborating was that the company was too diversified to have much in common with any other company. It was suggested however that collaboration in the "ZGC software park" is greater because firms are more specialised. Informal collaboration did however exist and the general view was that location in the park was positive because of the large number of technical people and short travel distances. The company however relied on few services from the park.

In terms of internal dynamics, high emphasis was placed on promotion, less on internal training. However there was little vertical disintegration. This was partly because it was felt there were very few service companies in China and little outsourcing. In an area like marketing it was felt that outsourcing would not be viable, because people still rely on very personal relationships for this.

Hardware C

This was an established and rapidly expanding company that was founded as a stand-alone firm, not a spin-off, which is unusual in ZGC. The firm had doubled its payroll in the past year but had found it hard to recruit staff in competition with joint ventures and Western firms that offered much higher salaries. To solve the recruitment problem, they developed a closed relationship with a research institution to train staff for them, who were then recruited by the company. Internal training and promotion were given priority and there was no evidence of vertical disintegration. The use of specialised services was very limited, for instance marketing was done in-house. There was no

networking resulting in the development of horizontal links outside the firm, in fact it was reported that there was little knowledge sharing outside the company at all

Data D

This was a spin-off from Tsinghua University and the firm maintained close ties with it and cited the university as a key source of technical co-operation. Important sources of external knowledge were cited by *Data D*, such as overseas visits and attending conferences, which was encouraged by management. They preferred to recruit from other companies.

IT E

Although *IT E* reported they don't network at all with competitors, very important informal social networks based on links with alumni were reported as helping them develop their skills. *IT E* was a spin off from a leading Chinese IT firm, itself a spin-off from an institute of the Chinese Academy of Science and consequently the firm maintained very close links with the founder body. They relied on connections (*guanxi*) with state bodies to secure contracts and stated that this gave them their competitive edge. There was no evidence in this company of open labour markets or vertical disintegration, the senior manager interviewed commented on the lack of specialised service companies in the Chinese IT sector.

Comments and conclusions

Despite the limited nature of the case studies, a strong case cannot be made that 'new economy' characteristics are present in the ZGN firms. Cluster (or regional) dynamics between firms were weak, with no evidence of significant vertical disintegration, outsourcing or knowledge spillovers linked to diversity or horizontal links in the region. External learning was important, but outside the cluster, not between actors on the frontiers of the firms. On the other hand, 'old economy' features such as internal learning and promotion were prominent and regarded the firm as the primary community for problem solving. The firms were viable and expanding, sometimes very rapidly, and innovative although not cutting edge technologically. External learning was linked to universities.

Although there are 100 peer group professional bodies in the ZGC region, who organise opportunities for knowledge transfer and networking at conferences, lectures and other intermediary institutions were not cited as significant in facilitating learning, knowledge sharing or technology transfer. The discussion therefore initially appears to support Hankanson's (2005) argument in relation to ZGC. Regional agglomerations emerge through university spin-offs and the region attracts firms in search of a favourable tax regime. These in turn attract labour. In the context of growing domestic demand, organisations can grow extremely quickly. However, evidence of agglomeration economies, in the sense of diversity of knowledge sources and specialised services however is thin, with overwhelming emphasis on internal mechanisms of learning.

The more direct information on the nature labour market organization in the park suggests strong features of internal labour markets for R&D staff, despite the fact that labour mobility overall is high (although this appears to be more feature of sales staff than R&D staff in some firms). The high reliance on internal training, promotion and weak vertical disintegration suggests an emphasis on firm specific learning. Similarly, the lack of agency service companies can impede higher levels of mobility.

Therefore across all companies there is little evidence that mobility translates into a wider range of specialist career options.

Underling this point, the responses around involvement of firms in networks suggests weak formal relationships between firms in the park. With the exception of *IT E*, senior managers professed little knowledge of their neighbours technology or the use of common service functions. Part of the reason for this may be the diversification of specialisms and the fact that many of the customer and suppliers appear to be located outside of the park, further weakening the ability to establish efficiencies through regional agglomerations. These suggest a low level of coordination amongst firms in the park.

Regional networks appear to be stronger through links with the universities. All the firms that were interviewed, even those that were not formally spawned or owned by university departments, appeared to have on-going relationships with universities, although the nature of the relationships varied. In the case of *Telecom A*, the link is quite explicit. The company uses its technical and cultural association with Tsinghua university as a badge of respectability. In others firms the links were more reliant on consultancy types relationship. Almost all firms used local universities for training and some degree of recruitment.

The nature of industry-academic relationship may be interpreted here in two ways. It may reflect the point that has been made before that, that unlike in the West, Chinese universities focus to a far greater on development rather than research. This means that strong links between university research and firms is facilitated. Indeed this may one of the defining and characteristic features of the Chinese innovation system. However, the closed network relationship may also impede broadening the networks to other sources of knowledge, such as overseas partnerships, or networking with specialised organisations with management experience, that appear to be the most scarce in China's high technology firms. In the context of the fact that Beijing appears to have been overtaken by other regions of China in terms of growth, the discussion suggests further research into the ZGCs business model may be useful.

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