2

Knowledge Creation and Innovation Systems in China

The importance of the spatial proximity of the firms to maximise the effects of knowledge spillovers in knowledge-based activities has been highlighted in the literature (Ghio et al. 2015). However, the spatial proximity approach ignores the role of institutions which set the rules of innovation at a national level which, because of this, can be assumed to be fixed. On the other hand, the level of innovative capacity is not the same at each point on the spatial plain (Acs et al. 2016). There are two ways in which innovative capacity can be theoretically explained. Firstly, the role of the entrepreneur in the context of the innovative capacity of the economy falls under the umbrella of the national systems of entrepreneurship (Acs et al. 2014). Secondly, there is the national system of innovation (NSI) which depicts how innovative activities arise as a result of firms behaving within the national institutional context (Nelson 1993). According to the latter, the validity of the NSI depends on a number of assumptions. Firstly, countries differ in terms of economic performance. Secondly, the extent of the economic performance of a country depends on the level of development as well as the stability of institutions, such as a codified legal code, an effective judicial system and an effective form of government. The greater the extent of the development and stability of institutions in

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a country, then the greater will be the positive impact on the country's technological and innovative capacity. Lastly, if a country is able to endear policies which favour technological development and innovation, then this will have a positive impact on the economic performance of a country. Furthermore, a knowledge economy is likely to facilitate greater entrepreneurial opportunities than is a non-knowledge based economy, (Acs et al. 2013). According to Hall et al. (2014), the framework of NSI depends upon a whole host of institutional factors which encompasses education and research, the labour market and training, the financial system, the tax regime as well as the strength of intellectual property rights. The major failing of NSI as a framework to analyse the nature of innovation in a national context arises from two different strands. Firstly, the nature and the role of entrepreneurship in innovating within the NSI framework are unclear. Secondly, the NSI is unable to account for the differences in the structure and the performance of innovative systems between emerging and developed economies (Acs et al. 2016). However, where countries do differ on the basis of the structure and the performance of the innovative systems, there are three approaches to understanding why this may be the case. The first approach is Competition and Entrepreneurship (Kirzner 1973). The second approach is the Competitive Advantage of Nations (Porter 1990). The third approach is the National System of Innovation (Nelson 1993). In the context of Competition and Entrepreneurship, there are two strands of thought which seek to explain how innovation, competition and economic growth may differ from country to country and from region to region. The Schumpeterian system, Schumpeter (1934), seeks to explain how the market mechanism evolves and innovates by changing the production function through a reallocation of resources. However, Kirznerian entrepreneurship, Kirzner (1973), suggests that economic activity takes place within the confines of the existing production function. If there is no change in the existing production function, then the implication is that there is no long-term improvement in national performance (Acs et al. 2016). The latter suggests that the reason why the production function changes according to the Schumpeterian system is that entrepreneurs are able to reallocate the factors of production by commercialising innovations by simply establishing new firms. However, according to NSI theory and Kirznerian entrepreneurship, the entrepreneur does not reallocate the factors of production, but commercialises innovations in the context of existing firms (Acs et al. 2016). The NSI framework, therefore, excludes the role of the Schumpeterian entrepreneur from the process of innovation and economic growth. But it does analyse country's economic performance from the perspective of differences in the quality, quantity and the nature of existing institutions. The NSI framework also excludes the role of governance in the formation of innovation systems. In the context of bioinformatics, it has been suggested that Chinese scientists lack the ability to set a research agenda, while the state lacks the expertise to form it (Salter et al. 2016). In a wider context, this assertion is not true as China has the largest number of domestic patent applications in the world. However, it can be asserted that the number of domestic patent applications is a dubious measure of innovative success because patents may have been filed by foreign MNCs. Furthermore, the quality of Chinese patent applications may be lower than that of other countries (Kennedy 2015). Nevertheless, it has also been found that increased government funding for university R&D will increase the quality of patents, while government subsidies for patenting will increase the quantity of patents but not necessarily the quality of the patents (Fisch et al. 2016). It is state funding that has enabled China to be at the frontier of stem cell research and China's spending on R&D is only second to the USA at a global level. In the case of India, which may lack a more formal and robust approach to innovation compared to China, it has been found that a culture of innovation at the firm level is important for the generation of new ideas (Jha et al. 2016). However, India has significant innovative capacity in software engineering with strong value chain links with the USA and Germany (Lema et al. 2015).

Modelling Innovative Systems

There are three major approaches to modelling innovative systems.[1] The first approach is that of Marshallian industrial districts. Marshall (1890) theorised that some economies are internal to a firm, while others are external to the firm. A spatial concentration of external economies can be achieved by concentrating small firms within a region. The application of special incentive policies such as low taxation of profits, no taxation on the imports of fixed assets and the retention by the exporting firm of foreign exchange earnings may be sufficient to persuade firms to concentrate themselves at a central point within the spatial plain. The theoretical logic behind SEZs and NHTIDZs emanates from the notion of Marshallian districts. Secondly, there is the concept of the innovative milieu approach or GREMI. In this approach, the presence or absence of a number of factors will influence innovative activity at a focal point within the spatial plain. These factors of innovation include qualified personnel to carry out R&D, freely available technical knowledge, the closeness of consumer markets, availability of local networking opportunities and availability of local inputs of production. The absence of one of these factors will increase costs associated with production or lower the return on the production of the goods. This school of thought also emphasises synergy of factors associated with collective learning, intensity of R&D and strategies for production among others. The third approach to modelling innovative systems is that of the regional innovation systems (RIS). This school of thought heralds the arrival of systems of innovation, which highlights the fact that the technological innovativeness and market competitiveness of firms are dependent on institutions within their local environment. Furthermore, innovation systems are classified on either a sector or geographical basis. The latter emphasises the fact that agents learn from each other and that knowledge is acquired from agents within firms and from agents between firms. The concept behind regional innovation systems is that national innovative performance is not dependent on just the innovativeness of individual firms but depends more on how firms interact to exchange R&D results as well as generating R&D results themselves. However, in a competitive environment, this exchange of R&D results is a naïve view, unless it is from an intermediate supplier firm to a producer firm. According to one definition,[2] the main features of a strong regional innovation system are strong linkages between centres of knowledge creation, firms who will use the knowledge to produce new technologically advanced products and institutions intermediating between the two. However, it is symptomatic that many regions do not have all the factors required to effectively form the linkages that an effective innovative system would need. This was the rationale for the Chinese government to institute policies to reform Chinese education and R&D. The reform policies strengthened knowledge creation and knowledge spillover effects. The intention of the reforms was to geographically proximate technological innovation, knowledge creation and final production within specific regions. For example, Zhongguancun in Beijing only became a RIS because it was, at the time that the reform policies were instituted, already an area of concentration of research facilities. The majority of enterprises sprang up in the area after the reform policies. Shenzhen only became an RIS in its own right because of the fact that high-tech producers from Hong Kong shifted manufacturing of goods from Hong Kong to Shenzhen to take advantage of low manufacturing costs. Moreover, research institutions in Beijing established branches in Shenzhen. These two examples indicate that while some geographical locations may not possess all or any of the factors required for generating the strong strategic alliances required of a strong RIS, the application of relevant policies will allow for alliances to form. Empirical analysis of the telecommunications industry in Shenzhen Hi-Tech Industrial Park has shown the varying levels of importance of cross-national, cross-regional and inter-regional connections to knowledge flows in Shenzhen (Wu 2016). According to the latter, cross-regional connections have a positive impact on-trade and non-trade interdependence, facilitating the exploitation of knowledge creation. On the other hand, inter-regional connections have a positive impact on on-trade interdependence and this enhances the exploitation of innovation. The importance of China's telecommunications industry to its national security has resulted in different levels of restrictions being imposed which has facilitated the flow of different levels of knowledge in Shenzhen (Wu 2016).

Another feature of an RIS which has not been identified in the RIS literature is the need for an efficient labour market and the promotion and development of entrepreneurial education in an economic and regulatory environment which is favourable to entrepreneurship (Bonnet 2016). While India and China may both have entrepreneurial education systems, India lacks an efficient and flexible labour market due to regulatory and legal burdens. Firms in India are also hampered by other legal and regulatory burdens as well as facing supply-side constraints such as the country's poor infrastructure. However, in the context of knowledge management support for innovation, it has been recognised in Indian entrepreneurial education that the best knowledge management support for education arises through the realisation that it is not an isolated process but one which best arises from the integration of the many activities of firms (Datta 2016). Recent developments within regional innovation policy suggest that governments have sought to expedite the diffusion of knowledge from universities to SMEs and from SMEs to larger corporations. The technological absorption and technological innovativeness of SMEs are being improved by improving networking opportunities among firms and the transfer of technology. There has also been a tendency for regional development and technology initiatives to converge in many countries.[3] A common strand in the regional innovation and development theoretical framework is that innovative agents have to be proximate in order to facilitate innovation. Proximate agents ensure good communication and networking opportunities. All three schools of thought have common aspects.[4] Firstly, there is a reduction in cost associated with 'neighbourly' communication and with learning and cooperation opportunities when firms are close together. Secondly, innovation systems are characterised by networking relationships among firms. Thirdly, there are interactions of an official and unofficial nature among firms in the proximity and an importance of domestic and global networking. Finally, in innovation systems, agglomeration economies occur due to the 'webs of local linkages and sub-contracting'. A number of theoretical models have also been developed in order to better understand the nature of economic systems. First and foremost, of these theoretical models, is the Triple Helix based upon which a number of variants have been developed. Variants of the Triple Helix Model include the Quadruple Helix and the Triple Helix Twins. According to the Triple Helix Model, the optimal conditions for fostering innovation result from effective interrelations between academia, government and industry (Cai and Liu 2015). The latter suggests that the Triple Helix Model represents a normative framework for understanding the linkages between economic actors involved in the innovation process. However, despite the positive view taken by many regarding the explanatory power of the Triple Helix Model, it has two main weaknesses (Cai and Liu 2015). Firstly, the model does not take into account differences between countries. Secondly, the model does not account for differences in social settings. The Triple Helix Model is essentially a theoretical model which results from the experiences of the evolution of innovation in developed countries. In the case of China, the geographical unit of an innovation system are the provinces (Chen and Guan 2011). These may be in contrast to other countries in which the units of innovation systems may be cities, for example. Due to provincial differences in R&D capability, the level of government support, the extent of academia, government and industry linkages, the development of innovative systems and the efficiency of innovation vary from one province to another (Cai and Liu 2015). According to the latter, in the case of China, the Triple Helix Model needs to be adapted because the extent of academia, industry and government linkages is dependent on 'top up' and 'bottom down' initiatives by central and local governments, respectively, with regard to innovation. Nevertheless, Cai and Liu (2015) studied the innovation process in the Tongji Knowledge Economic Zone in order to determine which factors impacted on the innovation process to the greatest extent. In this case, it was determined that there was inefficiency between 'top-down' and 'bottom-up' initiatives. This inefficiency was a result of the weak state of development of institutional mechanisms—legal and governance related which affected the extent to which 'bottom-up' initiatives could impact on the innovation process (Cai and Liu 2015). The latter also found that innovation in the Tongji Creative Cluster was based on knowledge-intensive services and this contributed more to the economic development of the Yangpu District than did high-tech manufacturing industries. The focus of the Tongji Creative Cluster was mainly due to the greater level of involvement of universities in the knowledge-intensive services compared to high-tech manufacturing. However, the university–industry link remains weak mainly because of the lack of protection and enforcement of intellectual property rights which have led to mutual mistrust (Cai and Liu 2015).

China's Innovation Systems

Innovation systems are necessary for the creation of knowledge, and their formation is facilitated by a concentration of infrastructure, good educational facilities and high R&D expenditure. The problem with China is that while a number of regional innovation systems coexist, mainly in the Coastal region of the country, a national innovation system has not yet formed. The three major economic systems in China include the Bo Hai Rim (BHR), the Pearl River Delta (PRD) and the Yangtze River Delta (YRD). Innovation systems have taken root mainly in the Coastal region for a number of reasons.[5] Firstly, central and local governments have provided the necessary resources for the establishment of scientific parks according to national science and technology programs. Secondly, the facilitation of FDI into China by the post-1979 reforms engineered a transfer of technology from developed countries. Specifically, FDI and its increasing technological content have tendered to favour the development of specialised operational clusters. It is the expectation of state policy makers that the production clusters formed in the three regions will evolve into technological clusters, which will in turn create an innovative climate in the whole country. Thirdly, the spontaneous development of industrial and technological clusters has facilitated the continuous development of innovation systems. Finally, education is stronger in these regions due to more funding opportunities, economic prosperity and the ease of delivery of education to end-users.

A feature of the clustering of centres of production in the Coastal regions of China has been the geographical concentration and subsequent agglomeration effects recognised by Krugman (1991) in his New Economic Geography. However, Sigurdson (2004) recognises that the spatial distributions of clusters will 'aside from a geographical concentration and also have to include sectoral or functional characteristics'. In these circumstances, Sigurdson (2004) suggests that 'functional proximity takes precedence over geographical closeness'. Furthermore, Sigurdson (2004) differentiates historically from the earlier stages of industrialisation in the nineteenth century and the nature of the industrialisation taking place in China today. He does this by suggesting that 'industrial plants as such are no longer the geographical concentration of complete production as was previously the case'. More relevant now to industrialisation and the formation of innovative high-tech clusters, especially in China, are the relevant knowledge linkages necessary to support production and a sufficient critical mass of business activities to activate a competence block. A competence block is the minimum set of competencies, which make up a functional innovation system, to profit and exploit from knowledge. Eliasson et al. (1996) define a competence block as,

> The total infrastructure needed to create (innovation), select (entrepreneurship), recognise (venture capital provision), diffuse (spillovers) and commercially exploit (receiver competence) new ideas in clusters of firms.

This definition suggests that education is the key to the formation of an innovation system. However, this definition does not recognise the importance of the role of government in facilitating innovation, entrepreneurship, the commercialising of innovation as well as the interlinking of the three at the same time. Both educational reform and reform of the research sector in China have created the environment in which innovative entrepreneurship can prosper. Reform of both sectors resulted in educated individuals engaging in innovative entrepreneurship. Many returning students from overseas have not only received Ph.Ds from American, European or ANZAC countries but also received further training. This has facilitated the transition of returning students, to China, into entrepreneurs. The Chinese government's reform of the research sector and associated benefits has proved to be fertile territory upon which the seeds of entrepreneurship have been sown. China has also made progress in its approach to modifying patent regulations in order to support emerging research in embryonic stem cells. For example, China has amended patent regulations so that more patents can be issued for embryonic stem cell downstream technology, although it can make its patent laws clearer (Peng 2016). On the other hand, while India has complied with Trade Related Intellectual Property Rights (TRIPS), the impact has been to divert innovation activity into other areas but it has had little impact on increasing India's export values (Bouet 2015).

China's Thirteenth Five-Year Plan (2016–2020) is indicative of the fact that the Chinese government will continue to encourage entrepreneurship by investing in new science and technology projects in the hope that it will lead to further innovation and the development of new technology Xinhua (2015). The latter suggests that the Thirteenth Five-Year Plan will focus on regulating the consumption of energy, water and construction land. Furthermore, there will be greater emphasis on investment in green energy and carbon emission regulations in energy-intense sectors such as power, steel, chemicals and building materials. At the socio-developmental level, there will be an emphasis on promoting health through the reform of the healthcare system and to lift more people out of poverty. The reform of the healthcare system will involve a government investment of 20 billion Yuan, as well as an estimated private sector investment of 40 billion Yuan, in 'precision medicine' in order to apply genome sequencing technology to fight chronic diseases such as diabetes, cancer and cardiovascular disease (Qionghui 2016). China's economy may have reached a 'tipping' point where there have been sufficient levels of capital accumulation in the economy such that the economy is transitioning from a focus on production to one based on innovation, whereas in the Indian economy this transition is taking time due to insufficient capital accumulation in the economy (Altenburg et al. 2008).

A competence block cannot be specifically designed[6] although, as in the case of China, the necessary policies, institutions and primary infrastructure can be created and applied to facilitate its formation. Sigurdson (2004) suggests that the creators of innovation do not have to be geographically concentrated in order to allow the competence block to function. Participants in the functions of the competence block could be part of a 'network that is dynamic and inventive in knowledge creation'.[7] Therefore, a competence block can exist primarily as a functional or sectoral cluster, and geographical location is of secondary importance. This feature is important because the availability of telecommunications and access to the Internet will make the formation of a competence block independent of its location. In order to trigger dynamic regional development and subsequent innovation-led growth, a number of factors are important. These factors include physical infrastructure, manufacturing, telecommunications infrastructure, science and technology research parks; and education. These factors allow not only regional development, urbanisation and the formation of cities but also the integration of regional innovation systems to form a national one. However, Sigurdson (2004) excludes the role of entrepreneurship in the process of innovation, the transition of knowledge into a usable product, service or solution. It has been shown in the context of the Indian crude oil industry that innovation is facilitated by entrepreneurial activity, resulting in new products and/or service which may be adopted by other firms in the sector (Iyer 2016). Moreover, in East Asian economies in which there has been little if any state involvement in the commercialisation of knowledge, resulting in innovation, it has been shown that entrepreneurial activity plays the role of a good substitute (Yoon et al. 2015). Furthermore, it has also been found that innovation in management practice is also important for efficiency in the Indian petrochemical industry. If senior management plays a leading role in the adoption of green technology, then this trend in the adoption of green technology will trickle down to the entire firm (Roy and Khastagir 2016).

The formation of cities caters for geographical closeness in two ways (Sigurdson 2004). Firstly, associated with cities is the territorial integrity with regard to the density of business services and population. Secondly, a city has the capacity to network with other cities which have similar characteristics. Sigurdson (2004) suggests that this two-dimensional geographical closeness attracts to cities, government and others, types of social and economic functions. However, with regard to industrialisation and urbanisation, China casts a picture very different from that painted by other countries going through a similar phase. In China, industrialisation accounts for 50% of GDP but only 30% of the population lives in urbanised centres. Regional development in China, especially in the Coastal regions, has given rise to four types of urban centres.[8] These are predominantly the pre-1949 foreign-led development of Coastal cities such as Shanghai, Tianjin, Wuhan and Guangzhou. These cities were only weakly linked to the interior hinterland, essentially because of a lack of transportation and communications infrastructure and deficient Social Capital. However, cities also formed in the interior or away from navigable waterways due to military or political reasons such as the need for balanced regional growth. These cities can be characterised by their less dynamic nature and inferior industrialisation. However, cities may also form because the area they are surrounded by has mineral resources. These include cities such as Tangshan, Datang and Ansghan which formed specifically because the areas surrounding them had mineral resources. The extraction of these mineral resources and the need for the transportation of these resources to centres of production were based on a desire to model the Chinese state in terms of the Soviet model. This led to the failed 'railways lead to prosperity' philosophy of 1949–1978. There were also cities which formed as a result of the 1978 economic reforms. These cities included Shenzhen, Dongguan, Wuxi, Suzhou, Yantai and Weihai. These cities formed due to the 1978 economic reforms, the subsequent influx of FDI and 'strong local support and new material and knowledge infrastructures'.[9]

The pre-1949 and post-1978 cities are those which have contributed significantly to the economic development of China. However, with regard to 'capturing' and maintaining comparative advantages in the production of goods and in the provision of services, the post-1978 cities have a greater role to play in the future economic development of China. Sigurdson (2004) suggests that:

> Capturing and keeping a comparative advantage will require specialisation. Technological clusters often play an important role and need a conducive environment that provides knowledge, supportive interaction and incentive structures to become successful.

Furthermore, in order to be successful, clusters of innovation require a well-educated workforce, R&D activity, transportation infrastructure and policy measures intended to increase the quality and quantity of labour and capital as well as encouraging the incubation of entrepreneurship.

Centres of Innovation

The foundation for manufacturing-led economic growth was laid, in China, in the late 1970s and 1980s. The foundations for innovation and technological growth in the Chinese economy were laid in the mid-1980s and the 1990s with the establishment of twenty-four New and High Technology Industry Development Zones (NHTIDZ) in 1991. The first high-technology park was set up in Zhongguancun, Beijing, in 1988. Zhongguancun benefited because of its proximity to a cluster of research institutes belonging to the Chinese Academy of Sciences (CAS) and centres of higher education such as Beijing University and Tsinghua University.[10] Furthermore, the closeness of central government and other related funding agencies meant that it was relatively easy for technological innovations to go from the drawing board to production. However, Sigurdson (2004) notes that the factors which favoured Zhongguancun are changing in three ways. Firstly, university researchers will often start up their own companies, independently from high-technology parks. Secondly, universities have moved away from enterprise creation to concentrate on teaching and their own independent research. Finally, the commercial incubation of discoveries is becoming increasingly institutionalised within universities rather than High Technology Parks. The NHTIDZs which followed were established using the Zhongguancun Technology Park in Beijing[11] as a model. A further twenty-seven NHTIDZs were set up in 1993 with an additional set up in 1997. Of the fifty-seven NHTIDZs, twenty-nine were established in the Coastal provinces, fourteen in the Central provinces and fourteen in the Western provinces. Guangdong, Shandong and Jiangsu are the provinces with the highest number of NHTIDZs, six, five and four, respectively. These provinces are all in the Coastal regions of China.

The transfer of technology and technological learning effects associated with spatial clusters in developing countries has tended to focus on the manufacturing and export sectors. However, a study by Zhou and Xin (2003) focuses on the dynamics of the interactions between multinational companies (MNCs) and domestic firms, with regard to technological transfer and learning effects in the ICT information communications technology (ICT) sector in Zhongguancun Technology Park in Beijing. Zhongguancun was originally the centre of technological research and education in Beijing. A number of renowned universities and research institutes were located in the area. This gave the cluster a rich concentration of scientific research expertise. However, this expertise served no purpose under the centrally planned economy because there was no need for product innovation. In the central planned economy, technological innovation and scientific research only served the needs of the military and the production process. Nevertheless, the post-1979 economic reforms unleashed forces of change, especially with regard to the funding of scientific research by central and local governments. This change in funding acted as a signal to scientists and researchers in universities and research institutions in clusters to become entrepreneurs and start up their own enterprises. Initially, these start-ups were engaged in the assembly and testing of parts as well as offering technological services. Nevertheless, they evolved into producing generic technological products for the Chinese language market.[12] Within the Zhongguancun Technology Park, there is a significant interaction between local firms and multinational companies in a hierarchical fashion. MNCs are 'top heavy' with regard to expertise and resources associated with management, technology and capital. However, the cultural, linguistic, low cost and local market knowledge difficulties often associated with MNCs operating in a foreign market have led the MNCs to follow a collaborative approach with local firms, fostering an atmosphere which facilitates the transfer of technology to and technological learning by local firms. The mechanism by which both are accomplished is through a division of labour between MNCs and local firms.[13] Indeed, at this time technological transfer and learning by local firms in the cluster were endogenous to that cluster as the resources required for technological innovation existed within the cluster. The growth of the technology market attracted MNCs to the Zhongguancun cluster which then went onto subcontract non-developmental work to local firms in order to comply with government regulations.[14] The move by the MNCs into the cluster disabled any incentive for local firms to technologically innovate. It is at this point that the framework of analysis departs from the one used to analyse technological clusters in developed countries. This is because technological learning by and technological transfer to local firms changes from an endogenous source to an exogenous one. However, this situation began to change in the 1990s when local firms began to make use of the knowledge they had accumulated as the marketing agents of the MNCs and develop their own products. One famous example of a local firm which successfully did this was Lenovo. Domestic firms which 'in-license' technology for use from foreign MNCs have been found to be more innovative than domestic firms which rely on endogenous innovation (Li-Ying and Wang 2015).

It has been found that MNC R&D investment in China is market oriented, while MNC R&D investment in India is resource (labour) oriented while the upgrading of R&D investment tends to follow an evolutionary pattern (Bruche 2009). Thus, in China, R&D investment focuses on the commercialisation of knowledge, while in India the focus of R&D investment is in education and training. MNCs can also be expected to gain local market knowledge through forming joint ventures with local firms or by simply buying them outright (Thite et al. 2016). The market orientation of foreign MNC in China is exemplified by the involvement of MNCs in China's energy industry. Both MNCs and domestic firms have increased energy efficiency in China, but there has been very little interaction between the two (Herrerias et al. 2016).

The bulk of the work undertaken by local Chinese firms in the Zhongguancun cluster falls into software development, systems integration and consulting fields for Chinese ICT users. This is in addition to sales and distribution services for the MNC's. The MNCs undertake high-end product development in Zhongguancun with a number, including Lucent, Motorola, Sun, IBM and Oracle, opening research centres in Beijing. Many Chinese employees gain experience with local Chinese firms before leaving to join an MNC on better pay. However, some may set up their own businesses. This brain drain slows down the development and growth of local firms in the cluster. Zhou and Xin (2003) chose Zhongguancun and the ICT sector to study the dynamics and synergies associated with the technological transfer to and technological learning by local firms, specifically because of the unique ability of this spatial cluster to accumulate and grasp the essence of exogenous technology and 'rewire' it for the Chinese market. The data for the study was collected by formal interviews with up to eighty senior executives of companies based in the Zhongguancun cluster. Questions asked in the interviews were related to company history, technological sources and development, interactions with MNC's, government bodies and research institutions, and the sub-contracting of technological work.

The evolutionary growth of the Chinese ICT sector as represented by firms in the Zhongguancun cluster has reached such a stage that companies are being forced by the needs of market specialisation to move from the basic business activities of installing systems and providing technical services to adding value-added activities. The interviews conducted by Zhou and Xin (2003) with senior executives of firms based in the Zhongguancun cluster illustrate this very point. For example, TongTech moved into the middleware sector for financial applications, directing its R&D research into this field. Legend shifted business strategy towards the manufacture of network equipment.[15] However, the Chinese purchasers of ICT equipment felt it safer to purchase ICT equipment from MNC's based on the reputation for the quality of their products, despite the fact that Chinese companies such as TongTech prided itself for producing ICT equipment which took into account the uneven infrastructure in China in product design. Nevertheless, MNCs had also begun to take into account the differences needed in product design and manufacture in order to take into account the differences between countries in the levels of infrastructure development as well as government policy. In order to achieve this, foreign MNCs had established local R&D centres.[16]

Zhou and Xin (2003) also suggest that indigenous R&D factors within the Zhongguancun cluster, such as the availability of science and technology research expertise, have also helped local firms to develop and deviate from the standard products of MNC's. Furthermore, the workforce in the cluster is not only highly educated, but also mobile and entrepreneurial mirroring the economic requirements of a market economy. This is in stark contrast to the immobility of labour and its non-entrepreneurial nature in the state-owned enterprises. Education, mobility and entrepreneurship facilitated the efficiency of the diffusion of information in the Silicon Valley cluster in the USA.[17] A further advantage favouring the diffusion of information and innovation for the Zhongguancun cluster is that the cluster is located in Beijing, a city which hosts a large number of international conferences and trade shows.[18] With regard to government policy, a shift occurred in 1999 when the administration of the Zhongguancun cluster changed from coming under urban district level to the municipal government. This gave firms based on the cluster access to the State Council with benefits flowing from the relationship including increased funding for universities based in the cluster and improvements in infrastructure. Furthermore, there was a shift by the government from directly managing state-owned ICTs to promoting and regulating the ICT market under free market conditions.

Elements of Centres of Innovation

Telecommunications Infrastructure Pre-1978

The Ministry of Posts and Telecommunications (MPT) was formed in 1949. The Directorate General of Telecommunications (DGT) was set up as a section of the MPT in 1950. The DGT had responsibility for regulation, supply services, financial and human resource management of all aspects of telecommunications in China. However, in the latter part of 1950, all these separate activities of the DGT were handed to separate departments within the MPT. The DGT was left in sole charge of the operations of the telecommunications network. Posts and Telecommunications Administrations (PTAs) were handed the responsibility of administering the edicts of the MPT at the provincial level. This form of organisation was seen as bureaucratic as each department of the MPT was reflected in the PTA. Decisions which were made at the provincial level were always referred up to the MPT.[19] As a result of the Great Leap Forward, all activities of the MPT except management of the Beijing and national trunk networks were handed over to local and provincial governments. However, towards the end of 1959 control of budgeting, planning and supply reverted to the MPT. This was due to the chaos, which had resulted from provincial and local government management of these activities during the Great Leap. In 1962, control of all telecommunications activity became centralised with control directly held by the MPT. Further developments did not take place until 1969 when the MPT was dismantled and the DGT was put under the jurisdiction of the military. In China after 1949, telecommunications were seen as a national security concern.[20] Therefore, little thought had been given to telecommunications as a service sector industry and an accessory to knowledge creation. Profits from the postal service, which had been amalgamated with the railways, were used to subsidise telecommunications deficits. The latter arose because the telecommunications sector was not profit driven and heavily subsidised by the state. Due to financial difficulties sustained over the years by the telecommunications sector, the MPT was re-established in 1973. At the same time, the PTAs were established under the dual control of both provincial and MPT administrations. Any profits made by the PTAs were handed directly to the provincial governments. However, the telecommunications sector lacked any market orientation. The development of telecommunications in China was subject to the requirements of the state and the military. The objective of both was the same—that of maintaining control of the general population. Moreover, the residential telephone was a luxury made available to only senior politicians and military officers.[21] Furthermore, prior to the 1978 reforms, there was no incentive for enterprise in China's telecommunications sector, and due to central planning, operating efficiency and profits were not relevant sector/firm objectives. The political disturbances of the Great Leap Forward and the Cultural Revolution contributed to the Chinese telecommunications sector operating inefficiently. Thus, the Chinese telecommunications sector suffered operating losses from 1966 to 1978. During this period, only 38% of the population had a fixed line telephone.[22]

Telecommunications Infrastructure Post-1978

Following the 'Four Modernisations' program of Deng Xiaoping in 1978, the telecommunications infrastructure was seen as integral to the economic development of China. Without access to 'instant communication' to local and foreign destinations, and in the absence of a multimoded transport network, multinational companies would be reluctant to take advantage of the opportunities offered by China's post-1978 economic reforms. Furthermore, the restricted availability of telecommunications to the general population made the dissemination of knowledge and its creation difficult. This argument ensured that the telecommunications sector in China became recognised as an industry in its own right in 1979. At this time, control of all aspects of telecommunications development was handed to the MPT. Moreover, directive 165 issued in 1979 stipulated that the post and telecommunications sectors should be separated and each sector should be administered separately. Nevertheless, this separation did not formally occur until 1998. Further reform of the Chinese telecommunications sector was necessitated because of the realisation that there was a lack of contractual obligations between the administrative units of the MPT and other institutions in the sector. This led the Chinese government to introduce three substantial changes to the administration of the telecommunications sector.[23] Firstly, the performance of the telecoms sector was delegated to enterprise management. Secondly, MPT administrative authority was handed to the lower levels of provincial governments. Finally, incentive schemes were introduced.

In 1980, Chinese government policy on telecoms was directed towards the development of intra-city telephone networks. Local PTEs were given authority over all locally collected revenue and the price setting of telephone installation fees. In 1984, the 90% rule was adopted. The implications of this move were threefold. Firstly, 90% of all government investment in the telecoms sector was to be considered as non-payable loans. Secondly, 90% of all foreign exchange revenue was to be retained by the MPT. Thirdly, 90% of all earnings were to be retained by the MPT. In 1988, the State Council adopted a policy document, which encapsulated four principles regarding the development of telecommunications infrastructure in China. Firstly, the MPT should coordinate all planning and development. Secondly, resources for infrastructure construction should be drawn from diverse sources. Thirdly, each administration level should have its' responsibilities clearly defined. Finally, government administration of the telecoms sector should be coordinated with that at the local level. In return, the MPT gave its departments more autonomy and set up two separate posts for the Director General of Telecommunications and Director General of Posts. The following year provincial-level regulatory bodies were set up. However, joint ventures between Chinese firms and foreign firms remained restricted, and in 1992, the MPT stipulated that all such ventures were forbidden. This was restated much more strongly the following year and excluded all foreign investment or management of broadcasting networks or wireless networks in China. Nevertheless, China Telecom became a recognised legal enterprise when the MPTs DGT registered it as such with the government in 1995. In the same year, the State Council lifted the embargo on foreign investment in China's telecom sector. This raised the prospect of much needed foreign investment into China's telecom sector which would bring not only new technology into the sector but also the opportunity for Chinese workers to acquire new technical skills. Forty-nine per cent of China Telecom floated on the Hong Kong stock market in 1997, and in the latter part of the 1990s, China Unicom was formed combining forty-five joint ventures. However, the Ministry of Information Industry [MII] decreed that this was illegal. In early 1999, the MII stated that China Unicom should unwind all its joint venture contracts with foreign firms. China Unicom was rewarded later on in the year when the State Council stipulated that China Unicom should gain a bigger share of the mobile network and that it should be the sole operator of the CDMA mobile system, in competition with China Telecoms GSM system. At the same time, China Netcom was approved as China's third major telecom company. Consideration was also given for the separation of China Telecom into four separate divisions: fixed line, satellite, paging and mobile communications. In mid-July 1999, China Unicom's plan to build long-distance networks in China was approved by the Ministry of Information

Services, and the number of China Telecoms fixed line users exceeded 100 million for the first time.

The first authorised foreign venture occurred when AT&T was allowed to own and operate an IP network in Pudong, Shanghai, in May 1999. This was seen as an offering to the USA to persuade it that it would be better to let China accede to the WTO. The number of mobile subscriptions in China did not begin to go up noticeably until after the year 1999. By signing the WTO agreement, China accepted that eventually there would have to be 49% foreign ownership of Chinese telecoms companies. In the first half of 2000, China Mobile was formed through the separation of China Telecom (HK) from China Telecom. The company expanded through the purchase of provincial mobile networks covering Beijing, Tianjin, Shanghai, Liaoning, Hebei, Shandong and Guangxi.[24] In September 2000, China Telecom started to divest itself of non-core businesses in order for it to become cost-efficient so that it could become an internationally competitive company. For the first time, China had 65 million mobile phone users which exceeded the 51 million mobile phone users in Japan. In July 2001, the number of mobile phone users in China reached 120.6 million exceeding the 120.1 mobile phone users in the USA.[25] This represents an 85% increase in approximately 11 months. Nevertheless, by July 2006 the number of mobile phone users in China had increased to 431 million. However, at this time there were approximately 376 million landline connections in China. By 2013, the number of mobile phone subscribers in China had increased to over 1.2 billion, while the number of fixed-line subscribers had fallen to 266 million. These figures suggest that mobile phone utilisation is almost universal in China. However, some people may have more than one mobile phone. So, care needs to be exercised in drawing any conclusions regarding mobile phone utilisation among the population. Nevertheless, it is clear that mobile phone telephony is allowing China to jump technologies. For example, instead of establishing branches in remote regions, banks can facilitate banking transaction through mobile applications. Moreover, the figures indicate the knowledge trajectory on which the Chinese economy is heading. The regional distribution of mobile phone subscriptions in China in 2013 suggests that the Coastal region of China has the largest number of mobile phone subscribers compared to either the Central or the Western regions of China. Nevertheless, the discrepancy between these two regions with regard to the number of mobile phone subscribers is much smaller in comparison with that between them each and the Coastal region.[26]

In the latter half of 2001, China Telecom was split into two companies, one servicing Northern China, which merged with China Netcom, and the other Southern China. A number of foreign ventures and contracts were entered into at this time. Motorola won a contract to upgrade and expand China Mobile's GPRS packet network and Alcatel took control of its Shanghai joint venture. In December 2001, China finally acceded to the WTO. Following China's accession to the WTO, there followed a number of foreign investments in the Chinese telecommunications sector.[27] For example, AT&T launched telephony services in Shanghai through a joint venture with Shanghai Telecom. Then, Alcatel Shanghai Bell was launched in Shanghai as a manufacturing centre. In August 2002, projects for the construction of a seventeen-city broadband network with foreign participants were announced. And in January 2003 UTStarcom won a deal for China Telecoms PHS network in Shaanxi.

3G and 4G Mobile Networks

3G technologies began to be deployed around the world in 2000 in order to meet the increasing bandwidth demands of multimedia applications (Dekleva et al. 2007). However, it was not until the beginning of 2009 that the Chinese government began to award 3G licenses to mobile phone operators in China (Jing and Xiong-Jian 2011). It is interesting to see that India and China adopted different 3G standards strategies (Liu and Jayakar 2016). While India allowed mobile phone operators to select any standard, China invested heavily in a domestic standard, the Time Division Synchronous Code Division Multiple Access Standard. China was probably being more entrepreneurial than India by specifying its own standards for mobile phone operators to use. The 2008 reforms provided the pathway to the issuing of 3G licenses (Xia 2011). In the 3G era according to the latter, at the end of 2008, China Mobile maintained a market share of 73.6%, albeit under stiff competition. It was in 2008 that the number of industry players in the provision of telecommunications services fell from six to three due to the combined effects of government reforms and industry consolidation (Xia 2011). The three remaining telecoms operators China Mobile, China Unicom and China Telecom were issued with different 3G licenses as well as retaining a 2G network upgraded to the technical capacity of a 2.5G network. According to Xia (2011), the government reforms resulted in the establishment of the Ministry of Industry and Information Technology (MIIT) to regulate not only the telecommunications sector but also the defence and the tobacco industry. Before 2004, the MII was in charge of the regulation of the sector, and it was much stronger than the SASAC.[28] However, after the industry was politically separated from the MII to the SASAC, a conflict of objectives arose. This was because MII was more motivated to increasing competition in the industry, while SASAC was not due to its protective role. This conflict of objectives remained until the latter half of 2008 when the government merged the MII into the MIIT.[29] After this, the MII was focused on the regulation of the technical aspects of the industry, while the SASAC was now focused on promoting competition in the industry (Xia 2012). The issuing of 3G licenses took place in the backdrop of rushed reforms, industry consolidation and an immature technological framework (Xia 2011). However, this has to be viewed from the perspective that at the time China and the global economy was engulfed in the aftermath of the Global Financial Crisis of 2008. Faced with rapidly declining exports, the Chinese government instigated a $580 billion dollar fiscal expansion through increased lending to state-owned enterprises and increased infrastructure building. In this context, the 3G investment could have been seen as stimulating the economic growth which is much needed for China (Xia 2011). However, the latter suggests that while 3G commercialisation faces a number of constraints, these constraints may be rapidly overcome by the adoption of 4G technologies which could catapult China into a lead over developed countries with regard to mobile phone telephony. The constraints to 3G commercialisation include the following factors.[30] Firstly, the lack of technological adoption due to switching costs, the substitution effect and technological barriers. Switching costs relate to the costs associated with the adoption of 3G compatible handsets. The substitution effect relates to the reluctance to switch from 2.5G to 3G services due to the similar data capacity of both. And technological barriers are those associated with the lack of information about 3G to potential adopters. Secondly, the efficacy of the integration of merged parties with regard to structural, cultural and organisation integration. Thirdly, the effectiveness of the convergence of telecommunications, the Internet and cable networks as proposed by the government. Lastly, institutional and regulatory uncertainty may act as a constraint to the full commercialisation of 3G due to the lack of investment by firms. However, to some extent, this last constraint is diminished because the three main mobile telephony providers are state owned. The effectiveness of the constraint to 3G commercialisation is reflected in the relatively low percentage of 3G users compared to the total number of mobile phone users at a national level. In June 2010, the total number of 3G users in China was only 3% of the total number of mobile phone users in China, while the global average represented 14% (Xia 2011).

It was in 1999 that China put forward a proposal for an indigenous air interface standard, the TD-SCDMA, for 3G mobile telephony to the International Telecommunications Union as an alternative to other 3G standards which were being developed by European–Japanese and US–Korean consortia (Stewart et al. 2011). However, the TD-SCDMA standard took 10 years to be implemented, and by this time, other 3G standards such as the UMTS/WCDMA and the CDMA 2000 had already been widely implemented and in use. Moreover, other global mobile phone operators were also starting to deploy 4G mobile broadband technology (Stewart et al. 2011). The development and the implementation of the TD-SCDMA 3G mobile telephony standard are an example of how Chinese government requirements have influenced technology knowledge spillovers from foreign MNCs to Chinese firms, resulting in indigenous technological innovation. Without collaborating with indigenous Chinese firms through joint ventures in order to satisfy Chinese government requirements, foreign MNCs would be unable to gain access to the profits which could be made in the potentially huge Chinese market. This may explain the entry of foreign MNCs such as Alcatel, Ericson and Siemens into the Chinese telecoms markets as well as the emergence of indigenous Chinese telephony firms such as Huawei and ZTE (Stewart et al. 2011). In this case, in order to develop the TD-SCDMA mobile telephony standard, software and chipsets, the Chinese government instigated the establishment of the TD-SCDMA Industry Alliance in October 2002. The Alliance was composed of firms such as Datang Mobile, Soutec, Holloy, Huawei, Lenovo, ZTE, CEC and Potevio. This was part of an informal strategy to promote indigenous innovation which became formal in 2006 with the unveiling of the 'National Guideline on Medium- and Long-Term Program for Science and Technology Development' covering the period 2006–2020. At the heart of this policy was the formulation of technology standards as a part of national science and technology programs within industry, universities and research institutes (Stewart et al. 2011). According to the latter, the development of the TD-SCDMA 3G standard involved the transfer of Siemens TD-CDMA intellectual property to a Siemens–Huawei joint venture with continued investment by Siemens. Moreover, in order to integrate TD-SCDMA technology into Alcatel's mobile technology, Datong Mobile worked with the joint venture between Alcatel and PIIC, Shanghai Bell (Stewart et al. 2011). The latter maintains that it was Chinese government strategy regarding the implementation of the TD-SCDMA technological standard which ensured that foreign mobile phone MNCs worked with relatively recently established Chinese counterparts in order to maintain access to the Chinese market. Chinese government intervention in the standardisation process has illustrated that the government, in place of the market, 'can act as a project founder, risk undertaker, interest moderator, collaboration facilitator and process monitor'.[31] Nevertheless, despite government intervention, the levels of 3G commercialisation in China fell short of government projections, due to commercialisation constraints which have been previously discussed, and by January 2011, the level of 3G penetration in China only amounted to 50 million subscriptions.[32] However, once the TD-SCDMA technology standard had been implemented in 2009, the Chinese government set its sights on post-3G standards and the development of the TD-LTE technological standard as a proposal to the International Telecoms Union as a 4G specification.[33]

Internet Development

The Internet and the computer are valuable tools not only for the transfer of knowledge but also for its creation. Research can be conducted through the World Wide Web, and people with innovative thoughts and ideas can explore the originality of their idea before expanding on it. Software packages accessible with computers can make the creation of knowledge a faster process. Such packages allow innovative thoughts and ideas to be written down, re-thought, researched and edited. In effect, research becomes more productive, and knowledge creation is enhanced in research institutions. Furthermore, the Internet, computers and software enhance Social Capital by strengthening the interactions between people.

In China, the Institute of High-Energy Physics was the first institution to access the Internet by dialling mode in 1987. More scientific personnel became the first users of the Internet when in 1994 a TCP/IP Internet connection was established. In 1994–1995, the growth of Internet access spread to educational and research sites, when the China Science and Technology Network and the China Education and Research Network were established. Following the establishment of these two networks, a national Internet campaign was launched, and initiatives such as the 'Inter-networking a Hundred Institutes' and 'Inter-networking a Hundred Colleges' were established.[34] In 1995 and 1996, two further commercial Internet applications were established: the China Public Internet and the China Golden Bridge Network. In 1996, the four networks became interconnected. Xiongjian and Xu (2001) suggest that the number of Internet users in China was 4.6 million in 1999 and breached the 10 million mark in September 2000. By 2003, the total number of Internet users in China had reached 63.2 million, and in 2000, the ownership of personal computers had reached 15.9 million. In 2007, there were 210 million Internet users which mean that 84% of China's population is still not online. However, by

2012, there were 564 million Internet users in China. These figures represent an indicator of the Chinese economy's knowledge creation trajectory. This view is supported by the fact that by the end of June 2015, the number of Internet users in China had risen to 668 million.[35]

The Internet in China

In 1997, the State Council announced that the China Internet Network Information Centre and the four major inter-connecting networks in China would be responsible for collecting statistical data on the development of the Internet by conducting user surveys. The first such survey was conducted in October 1997 and in subsequent years in January and July. The data collected and definitions used in the first survey were refined in subsequent surveys. The detail of the data and the additional data presented in subsequent surveys by CINIC can only result in better conclusions being drawn from the demographical, educational, income and usage factors governing the development of the Internet in China since 1997. However, data redefinition, specifically with regard to changing and expanded categories, has presented some difficulty in compiling data tables for analysis. Nevertheless, it has been possible to determine that the number of Chinese Internet users was 137 million in 2006. However, this figure had increased to 564 million by 2012. This represents an increase in the number of Chinese Internet users from 2006 to 2012 of 312%. The number of Internet users in China in 2012 represents 41.75% of the total population. Clearly, in order to take better advantage of the 'knowledge'-based economy offered by the Internet, its use by the general population should be expanded significantly. However, Internet utilisation in China is growing. But, in 2011, approximately fifty-six out of every hundred Internet users in China were male. However, by January 2012, this figure had stayed around the same level. The data also suggests that the Internet in China is still relatively a male preoccupation. However, the gender gap in Internet usage has had a tendency to equalise over the period 1999–2005. Furthermore, since the first Internet user survey in 1997 to the one in January 2005, on average seventy-three out of every one hundred users of the Internet in China have been aged thirty or below. The only other age group which has seen any substantial growth in percentage usage over the sample period has been the 3640, moving from four out of every one hundred users in 1997 to nearly eight out of every one hundred users in January 2005. Nevertheless, Internet usage by age has not remained in ascendancy among those aged thirty or below. Internet usage by other age groups has also increased significantly from 2005 to 2011/2012. As younger people become old, Internet usage is a growing trend, perhaps facilitated by rising incomes and increased accessibility of technology. Moreover, in 2005, it was those mainly with a high school education and a bachelor's degree used the Internet in China. However, this may be due to the fact that the survey was biased because a significant proportion of those surveyed had a bachelor's degree or at least a high school education. Nevertheless, the observation may be attributable to the fact that the majority of those using the Internet in China are either or have been enrolled in high school or below or enrolled on an undergraduate degree. This feature clearly establishes a link between the Internet, its use and the facilitation of knowledge diffusion and knowledge creation. Nevertheless, the Internet usage remains a predominant pastime of those still in high school in 2012. However, the number of Internet users in university and above seems to have been fallen, comparing 2012 to 2005.

Furthermore, data based on the average monthly income of Internet users in China suggests that in the early part of 2005, forty-seven out of every one hundred Internet users in China earned fewer than one thousand Yuan.[36] This is in contrast to data suggesting that six out of every one hundred Internet users in China had no income. Due to the fact that there is no unemployment benefit in China, it is therefore highly likely that those with no income accessing the Internet in China are dependents of income earners. Thus, there may be double counting included in the income-based data of Internet users in China. A surprising feature of the income-based data on Internet users in China is that fifty-three out of every one hundred users are accounted for by middle- and high-income earners, while the latter (above 4000 Yuan) account for only five out of every one hundred users.[37] The data presents a contradiction as it is intuitive to expect that high-income earners would represent the greater number of Internet users as it is expensive to pay for computers and connection services to third-party vendors. However, this does not seem to be the case, and therefore, one has to conclude that the contradiction can be accounted for the fact that students and children are accessing the Internet from campuses, Internet cafes or the parental home. However, by 2012, Internet usage by income group had begun to increase in higher income bands. On the other hand from data[38] relating to the regional distribution of Internet users in China from October 1997 to January 2005, it can be seen that Beijing and Shanghai started off with a high proportion of users, Sichuan and Hebei with a low percentage of users, Guangdong, Shandong, Jiangsu, Zhejiang with a medium percentage of users but through time these provinces have lost percentage share (Jiangsu, Hubei, Shanghai, Beijing, Hebei) to other provinces or stayed at relatively the same level.[39] Another distinct feature of the data[40] is that Coastal provinces (Guangdong, Shandong, Jiangsu, Zhejiang) and well-developed municipalities (Beijing and Shanghai) have a relatively high percentage of the total number of Internet users in China, while any growth in the number of Internet users in Western provinces such as Yunnan, Gansu and Xinjiang has remained almost static. This suggests that the Internet facilitates knowledge creation mainly in the Coastal region and in well-developed urban centres nearer to the sea than the Western and Central regions of China. The data[41] for the regional distribution of Internet usage in China up to 2012 suggests that even in 2012, Internet usage remained a predominant activity of the Coastal or East China in comparison with Central China and Western China. The static or low growth of Internet users in Western China may be due to income effects, power supply constraints and low levels of educational attainment. The post-1978 reform policies have facilitated the development of the Coastal regions and some of the certain municipalities of China. The economic prosperity associated with the Coastal regions has aided in the spread of Internet use by males, students and dependents of income earners, those with a high school/lower or undergraduate degree education and those aged under thirty. Further, it may seem that the provision of the infrastructure associated with the Internet is more easily facilitated in more urbanised areas. This contention is supported by the trend in the urban–rural penetration rate data.[42] However, while Internet usage has remained the preserve of the urban sector, the growth in its usage has increased from 2008 to 2012 for both urban residents and rural residents. This may suggest that incomes may be increasing at the same time that infrastructure is also improving.

In China, the Internet has become a medium by which knowledge is being desseminated to students studying online courses. According to available data,[43] a variety of courses and subjects are studied using the Internet as a method of delivery. The most popular of these courses in terms of total enrolments is Management. The Internet would be an ideal medium to deliver education to the interior hinterland, where the geographical features of the land mean that the delivery of education by conventional methods is difficult compared to its delivery to the Coastal regions. The Internet can thus act as a facilitator of knowledge creation in the interior of China. This aspect of the delivery of education in China is identified because, due to its geography, the delivery of education to sparsely populated Gansu is difficult. The use of a technology such as the Internet in delivering education will assist in eliminating the income disparities between China's interior hinterland and the prosperous Coastal region, by facilitating innovation and economic growth. However, the problem most often associated with a freely available Internet resource is that it may be used to stir political dissent within the country. It is perhaps for this reason that the Internet in China is tightly regulated by the government.

In June 2007, the number of Internet users in rural China had reached 37.41 million out of a total rural population of 737 million.[44] However, in urban areas, the number of Internet users numbered 125 million, representing an urban penetration rate of 21.6%.[45] The ownership of computers among rural and urban residents is also a similar story. In December 2006, while only 2.7% of the rural population owned computers, this figure was 21.6% in urban areas. The year-on-year increases in computer ownership were only 0.6% for rural areas, while for urban areas this figure was 5.7%. Nevertheless, by 2012, the Internet penetration rate in urban China had increased to 48.7%, while the Internet penetration rate in rural China had only increased to 23.7% of the rural population, as shown in Table 3.8. This may be due to the lack of technical infrastructure in rural areas to facilitate Internet usage or perhaps because people's lifestyles have developed no need for Internet usage as of yet. Moreover, people living in rural areas may lack the skills as well as the educational level to be able to access and use the Internet. Nevertheless, the main characteristics of rural Internet users are that they are predominantly male, below the age of thirty with at least a senior high school education.[46] The first two characteristics are borne out by the analysis above, but not the latter. This may be because the data has not been analysed in terms of rural or urban sectors, but at an aggregate level by region. But, the findings in the analysis above and the findings of the CINIC (2007) report suggest that more investment needs to take place in both the education of the rural population and in the Internet infrastructure in these areas.

Research Institutes and Corporate R&D

The reform efforts of the Chinese government with regard to research institutes since 1978 have been geared towards increasing the spillover of knowledge creation into the productive sector of the economy so that economic growth in China will be dominated by innovation and invention. Indeed, five industries were earmarked by the Chinese government for strategic development.[47] These industries include bio-technology, e-business and knowledge-based services, software, design of integrated circuits and clean coal. The growth of these sectors requires a high level of innovation and invention in order to be internationally competitive. The ratio of corporate R&D increased by 50% over the 1990s (NBS 2002). This is significant, and the implication is that R&D spending by enterprises has overtaken R&D spending by the government. However, the increase in R&D spending by enterprises has been the backdrop to a shortage of core and advanced technology.[48] The government attempted to resolve the issue by transforming the nature of research institutes at the end of the 1990s.

After 1949, all research work was carried out in a number of institutions and all funding was provided by the central government. Such funding was provided for research carried out by sections of various ministries, the Chinese Academy of Sciences, universities, research carried out by central government departments and S&T research carried out by local government. Before the 1978 reforms, most state-owned enterprises had attached research units. However, all research activity was geared towards the innovation and invention of production techniques and processes as opposed to product innovation and invention. This was a direct consequence of central planning and a lack of competition amongst state-owned enterprises. There was no need for product invention or innovation because there was 'no consumer'. However, as a result of the 1978 economic reforms, two important changes were introduced with regard to science and technology and research institutes in China. These changes included the science and research responsibility system and the contract on charge system. The implication of these two changes was that research was carried out only on those projects with an NPV greater than zero, and individuals carrying out the research could benefit economically from their research. The next major reform with regard to research came in 1985 when the State Council offered a 'Decision on the S&T System'.[49] The implications of this reform were threefold. Firstly, for the first time, the government stipulated that the results of research should be used for profit. Secondly, institutes which exploited technology were encouraged to join forces with manufacturing factories or spin-off into manufacturing units themselves. Thirdly, the government encouraged the importation of technology to improve existing productive capital or the implementation and use of new productive capital. As Kong (2003) notes, the major impact of the 'Decision on the S&T System' was that research became profit orientated and central government could no longer be relied on for funding the research work of institutes. The impact of this reform was to incentivise entrepreneurship and knowledge spillovers. The next major reform of research work in China came in 1992 following the inauguration of the socialist market economy in China. In order to take advantage of the earlier reforms of the research institutes, the government expected the institutes to implement organisational innovations. In order to encourage the research institutes to implement these organisational innovations, the government instituted the 'S&T Progress Law of PRC' and the 'Climbing Programme'.[50] As a result of the implementation of laws and programmes by the government, a number of changes to R&D activity in China occurred. Firstly, state-owned research institutes implemented the rent responsibility system. This allowed researchers to monetarily benefit from the activities of their own research efforts. Secondly, research institutes became commercialised in nature, but their legal status only changed in 1999. Thirdly, one hundred research institutes were granted S&T import and export rights and the right to engage in foreign trade. Finally, central government encouraged the development of technological industry zones and private new technology enterprises.

The next major reform of research institutes in China occurred in 1995 when the government introduced the 'Decision on Accelerating S&T Progress' and the 'Decision on Profound S&T System Reform'.[51] These reforms were designed to endow the research environment in China with structure and incentives to innovate. For example, it was proposed that all research activity in China should be organised around a core of universities and institutions. The new reforms were also intended to ingrain economic awareness into all research activity. Moreover, it was intended that the focus of research activity was to be on the development of innovations with a high-technology content and the commercialisation of all research activity. In 1999, the 'Bayh–Dole Act' came into effect in China; its effect was that Chinese institutes conducting research using Chinese government funding could patent the research results. This led to more collaboration between research institutes and enterprises through joint venture vehicles (Boeing et al. 2016). In 1999, research institutes could be categorised by those which exploited technology and those which carried out research with a public orientation. Kong (2003) notes that the main changes made to the institutes were with regard to organisation, system and structure. As a result of these reforms, 242 research institutes had been transformed into enterprises by the end of 2000. Following the successful transformation of the first group of research institutes, the government began the transformation of a further one hundred and thirty-four institutes in the latter half of 2000. The government saw the need for the transformation of the institutes as a way to accelerate the flow of research results into the productive sector of the economy. In this way, economic growth in China could take place through knowledge creation, rather than imitation. However, although economic indicators such as total income and profits of research institutes increased, salaries of researchers and taxes paid by the transformed institutes to the central government increased disproportionately, Kong (2003) suggests that the innovative and inventive capabilities of the research institutes suffered as a result of the transformation of research institutes organisation, system and culture due to reform. This may be due to the increased competition between institutes to produce research which would impact on the Chinese economy through the productive and manufacturing process. Furthermore, the competition for funding of projects, following the loss of central government funding, meant that the number of possible research projects fell to those with a positive NPV. After China joined the WTO in 2001, there was a surge in R&D investment, primarily because Chinese firms could capture more market share abroad through product and process innovation. The latest reform of China's R&D and innovation policy by the state was the 'Medium- to Long-Term Plan for Science and Technology Development' from 2006 to 2020. This specific reform brought considerable changes to China's innovation policy with the aim of improving the Chinese economy's technological sovereignty (Boeing et al. 2016). Furthermore, the objective of the 'Medium- to Long-Term Plan for Science and Technology Development' (MLTPSTD) is to shift the burden of promoting economic growth from investment to innovation (OECD 2014). However, the MLTPSTD is not a policy in isolation. It runs congruently with the 'State Medium- to Long-Term Human Resource Development Program' (2010–2020) and the 'State Medium- to Long-Term Educational Reform and Development Program' (2010–2020). The three congruent and integrated programs represent a mechanism for integrated innovation which will allow China to become a powerhouse in innovation through the improved management of the development of human resources, an increase in the number of skilled personnel and scientific projects which result in innovation (Angang et al. 2014). China's R&D reforms and innovation policy as ensured that China is the number one economy in the world with regard to the total number of patent applications received annually by the domestic patents office.

This has been the case since 2011 (Boeing et al. 2016). At the moment, China is second only after the USA in terms of value in monetary terms with regard to national R&D expenditure.

Kong (2003) finds that the number of LMEs undertaking S&T research activity has fallen since 1991. LMEs instead focused on things like customer service rather than improving the technology of their business. This implies that research activity was contracted out to universities and research-oriented enterprises. This may explain why the revenue from the sale of new products by LMEs between 1991 and 2001 increased by only 6.41 times.[52] Nevertheless, Kong (2003) finds that in the ten-year period 1991–2001, enterprises themselves funded their own S&T research work, while the funding of research projects by central government and bank loans decreased. However, it is because enterprises have had to fund their own research that Kong (2003) finds that research activity by LMEs has fallen since 1991. Thus, while overall corporate R&D in China has increased since the commencement of reforms, this has been against the backdrop of decreased research activity by LMEs themselves.

Despite the reforms, data[53] suggests that government funds and enterprise funds account for the major funding sources for science & technology (S&T) activity in China. It can also be ascertained that while government funds account for the second largest source of all S&T funding in Western China, enterprise funds account for the foremost source of all S&T funding in Coastal China. This suggests that an entrepreneurial motive for the creation of knowledge and its commercialisation is greatest in Coastal China. Empirical work suggests that differences in the networking activity of entrepreneurial firms are a good determinant of inter-regional growth differences within a country (Huggins and Thompson 2015). An analysis of available data[54] suggests that the Eastern/Coastal China has the greatest number of scientists and engineers, and institutions of all three types [institutes of higher education, LMEs and independent research] employ the largest number of scientists and engineers in the East, with large and medium enterprises accounting for the largest employment of scientists and engineers. With regard to the number of scientific and technical personnel in state-owned and collective enterprises and institutions by region, the data[55] suggests that the Coastal region dominates in the employment of scientific and technical personnel in all sectors except in the agricultural sector, in which the Western region dominates. This could be because agriculture dominates manufacturing in the Western region and there is less inclination there towards the tertiary or knowledge-based sector. However, in all three regions, the number of scientific and technical personnel employed is greatest in teaching, whereas scientific research employs the least. This may be because scientific research requires more qualified scientists and engineers, whereas scientific and technical personnel are less qualified technicians, which is why they are so plentiful. Moreover, according to the data,[56] it is clear that the Coastal, Central and Western regions of China have the greatest number of the full-time equivalent of R&D personnel in descending order, respectively. Similarly, in that order, the R&D personnel in the Coastal region are more focused on experimental development which tends to be more practical than the other types of research indicated. This focus could be due to the fact that there is more focus on manufacturing in the Coastal region. On the other hand, the full-time equivalent of R&D personnel involved in either applied research or basic research is the lowest for all three regions in descending order.

Invention in Geographical Space

Patents

Figure 4.8, Chapter 4, Vol. 1, shows that innovation and technology are the key driving force of an economy which is at its PPF. Such an economy cannot grow any further through the greatly reduced impacts of externalities brought about by improved transportation infrastructure. It was discussed in Chap. 4, Vol. 1, that in a developed economy markets are less fragmented and therefore the impacts of externalities and spillover effects brought about by improved transportation infrastructure would not have the same impact on economic growth that they would have in a country like China which is characterised by fragmented markets. In China, externalities generated by infrastructure investment will tend to merge fragmented markets.

The interpretation of the role of knowledge creation on economic growth varies according to which school of thought is followed. In Chap. 3, Vol. 1, both the neoclassical and endogenous strands of growth theory were evaluated. The effects of technology and innovation have for many years been downplayed because of the pre-eminence of neoclassical growth theory which considers technology to be a public good requiring neither capital nor labour for its formation. Economic growth due to knowledge creation remains a black box according to this approach, suggesting that there is no role for government in this regard. However, the advent of endogenous growth theory caters for the dynamic effects of technology and innovation on economic growth, thus assigning government a key role in its facilitation and economic development.

A key measure of innovation and technological progress is the number of patents which are granted by the Chinese patent office. In the case of China, the distribution, number, types and regional distribution of patents can be seen as a sign of regional development. The patent system in China is organised in such a way that it encourages the diffusion of technologies.[57] Furthermore, Sun (2003) has carried out three sets of regression analysis using 'Patents in the US', 'Chinese IMPORTS' and 'DISTANCE' of the patent registering country from China as the dependent variables, regressed against 'Total Patents', 'Inventions' and 'Utility & Design Patents'. The results of the regression analysis suggest that demand quantities such as imports rather than FDI are important determinants of foreign patent registration in China. However, in his regression analysis, Sun (2003) has left out FDI as an independent variable because used with 'IMPORTS' data it would have caused multicollinearity problems and consequently made the results misleading. It is because Sun (2003) has not sought to use data on FDI in his analysis that his conclusions are open to question. Another empirical study has found that foreign ownership of a domestic Chinese firm has a strong effect on the volume of patent registrations by that firm (Choi et al. 2011).

In China, for statistical reasons, patents are classed under three headings. Firstly, patents may be classed as invention patents, which include new products or methods. Secondly, patents may be classed as utility patents, which include new shapes or new structures of products. Finally, patents may be classed as design patents, which include new shape, design or colour of a product. Clearly, the first type of patent, as an indicator of innovation, has a bigger impact on the economic growth of a country than the second or third categories. The literature is suggestive of the fact that in China there is a geographical concentration of patents in two types of provinces.[58] The first type includes the Coastal provinces such as Guangdong, Fujian, Zhejiang, Jiangsu, Shandong and Beijing municipality. The second type of province includes populous provinces such as Sichuan, Hunan, Hubei and Liaoning. The distribution of patents between East, West and Central China is shown in Fig. 4.9, Chapter 4, Vol. 1, which illustrates aggregate data on domestic invention patents granted by region. At the aggregate level, it is clear that centre of invention is East China. This may be reflected by the three innovation systems within that region. Nevertheless, the problem with aggregate data is that it excludes provincial effects at the microlevel. Furthermore, aggregating data misses out fine points such as that the populous Coastal provinces are the regions of innovation. The implication is that a large population base allows for an increased number of human–human interactions and an increased frequency for the exchange of ideas, leading to increased innovation and invention. However, although the population is useful in considering human interactions, the population density is more relevant for this purpose.

Sun (2000) has carried out an analysis on the spatial distribution of patents in China using data on demand-pull and technical infrastructure. He defines the latter has a network of firms which provide business services, technical knowledge and R&D. The definition suggests that a clustering of these activities facilitates invention in both products and methods of production. Moreover, Sun (2000) suggests that the location of business services within an innovative cluster is critical for the functioning of that centre of innovation in commercial terms because of the need for the marketing of new products, technologies and methods. Therefore, the clustering of demand and supply factors creates agglomeration effects, economies of scale and an environment in which agents interact frequently. Thus, Sun (2000) suggests that the distribution of patents implies that invention and innovation are urban processes. This view is in contrast to Sigurdson (2004) who suggests that invention and innovation are processes that do not depend on the notion of geographical distance or the concept of urbanisation, but rather clustered more on functionality and by sector. This paradox can be resolved by recalling a number of facts. Firstly, government policy in the 1980s and 1990s favoured the commercialisation of research results with funding for projects being determined by the practicability of research results. Secondly, in the East of China, the majority of the funding for S&T projects comes from enterprise funds (LMEs), and the East of China is much more prosperous than Central or Western China, presenting more funding opportunities for S&T projects. Finally, most of the new technology parks were set up in urbanised provinces and municipalities. These three factors account for the finding by Sun (2000) that urbanised areas are centres of innovation. Sigurdson (2004) on the other hand looks at innovation from a global perspective, where clusters of knowledge creation and innovation do not have to reside close to clusters of manufacturing in geographic space.

Intuitively, this can be explained by the ready availability of telecommunications and Internet access, which ensures that R&D can be geographically independent of centres of manufacturing. Clusters of manufacturing exist in geographic space to allow firms to take advantage of agglomeration economies, the division of labour and specialised production. However, the creation of new products, e.g. a bioengineered drug, may involve an expensive investment over a lengthy period of time with no definite chance of success. Table 2.1 extrapolates the differences between manufacturing and research.

Sun (2002) has also analysed the sources of innovation in China's manufacturing sector. In his analysis, Sun (2002) uses three measures of innovation. These include patent certifications, new product sales and product applications. These measures were the dependent variables in the three sets of regression analyses carried out by Sun (2002). The dependent variables were regressed on a number of independent variables including the number of enterprises by region, number of

Table 2.1 Differences between manufacturing and research

Feature	Manufacturing	Research
Type of labour	Unskilled	Highly qualified
Productivity	Large	Low
Cost	Low	High
Probability of success	High	Uncertain
Duration	Short	Long
Economies of scale	Specialisation/Division of labour	Similar projects/Knowledge gained reapplied

Source Author

employees, total sales of enterprises, new product sales, patent applications and patent certifications. The major independent variables were the number of enterprises with in-house R&D, expenditure on technology absorption, expenditure on domestic technology markets and gross transactions value in local technology markets. New product sales are an important indicator of the effective commercialisation of the invention and thus, contribute to GDP. The results of Sun (2002) indicate that creativity in Chinese industry, as measured by granted patents, is accounted for by the in-house R&D activity of Chinese enterprises rather than by spending on imported technologies. Furthermore, Sun (2002) argues that the innovation in China is fragmented, ineffective and prone to regional variation because of the expenditure on the absorption of imported technologies. This conclusion supports the argument that while China may have a number of regional innovation systems, in the Coastal regions, it lacks a national innovation system. Sun (2002) makes policy recommendations on the integration of research. Nevertheless, despite the findings of Sun (2002), in China the data[59] suggests that there is a great emphasis on R&D activities and new product development in high technology industry. The focus of this strategy is on electronic and communication equipment, medical and pharmaceutical products, electronic computers and office equipment and electronic components. However, the adoption of new technology by consumers, such as 3D printing, is not dependent on the level of education but is dependent on age as absorptive capacity begins to decline as age increases (Wang et al. 2016). Furthermore, according to the Wang et al. (2016), design-oriented consumers are more likely to adopt 3D technology despite their level of education.

Scientific Papers

While the number of patents granted by region is an important indicator of invention and innovation with direct relevance to the commercial world, the publication of scientific papers is an equally important indicator of regional and institutional knowledge creation often neglected in the literature. Furthermore, data relating to the publication of scientific papers in China has not been subjected to rigorous analysis, perhaps in the same way as patent data.

The regional distribution of scientific papers taken by the major referencing system based on discipline is another indicator of knowledge-intensive activities. According to the data,[60] it can clearly be seen that the Coastal region leads in all three types of paper (ISTP, EI and SCI)[61] taken up by the major referencing system. Furthermore, a detailed analysis of the data[62] associated with scientific papers published by discipline and by type of institution clearly shows that the centres of knowledge creation in all disciplines except astronomy, earth sciences and medical care are universities. If it is now assumed that universities are responsible for a disproportionate amount of knowledge creation and that greater student enrolments/numbers of regular institutions of higher education occur in the Coastal region of the country, then it is safe to refute the argument that knowledge creation is only due to the activities of MNC's in that part of the country. In the context of the number of schools and students in undergraduate or specialised courses in institutions of higher education by region in 2010, the data[63] confirms the view that knowledge creation is embedded in the Coastal region because this region has the highest number of degrees conferred, graduates with degrees or diplomas, enrolments and entrants into educational institutions as well as the highest number of schools. In this context, the Coastal region is followed by the Central and Western regions in descending order.

The findings, which have been established, contradict the literature to an extent. In its' current mode of economic development, the Chinese economy has moved from an economy manufacturing low-technology exports to one manufacturing high-technology exports through the transfer of technology from foreign MNC's, either through joint ventures or the reemployment of trained Chinese personnel from foreign MNCs to domestic companies. However, endogenous Chinese innovation seems to be taking place only in manufactured goods with low-technology content.

Jakobson (2007) writes 'in 2005, 88% of China's high-tech exports were produced by foreign corporations. So globally China is a borrower, not a creator of technology. An innovation system needs to be built that can transfer innovation into economic growth and welfare'. Physical [roads, railways, telecommunications] and soft infrastructure [Education] are key factors in the development of innovation systems and the development of both forms of infrastructure goes hand in hand with government policy towards creating an innovative economy. Kroeber (2007) notes that China is not yet a high-tech powerhouse. This is due to three reasons. Firstly, the process of production encompasses the final assembly of low-value goods. Secondly, foreign MNCs dominate the economic landscape. Finally, innovation in the Chinese economy is limited. Figure 2.1, above, shows the inter-linkage between Social Capital, infrastructure, knowledge creation and knowledge spillovers in contributing to overall economic growth in China.

It would be useful at this point to surmise some of the key points which have been established in this chapter. Innovation systems, according to theory, can be categorised as Marshallian industrial districts, GREMI or regional innovation systems which rely on location on the spatial plain. A common theme with regard to innovation systems is that innovative agents have to be proximate in order to facilitate innovation. A classic example is Zhongguancun in Beijing. Regional innovations systems in China number three. These include the Bo Hai Rim, Pearl River Delta and the Yangtze River Delta. Nevertheless, an argument that innovation is geographically independent has been countered by an argument which says that it is. However, the key to understanding innovation systems is the concept of the competence block. A

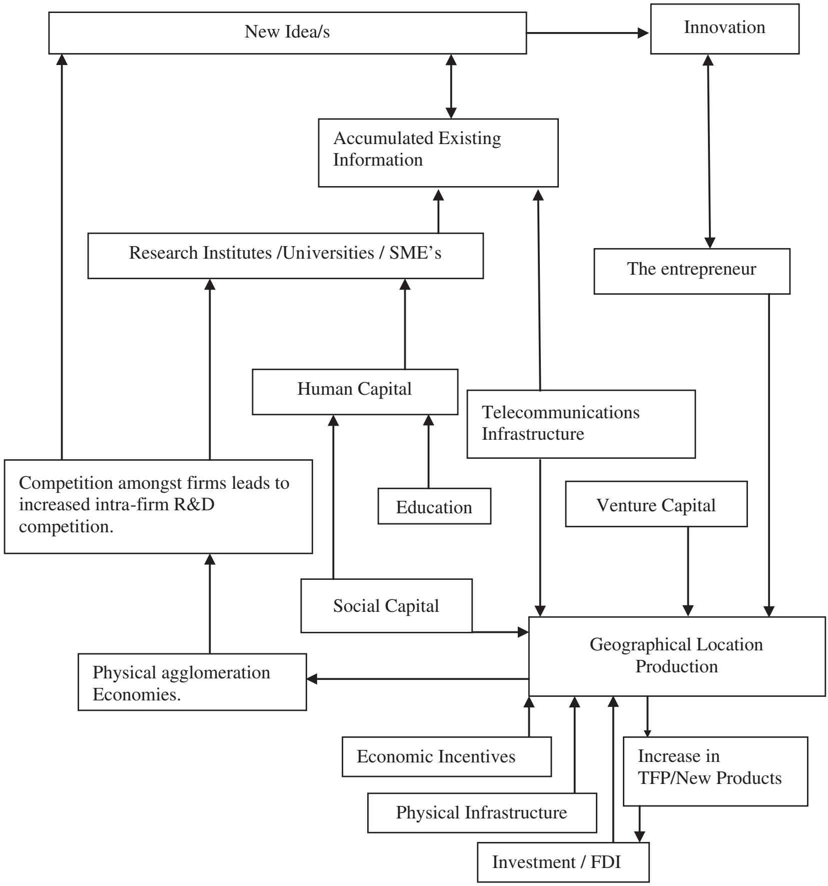

Fig. 2.1 Invention, innovation, knowledge and economic growth. *Source* Author

competence block has key factors associated with it. In this regard the role of telecommunications, the Internet and R&D in innovation in China was evaluated. Telecommunication, pre-1978, was not a profit-oriented sector acting as a civil population control mechanism as well as being restricted to military personnel and party cadre. Post-1978, the importance of telecommunications to commerce was realised and the necessary reforms put in place. The Internet is still very much an urban phenomenon; its use is being restricted to the Coastal region of the country. The rural uptake of the Internet and computers is constrained by the lack of skills of the rural population as well as a lack of ICT infrastructure in the rural economy. With regard to R&D, the government focused reforms on maximising the spillover of research in institutions to commercial enterprises. The way in which this was to be done was to encourage entrepreneurship among academia. Finally, it has been recognised that infrastructure is essential for the development of innovation systems. In China's case, a lack of a nationally integrated infrastructure network has prevented the development of a national innovation system. The following chapter will evaluate government policy with regard to education and other institutions which have impacted on knowledge creation and spillovers at the aggregate level with specific reference to innovation systems and the competence block.

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