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PAPER

Is R&D Upgrading China from Imitation to Innovation? An Institutional Analysis of Absorptive Capacity

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Abstract
With its massive investment in R&D, China is generally believed to be getting out from the stage of little in-house R&D, building up more R&D capability quickly, and will gradually become powerful in its own in-house R&D so as to remain globally competitive with its own technology. This paper evaluates China's innovation capability at the firm level, with consideration of the overall situation of R&D activities carried out by firms in China. It is true that many Chinese local firms have jumped from the OEM stage to ODM stage, and many private and State-owned firms begin to have heavy R&D investment as well. But these product design and R&D activities seem to stagnate at a halfway level. Also some high-end R&D efforts seem to be shrinking. Though most Chinese firms, through a long period of process of technological learning and capability accumulation, finally begin to invest in R&D and carry out relevant projects, the quality of R&D activities is not so well achieved. The low quality of R&D investment of Chinese firms is due to the absence of absorptive capacity, i.e., the high quality external linkages established around Chinese firms, which in turn impedes the efficiency and effectiveness of in-house R&D projects. Such an absence of absorptive capacity or efficient innovation linkages has its institutional reason in the Chinese context. Chinese policy makers shall deepen their perspective on the so-called national innovation system, discover and tackle the real linkage problems which are depressing China's innovation capacity right now.

Keywords R&D investment - China - absorptive capacity - innovation - institution

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1. Introduction

Macro statistic data shows that China has recently made huge progress in science and technology development. Its number of patents, number of publications, and ratio of R&D expense over GDP are all impressive. Its gross domestic expenditure on R & D jumped from 1% of GDP in 2000 to 1.75% of GDP in 2010. Amount invested in R & D multiplied by 6.6 between 2000 and 2010 (reaching 700 billion Yuan). There are 3.1 million people working in R & D in 2010. It ranked number 1 in terms of patents registrations: 526,412 applications were filed in China with an increase of 41.3% in 2012. Since the reform of 1979, China has its S&T policy focusing on science and technology as premier force of production, and enacting the nation through science and education. From late 1990s, the Chinese government implemented a series of policies to build an "innovative nation", under the strategy of "indigenous innovation". According to the Chinese official definition, indigenous innovation includes original innovation, integrated innovation, and innovation based on introduction, assimilation, and absorption of foreign technology.

There is no doubt that from the end of 20th century China is becoming a world giant in R&D, but does the country will naturally weigh the same in innovation soon? On one hand, the success experience from East Asian economies, such as Japan, South Korea, and Singapore seems to give a "yes" answer. Innovation depends on the translating and commercializing of inventions (patents and publications are most obvious forms) into new products by firms. The firms in all these economies have made intensive investment in in-house R&D or other R&D equivalent activities for creating new products and services in market, then rapidly moved their whole economies up to innovation ladder. South Korea is even ranked as the most innovative country in the world in 2013. On the other hand, firms from Taiwan and Hong Kong developed active and closed interactions among their networks of firms, instead of increasing dramatically their formal R&D investment. Yet these "dragon" economies have been also approaching the innovation-driven stage. R&D for their innovation capabilities seems not to be a necessity. This paradoxical view of R&D is due to the fact that usually people substitute "innovation" simply and directly by "R&D" in assuming a country's scientific and technological capabilities become sufficient conditions of its innovation capacity. However, more detailed analysis shows that R&D is just one of many inputs in the complicated process of innovation; and scientific and technological capabilities need to be integrated into a country's production system to make firms innovative, especially for those in a more or less globalized competitive market. From a national economic development perspective, R&D itself is hardly to be said as a purpose, but rather a means which can lead the country to a new growth model. What finally counts for a country is the economic growth driven by its competitive firms as a result. If it is important to know the state of art of China's R&D activities as an "input" and its patents and publications as "potential sources", it should be even more important to detect the dynamic and innovation capacities of Chinese firms as an "output" of these efforts.

Thus this paper discusses how China's R&D investment with its State capitalist style is influencing its move from imitation to innovation. After reviewing some literature and defining the key concepts such as absorptive capacity in Part 2, Part 3 gives a qualitative analysis of R&D investment of China. First, China's innovation & technology policy since economic reform and opening are described in order to provide an institutional framework, with emphasis on the recent efforts and policies on R&D investment as driving force of overall industrial upgrading. The Chinese State has a full intervention at national and local levels in the domain of science and technology development to a variety of enterprises (developing endogenous projects, assimilating foreign tech transfer, as well as inserting in global value chain, etc), especially through its State-owned enterprises (SOE). Then statistics and stylized cases are used to evaluate the nature and characteristics of firms' innovation capacity. This part reveals that the development of innovation capacity of Chinese firms through increasing R&D investment is blocked by the weakened formation of "absorptive capacity" and external linkages outside firms' organizational boundaries. And the lack of such absorptive capacity is not due to the incompleteness of Chinese national innovation system, but the specific institutional setups in the Chinese context: the so-called Chinese capitalism is characterized by the conjunction of an opportunist State and a networked society which together exclude institutionalized trust among firms and organizations. Therefore the quality of innovation linkages impacts negatively on R&D capacity deepening of Chinese firms. Based on this observation, Part 4 identifies some potential targets for China's innovation policy makers and Part 5 summarizes the main findings from a broader point of view.

2. Literature Review: Detailing the Upgrading from Imitation to Innovation

At macro level, the perspective of national innovation system (NIS) focuses on interactive institutional arrangement upon which firms develop their innovation capabilities. The institutional aspect occupies most of the OECD reports. Indeed, within this enumerative vision of institutional system, the micro-dynamics underlying technological development and interaction between economic and technical actors disappear. Technological capability is translated into national plan set out by official innovation policy. A country is supposed to gain innovation capability through completing a national institutional structure composed by various functions, such as provision of R&D results, formation of new product markets, articulation of new product quality requirements, creating and changing organizations, networking through markets and other mechanisms, creating and changing institutions, incubating entrepreneurial activities, financing of innovation processes, and provision of consultancy services (C. Edquist, 1997). If innovation capacity emerges through only the building of such a system, China should have already reached the level since the country had finished the whole picture of NIS with these pieces of institutions many years ago. Nevertheless, as Kline and Rosenberg (1986) rightly pointed out, innovation is a complicated linked-chain process of activities from research to market need detection, invention & design, development, engineering, production, distribution, and market commercialization, etc. The successful process is determined by many critical linkages across these activities in the economy, such as linkages among the internal activities of firms at different stages of innovation development, among scientific activities and industrial invention & design, among firms' market detection activities and society's research activities, among a society's research activities and internal development activities of firms, and finally among distributing & consuming activities and firms' market searching activities, etc.. Therefore, a country's innovation capacity shall not be evaluated at simply aggregate level with statistical indicators or official policy announcement, but at a more down-to-earth firm level which reflects often the unofficial but realistic behavior and quality of linkage building by innovation actors within the country.

Even at the firm level, there exist two different opinions about how firms in catch-up economies (latecomer firms) can advance from imitation to innovation. One can be called "sustaining perspective" and is represented by the works of A. Amsden and M. Hobday. Amsden (Amsden, A. 1989; Amsden, A. H. and W-w. Chu 2003) pointed that technological learning at shop-floor of firms is the original driving force of such an upgrading. She detailed the three aspects of technological learning as speed of learning (how rapidly foreign technology is borrowed, which depends on investment rate of firm, investing in foreign design, and arrangement of technology acquisition or transfer), scale of learning (whether foreign technology is utilized at the appropriate scale, which depends on how fast the market is growing and whether firm is producing at an appropriate scale), and efficiency of learning (how efficiently foreign technology is employed, which depends on firm's experience related to cumulative production and the effects of learning-by-doing on firm). Very much in line with Amsden, Hobday (1994; 1995) shows how electronics companies in the four dragons of East Asia link their technological learning to export markets; specifically, subcontracting and original equipment manufacturing (OEM) mechanisms acted as a training school for latecomers, enabling them to overcome entry barriers and to assimilate manufacturing and design technology. In contrast with R&D and design-led strategies, latecomer firms began with incremental improvements to manufacturing processes which led on to minor product innovations. Since the development of technological capabilities during catch-up is a learning process, firms' internal development and design capabilities grow as it moves between successive stages from OEM to ODM (original design manufacturing) and OBM (original brand manufacturing), but there is no role for research. On the basis of the East Asian experience, the sustaining perspective asserts that successful latecomer firms may go through a kind of 'reverse product cycle.' They begin with simple assembly processes but gradually and systematically accumulate the capability to modify, design and build their own new product and process technologies progressively. Customers play a major part in this cycle, which proceeds through successively higher value-added forms of production.

The other opinion about imitation to innovation can be termed as "disruptive perspective". Through the case of a Mexican company Vitro, the largest glass company in the world after Owen-Illinois, Gabriela Dutrénit (2000; 2004) argues that there is no simple linear progression from the early stage of accumulation of the minimum levels of innovative capability to the management of knowledge as a strategic asset and the deployment of core capabilities. On the contrary, the transition process is complex and while latecomer firms make that transition, they have to build deeper and broader specialized knowledge and develop new ways of strategic integration. The innovation capability can be reached only through a specific kind of "spontaneous" actions rather than a succession of different stages of formation of technological capabilities. In using South Korea's transition from imitation to innovation, Linsu Kim (1997; 1998) argues that cumulative learning of firms takes place through learning-by-doing, but discontinuous learning takes place in crisis. Effective learning firms (such as Hyundai) construct a crisis (by setting ambitious targets) intentionally to develop organizational systems and manage their processes to make the crises truly creative. Although creative imitation (producing knockoffs and clones) through reverse-engineering is still important, it is the continuous increase in in-house R&D investment that plays the key role in leap from coping imitation to indigenous innovation. He suggests that latecomer firms shall intensify dramatically their formal R&D activities to engage in independent product innovation and participate actively in global alliances.

More empirical studies support the disruptive perspective in concluding that explicit investment in endogenous and formal R&D activities of latecomer firms always matters, particularly when local firms intend to jump to upper level in the value chain. Li (2011) shows that investment by Chinese firms in foreign technology alone does not enhance innovation in domestic firms, unless it is coupled with own in-house R&D. In fact, R&D not only generates new knowledge but contributes to the firm's absorptive capacity. According to Cohen and Levinthal (1989; 1990), absorptive capacity is the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities. Absorptive capacity may be a byproduct of R&D investment or manufacturing or through training. Generally, it depends on the firm's own R&D. In big firms, specific R&D projects will often be triggered by practice (problems with a product, new user needs, problems with producing) but almost immediately attempts will be made going through its earlier work as well as looking for insights that can be drawn from outside sources. Therefore, absorptive capacity will in return condition the success and sustainability of its innovative activity, or R&D in the narrow sense. Because a firm's absorptive capacity influences the effects of appropriability and technological opportunity conditions on its R&D spending, it becomes the essential condition of R&D deepening.

The continuous reinforcement and development of absorptive capacity itself also needs appropriate conditions external to the firm. These external conditions are mainly the nature of linkages and interactions that the firm establishes with potential knowledge sources. Vertical linkages are interactions in terms of new product development with suppliers, buyers, end-users, channel members, and down-stream manufacturing customers, while horizontal links are collaborations with other companies, industrial research laboratories, public research institutes, universities, technical consulting firms, and even competitors amongst others. Together, the vertical and horizontal linkages are often termed as ecosystem of innovation of "world" of innovation. Though vertical linkages can be vital for elementary technological learning, horizontal linkages offer more opportunities for firms to gain access to complementary knowledge that tends to lead to more innovations. Vertical and horizontal linkages together can be termed as ecosystem or “world” of innovation (Arvanitis, R., D. Villavicencio, and W. Zhao, 2014). Shu (2003) uses examples of Taiwanese IT firms to show that these OEM/ODM manufacturers receive product specifications from their customers such as IBM, Dell and HP in terms of design, manufacturing and delivery of finished products, but their intensive horizontal linkages and interactions with other Taiwanese firms and public research institutions within the network were so important that it substituted partially the formal internal R&D activities. In fact, the horizontal linkage with other Taiwanese firms was found to be the most significant contributor to both the technical and marketing knowledge for commercial ends.

More precisely, the development of such absorptive capacity depends on the easiness and quality of linkage building. For firms, external linkages should be neither too difficult, nor too easy to establish. A survey about the South Korean automobile industry (Kim, 1997) found that compared with wholly-owned firms, joint venture firms were lag behind in terms of developing absorptive capacity, due to their easier access to technical knowledge from foreign partners. On the contrary, having no quick access to foreign technology, Hyundai Motor Company had to accumulate more prior knowledge, invest more resources in R & D resources, and adopt a more aggressive attitude towards knowledge learning and acquisition. As a result, Hyundai developed a stronger capacity of technology absorption and R&D than joint-ventures.

For upgrading to innovation, of particular importance is the quality, i.e., form and nature of these external linkages (Furman, J. L., M. E. Porter, and S. Stern, 2001). Absorptive capacity building needs sustained interactions that go beyond arm’s length market transactions and that involve more than the information about prices and volumes. These include what Lundvall (1988; 1992) called as user-producer interactions, i.e., direct cooperation and exchange of qualitative information based on mutual trust and codes of communication in relationship. Storper (1997) called these different types of linkages and interactions “conventions” and identified five forms: (a) inter-firm "hard" transactions, as in buyer-seller relations that involve market imperfections; (b) inter-firm "soft" transactions, as in the sharing or diffusion of non-traded information about the environment or about learning; (c) hard and soft intra-firm relations, as the bases for the functioning of large firms which are "internally externalized" ; (d) interactions in factor markets, especially labour markets, which involve skills that are not entirely substitutable on an inter-industry or inter-regional basis, i.e. where there are industry- or region-specific dimensions to workers skills; and (e) economy-formal institution relationships, where universities, governments, industry associations and firms are only able to communicate and coordinate their interactions by using channels with a strong relational-conventional content. Callon, Larédo and Mustar (1995) put them together under the concept of “socio-technical network”, which contains two elements: a) Form of coordination: acquisitions, purchasing, through licensing and contractual agreements, and inter-organizational relationships, including R&D consortia, alliances, and joint-ventures. b) Content of interaction: it may be written documents (scientific articles, reports, patents ...) , embedded skills (researchers , engineers from one firm to another ...) , more or less developed technical objects (prototypes , machines, products for final consumption ...), money (cooperation agreements between a research center and company , financial loans, paying customer of a good or service ...), and informal orders or exchanges (hierarchy and trust) .

Ultimately, laws, regulations, social rules and norms, technical standards and cultural habits constitute the institutional context within which firms and organizations interact. Such institutions may foster or hinder the interactive learning and linkage essential for absorptive capacity, R&D, and upgrading to innovation. Here institutions include not only the more formal laws and regulations, judicial decisions, and enforcement of contracts, but also the less formal norms, commercial conventions, and preconscious cognitive and ideational elements that are embedded in culture and widely accepted in a society (North, 1990). In fact, commonly held commercial norms and cultural conventions as informal institutions themselves often are the linkages and used to replace formal contracts, and a variety of legitimizing activities to secure the firm's position in the market. As all these institutions, interactive linkages, firms' absorptive capacity, R&D investment, and national innovation capacity co-evolve over time, they constitute the fundamental dynamic nature of the whole economy at a macro level (Nelson, 2008). The following analysis of China's situation is very much in line with this logic of institutional environment – external linkages – absorptive capacity – R&D deepening of firm.

3. Analyzing R&D Investment of China: Institution, Policy and Firm

3.1 The structure of R&D investment in China

Even China had no official statistics of industrial R&D before the year of 2000, the country's national R&D policy can always be described as a "Big Push" approach. Chinese government is capable of mobilizing massively all kinds of resources to invest in R&D activities. China has now the world's biggest number of professional R&D staff (3.2 million people) and its annual R&D budget has already been number 3 in the world since 2010. Potentially, the country has a stock of 51 million scientific and technical persons as human resources to get involved in R&D and the aggregate R&D expenditure was even accelerated after 2005 with an average growth rate over 20%. During 2000 and 2012, China's R&D intensity (ratio of R&D expense over GDP) jumped from 1% of 2000 to 1.97% of 2012 (see Table 1). In 2012, the country's R&D budget reached 1024 billion RMB Yuan, of which 74% was expended by enterprises. Its output value of high-tech industrial production has exceeded 1 trillion Yuan and counted more than 30% of its total export. The overall average annual growth rate for R&D expenditure of large and medium-sized enterprises has been more than 25% since 2006.

Table 1 China's national R&D Expenditure (2006-2012)

	2006	2007	2008	2009	2010	2011	2012
R&D Expenditure (Billion RMB Yuan)	300.31	371.02	461.6	580.21	706.26	868.7	1024
Ratio to GDP (%)	1.42	1.49	1.54	1.7	1.76	1.84	1.97

Source: National Bureau of Statistics and Ministry of Science and Technology (ed.), China Statistical Yearbook of Science and Technology (Beijing: China Statistics Press, various years).

Policy measures were implemented concretely over the country, often with fixed quantitative goals to achieve. For example, between 1997 and 2007 patent subsidies were introduced in 27 provinces to stimulate the usage of intellectual property rights and boost provincial and national patent statistics. The result was tremendous growth of patent applications. In 2010, China recorded 363,329 patent applications and 1,423,545 scientific publications with an average citation count of 6.21 times for the Chinese international publications (about 14.84 million papers), lower than the world average count of 10.71 times for international publications. Chinese industrial enterprises applied 266,000 patents, 10.2 times more of the patent application in 2000. The applications included 92,000 invention patents, 11.6 times more of invention patent applications in 2000. In 2012, patent applications reached 526,412, an annual increase of 41.3%, and made China number one in terms of patent volumes, although patenting in China has only a small impact on productivity growth and the problem of quality of research and its commercial relevance still exists.

However, with the expansion of R&D activities, China's R&D quality is problematic. For example, in most of the high-tech sectors, China's R&D intensity is lagging behind the major players in the world. In the aircraft and spacecraft industry, the R&D intensity just reached half of those in Germany, France and the United Kingdom. China's focus in R&D activities mainly concentrates on applied research and especially experimental development. Experimental development expenditure over total R&D spending increased from 68% in 1995 to 87% in 2008. In 2009, this ratio decreased to 82.75% and remained at 83.5% in 2011. The fact that most R&D expense was used in the experimental development showed that R&D activities in China mainly concentrated in the latter-end of R&D. Meanwhile, the expense of fundamental research in total R&D expense stayed at the level of 4.7% after 2009, even its absolute amount increased steadily after that year. Basic research might not have immediate commercial success, but is often essential for progress and constitutes the foundation for innovative products. China's spending on basic research as a percentage of the GDP is ten times lower than basic research expenditures in the United States. The weak fundamental research capability in China is reflected by the fact that China's patents and scientific papers per population are maintained on a low level compared to developed countries and also quality issues remain, though the quantity of scientific articles and patent applications are increasing rapidly. Regarding the famous growth of Chinese patents in recent years, the share of “invention” patents over total registered domestic patents fluctuated. It climbed up at 25.9% in 2004 and fallen to 22.7% in 2008, then jumped up to 34.8% in 2010. Besides, the Chinese patent explosion is driven by a small group of companies in the information and communication technology equipment industry.

Another characteristic of China’s R&D is the nature of activity. In 2009, 50.7% of national R&D budget was spent for developing brand new product, 30.3% for increasing product functionalities and improving quality, 6% for energy using reduction, 3.3% for improving labor productivity, 2.7% for pollution reduction, 2% for technical theorem research, and 1.7% for raw material using reduction. Roughly speaking, 80% of Chinese R&D budget was allocated for product innovation and 15% for process innovation, and 5% for long-term non-commercial development. Chinese R&D projects preferred much the short-term economic returns.

The major financial source of China’s R&D activities is government’s fiscal budget. In 2010 and 2011, the government fiscal source of R&D was 411.4 billion Yuan and 490.2 billion Yuan, representing respectively 58% and 48% of the national R&D expenditure. The shares of R&D expenditure by enterprises, government-owned institutes and public universities in national expenditure remain around 75%, 15% and 8% respectively, which indicates the current institutional structure of R&D activities. Chinese academic circle is made up of its 3900 research institutes, university laboratories, and national key laboratories (there are 220, mostly from universities). They are related, even intermingled with firms and work for corporate R & D in the form of research contracts. In 2012, this type of contract carries a total amount of over 600 billion Yuan in China. Regarding enterprises, in 2009, there were 36387 industrial enterprises which carried out 194,000 R&D projects. This number of enterprises having R&D was only 8.5% of total number of enterprises in China. Within these firms having R&D activities, 12434 were middle and large sized enterprises, representing 30.5% of total middle and large sized enterprises. All these R&D projects by enterprises spent 377.6 billion Yuan of which 85% were spent by middle and large sized enterprises. Averagely, enterprises in China spent 0.7% of their sales on R&D if they do, while middle and large sized enterprises spent 0.96% of their sales on R&D if they do. Among the enterprises having R&D activities, 4.8% were State-owned enterprises (1737) while they have 17.1% of industrial R&D budget (64.46 billion Yuan); 72.6% were non-State-owned enterprises (26418) while they have 56.5% of industrial R&D budget (213.44 billion Yuan); 22.6% were foreign invested enterprises, including investment from Hong Kong, Macau and Taiwan (8232), while they have 26.2% of industrial R&D budget (99.68 billion Yuan). A glance at the top Chinese companies in terms of R&D investment will show that most of them are State-owned enterprises who often get involved in national mega R&D projects, and the very few private companies are those whose names begin to be known in international market, such as Huawei, ZTE, Lenovo and BYD. These namely superstar private enterprises also participate in national R&D projects and undertake projects of new product development and technological studies (see Table 2).

Table 2 Top 20 Chinese Companies in R&D Investment (The 2012 EU Industrial R&D Investment Scoreboard)

	Company	World Rank	R&D Expenditure (Million Euros)	R&D Intensity (%)
1	Huawei	41	2906.5	18.6
2	PetroChina	68	1622.0	0.7
3	ZTE	99	1129.8	10.7
4	China Railway Construction	106	1039.2	1.9
5	SAIC Motor	151	702.3	1.4
6	China Railway	157	655.6	1.2
7	China Petroleum & Chemicals	169	596.4	0.2
8	Dongfeng Motor	223	424.3	2.6
9	CSR China	251	363.2	3.7
10	Lenovo	259	347.7	1.5
11	BYD	277	326.3	5.7
12	HBIS	299	298.5	1.9
13	China Communications Construction	310	283.8	0.8
14	Metallurgical of China	316	275.1	1.0
15	China CNR	323	267.7	2.5
16	Chongqing Changan Motor	392	197.6	6.4
17	Shanghai Electric	435	173.0	2.1
18	Dongfang Electric	494	147.3	2.8
19	Huyau Automotive	560	129.3	2.0
20	Great Wall Technology	643	107.7	0.9

Source: European Commission 2012.

The disproportionally high percentage of R&D budget for State-owned enterprises in China raises the question about the role of privately-owned Chinese domestic enterprises in technology development. Although China's privately-owned enterprises are expanding rapidly and in terms of absolute amount of R&D expenditure they are bigger than the State-owned enterprises, they are still lagging behind their State-owned counterparts in terms of R&D investment intensity. This is due to institutional constraints in China such as limited access to finance for non-State-owned enterprises and government preference of grants to State-owned enterprises.

3.2 Chinese State capitalism and institutional foundation of R&D

Macro statistics illustrates the extremely important role of Chinese government in leading and organizing R&D activities. Science and technology has been the cornerstone of China's development strategy since the 1980s, with a heavy initial emphasis on public funding of projects and investment in infrastructure. The structure of China's national R&D system has evolved from a central-planning model in which industrial R&D centers are located in ministries and organized by product. This structure separated and prevented interactions among scientific research and industrial application of R&D results. Since the mid-1980s government has encouraged closer integration among R&D institutes and science parks through investment in R&D clusters, and mergers of R&D institutes into enterprise groups (some such as Huawei, Datang and Lenovo subsequently evolved into major IT enterprises). As a result of such policies and China's openness to foreign direct investment, technology market transactions increased, as did in-house R&D. Outsourcing of science and technology from universities and research institutes to various types of domestic enterprises and to international enterprises expanded. Even in 1985 China has begun to reorganize its research and development (R&D) structure through reducing the numbers, downsizing the scales, and directing to lucrative purpose of its R&D institutions. During all the 1990s, the government encouraged the creation of all sorts of technological poles and industrial parks in the coastal provinces, then the scientific incubators and economic and technological development zones in major urban areas. The State financed and established national and local –level laboratories in all disciplines across the whole country. It controlled often directly the most important research laboratories, universities, and technical centers, as well as maintained in its arms the strategic and military sectors. Combined with national industrial policy, the Chinese government searched to build up "national champions" in terms of technology and research capability, often State-owned enterprises, but also some selected non-State enterprises, such as the Chinese giant companies in telecommunication industry, in petrochemical industry, and in transportation industry, etc. Since 1999, in adopting the concepts and frameworks of national innovation approach, China's national science and technology was transformed into innovation policy and the investment in R&D activities was greatly accelerated.

This "big push" of China's R&D expenditure since 2006 is in fact the result of the continuing investment efforts and R&D system reform of Chinese government. The same year, Chinese government announced a national "Mid to Long Term Science and Technology Development Plan, 2006-2020" with the following goals by 2020:

1. R&D input should achieve 900 billion Yuan
2. R&D/GDP ratio should achieve 2.5%
3. To build an "Innovative Nation"
4. High R&D input (annual increase rate of 10%)
5. High contribution of S&T to economy (more than 70%)
6. Indigenous innovation capability (reduce the reliance on foreign technologies from 60% to 30% in terms of licenses fees)

7. High S&T output like patents

Shortly after the announcement of the Plan, 99 supporting policies were presented which define concrete action plans to implement the strategy. Each supporting policy is under the responsibility of one lead government institution. Main priority is given to the development of technologies on energy conservation, water resources, environment protection, biotechnology, space and aviation, on the mastering of core technologies, on the comprehension of intellectual property in the manufacturing sector and on the strengthening of basic and strategic research. Alongside the identification of priority fields for future research activities in detail, the plan also defines 16 key projects (megaprojects), for example sending a Chinese astronaut to the moon or developing the next generation of large planes. In 2010, the Chinese government specified seven sectors as strategic emerging industries and reemphasized R&D investment in these sectors: (1) energy efficiency and environmental protection, (2) next generation IT, (3) biotechnology, (4) high-end equipment manufacturing, (5) new energy, (6) new materials and (7) new energy automotive.

Since 2006 China's innovation policy is labeled by the term "indigenous innovation". The Plan stated that it could be achieved through various approaches (including innovation through originally creating newness, innovation through creatively integrating technologies, and innovation through renewing imported and assimilated technologies), but the chosen term "indigenous" implies also some intentions of the Chinese government underlying its innovation strategy. First, "indigenous" implies "independent" and "self-determined" development of certain sectors identified as strategic through organizational coordination and heavy State investment in science and research activities of universities, institutes and State-owned enterprises. The implementation of such kind of science policy essentially divides technological R&D from industry production, with universities and research institutes actively engaged in downstream industrial projects and enterprises focusing on fulfilling assigned producing quota. Compared to developed countries where firms are a major source of innovation, the extensive involvement of public research in industry R&D in China constitutes an important character of its national innovation projects. As a result, the process of research–invention interactions in China is often unidirectional, with the knowledge flowing from university to industry.

But "indigenous" has another implication. It means also that the innovation should be original, not copied, and constitute intellectual property rights owned by Chinese organizations, especially Chinese enterprises. This concern reflects the facts that till now most of the so-called innovations in China are imitated from foreign technologies. In fact, during the 1990s till 2005, the Chinese technology strategy in practice can be summarized as "market in exchange of technology". Automobile industry is a typical case of this State strategy. In 1984, when China granted foreign auto manufacturers market access, it imposed foreign companies to form joint ventures with Chinese local partners, often State-owned enterprises designated by the authorities or to obtain their consent. China knew its car makers were behind the curve on precision manufacturing, so it hoped that the State-owned car producers could learn through contact with foreign partners to bolster domestic technology expertise, and gradually take ownership of the learnt technologies. Similar obligations of technology transfer were also imposed to heavy equipment vendors. As the country invested in acquiring aerial fleets, thermal and nuclear power stations and modern rail network, the State always required forming joint-ventures in order to have access to the most advanced technologies. Yet the Chinese car companies find it tough to improve their quality, in part because they lag on in-house research and development spending. Most Chinese companies just think several years out with their R&D spending and try to compete with international companies that are already doing R&D 20 to 25 years out. Chinese JV partners spent less on nurturing innovative engineering and design. Instead of creating a car from scratch, which would allow them to claim half the patent rights, Chinese JV partners will take existing foreign vehicle blueprints, make a few changes and call it a new JV auto: GM and SAIC's first JV car, Baojun 630, is built on the old Buick Excelle, while Dongfeng and Nissan's first Venucia vehicle is fashioned after Tiida. Chinese JV car companies want to gain quickly consumers' confidence through their reliance on foreign tech for quality. The government wants to see the domestic capabilities in car industry, but many of the Chinese companies are just happy on successful foreign joint ventures to contribute to their profitability.

To change this situation, the Chinese government translated the implementation of this "indigenous" innovation strategy into a series of mega-industrial projects with ambitious "techno-nationalist" goals and public funding: High-speed railway; big commercial aircraft C919; new generation of nuclear enter; wind power energy, etc. are all examples. In history, Chinese government had habit and experience in organizing and implementing national mega-projects. During the period of 1978 to 1985, it organized and implemented 108 sectional science and technology projects. Since 1986, it launched 3 basic national R&D projects and 2 supplementary projects. The 3 basic projects are: 863 Programme, Tackling Programme, and 973 Programme; and the 2 supplementary projects are: Torch Programme and Spark Programme. Since 2000, Chinese government realized that its R&D projects aiming at scientific "big bangs" or leaps need to be connected to the country's production system and extended to downstream activities of industrial chain. Therefore, 12 National Specific Programmes of Significant Technologies were established. Comparing with former S&T projects emphasizing research and science activities, these projects of national significant technologies directly contained industrialization and commercialization of R&D results. They emphasize the participation of enterprises in order to implement the activities of design, development, production, and commercialization. Enterprises should not only participate, but also behave as project leaders. Covering very different technological fields, the 12 national projects gave priority to the market formation of national R&D outcomes. The Chinese high speed train is in fact one of the fruits of these national projects of significant technologies. Encouraged by the success of these projects, the Chinese government decided in 2006 to establish another 16 national projects of significant technologies to be implemented till 2020. The new projects correspond in fact to the 16 strategic industrial sectors with technological importance, in which 3 are in military fields, identified by the 2006 national innovation strategic plan.

By now, China's new generation of techno-nationalist mega projects have achieved to mobilize the country's resources at a very exceptional speed and scale to integrate science and technology in industrial production. Nevertheless, beyond the apparent effectiveness, they have some hidden problems and limits. The implementation and organization of such projects depend almost completely on the technocratic administration structures of Chinese government and State-owned enterprises. National innovation policy is now elaborated through 3 central ministries: National Commission of Reform & Development, Ministry of Science & Technology, and Ministry of Finance. The formation and execution of projects need coordination among more ministries and involvement of local governments. Powerful ministries such as Commission of Reform & Development, Ministry of Industry and Information, departments of Ministry of Science & Technology are all chasing big projects with allocation of big budget. The continuous R&D investment has promoted the emergence of a stabilized class of technocrats with their interests related to China's R&D system. Traditionally, Ministry of Science & Technology has more influence on the direction of national R&D projects. It has tendency to emphasize the scientific and technological aspects of projects and public institutes and universities become naturally main undertakers of the projects. Thus national innovation objective is easily translated into academic research activities. Within the closed circle, the technocrats establish their own criteria of project. The S&T technocrats transplant directly the government's performance evaluation system to R&D system, using quantitative methodology, setting up complicated indicators and executing strict paper-work auditing over researchers in laboratories. Time and energy of researchers are used to deal with administration. Besides, the class of technocrats itself is a big spender of R&D budget. For example, in 2009, 83.91% of total R&D expenditure was for ordinary administrative expense such as traveling, meeting, buying stationary, etc. (486.88 billion Yuan), which is five times more than expense on assets. It was only in the end of 1990s, after some policy reports done by international organizations (IDRC, World Bank, OECD, etc.) and the diffusion of national innovation system approach in Chinese academia, that some top leaders recognized that the majority of inventions recorded as patents were never introduced on a commercial basis and most of successful innovations were initiated as the result of perceived market needs. So the former projects driven by scientific or technical breakthroughs were redirected to have linkages with industrial production and market commercialization, but mainly in State-owned enterprises.

China's national mega R&D projects also inherit the legacy of its centrally planned economic system. Plan fails to recognize the importance of non high-technology, incremental innovation, driven by market competitive forces that is widespread among non State-owned enterprises. Through tailored government policies and assured funding, national R&D projects become vertically integrated enterprises by linking public institutes' research and State-owned enterprises' production. The industrialization of R&D outcomes is normally found in a domestic monopolistic market or with government as final purchaser, such as transportation, telecommunication infrastructure, aircraft, energy, petroleum, etc., so that risks and costs of projects can be internalized by government itself. But wider linkages with other domestic non-State enterprises and international markets are not established. Because science, research, and technological activities are vertically linked to industrial development, production and distribution within the government projects, China can quickly catch up the targeted technological fields once the industrial-technical system is well identified. Thus this kind of projects is especially suitable to the development of technical complex product systems, which require much interactions between central activities along the innovation linked chain and a society's research activities and knowledge base. However, the Chinese technological catch-up through these projects happens only in the existing techno-economic paradigm such as high-speed train and nuclear power station. Even with an initial preference to high-tech content, China's mega projects have not created any new-to-the-world techno-economic paradigm, but replicated the existing ones through developing its own technological capabilities. It should be mentioned that much of these technological capabilities were also originally obtained by learning from foreign partners, of which the establishment of numerous Sino-foreign joint-ventures within the framework of China's grand airplane projects is a proof. In fact, China's national R&D projects represent a transition from a "process driven by scientific and technical breakthroughs" to a state of combing the "process of essential development activities" with the "process of research and knowledge exploitation". According to the conceptual framework of Kline & Rosenberg (1986), China's national R&D projects will help effectively develop science and technology capabilities in the upstream of the innovation chain.

3.3 Institutional conditions of absorptive capacity by Chinese firms

The experience of East Asian newly industrialized economies especially that of Japan and South Korea, has suggested that the key of enterprise' jumping from the stage of imitation to stage of innovation is intensified in-house research and development (R&D) activities, even though R&D activities can be very costly and their results are uncertain. Taking the Japanese companies as examples, in fact, their continuous investment in reverse engineering is a special form of R&D efforts. Reverse engineering involves taking apart something (a mechanical device, electronic component, computer program, or biological, chemical, or organic matter) and analyzing its workings in detail to make a new device or program that does the same thing without using or simply duplicating the original. Through reverse engineering, Japanese enterprises often added new functions or features to imported products and tailored them to fit local demand. This process needs deep understanding of the technological and scientific logic of the product and system, and often leads to formal R&D. From the 1950s to the 1970s, China also used reverse engineering to try to acquire technology. However, because of the State-owned companies, there was less incentive to invest in R&D. The government did say that there was a need for reverse engineering, but reverse engineering failed to become the popular or dominant way to develop indigenous technologies. Since then, the potential bridge between in-house R&D and foreign technology transfer and importation has been broken within the Chinese enterprises. The lack of attention to R&D efforts led Chinese enterprises to import new technology or products from advanced economies or rely on joint venture partners to provide new technologies. As a result, technology imports still play an important role in China and the share of expenditure on technology importation is still high. Compared to Japanese and South Korean enterprises, during long time Chinese enterprises spent little money on assimilating the imported technology. The allocation of resources for assimilation has been increased in recent years.

As early as in 1997, the Chinese government was already well aware that the key of making China an indigenous innovation machine was to upgrade the capacities of its enterprise sectors. But it was until recently that it recognized that it was especially the non-State and private sectors that remained a weakest part in the national innovation system. A quick look on the list of most R&D intensive enterprises in China will demonstrate that most of them are State-owned enterprises in the non-competitive market. Since then, policies of favorable tax policies and various other fiscal incentives are elaborated to increase investment in in-house R&D and enhance the innovation capabilities in the enterprise sector. In the beginning of 2013, the central government called on companies to make greater efforts to upgrade and innovate. By 2015, the government would help enterprises establish their "technological innovation system" which combines the functions of research, development and production. To do this, the government will directly set up R&D utilities for industrial sectors, support small and medium enterprises, train more qualified talents, and improve financial policies. The government also required other public institutions, such as universities and technical centers, to cooperate with enterprise sectors, which are not only State-owned sectors, but also include the non-State and private sectors. Government also encourages all kinds of enterprises to participate in the development of the "strategic emerging industries" identified since 2010, including energy saving and environmental protection, new generation of information technology, biology, high-end equipment manufacturing, new energy, and new energy vehicles. These sectors traditionally reserved only to State R&D investment now solicit more private participation. With all these policy supports, will the Chinese enterprises invest more in indigenous R-D, get away from simple imitation, and develop technological capability of innovation?

For most of Chinese non-State-owned manufacturers, they have traditionally had a manufacturing-led focus on reapplying existing business models to deliver products for fast-growing markets. Furthermore, their success depends on local resources—for example, lower-cost labor, inexpensive land, and access to capital or intellectual property—that are difficult to replicate elsewhere. The main sources of technologies are from technology importation. If there is R&D in these enterprises, its main content is in fact absorption and assimilation of imported technologies. And even the investment on technology absorption through internal R&D is very low. For instance, for a long period of time the expenditure for assimilation and absorption in Chinese textile industry was below 1.5% of the machine and equipment importation expenditure. The innovation process in these enterprises, if there is one, is based on the linear chain activities from design to development to industrialization, without much investment in formal R&D,

without much links to the country's research activities, and without multiple feedbacks from distribution and market detection. For example, in consumer electronics sector, China purchases 33 percent of the world's chips ($100 billion worth), using them both in products sold domestically and in exports. But most of the Chinese industry competes in commoditized areas such as chip assembly and testing, and Chinese semiconductor companies hold 4% or less of the most prized segments of the global value chain in chip design and manufacturing. Chinese enterprises have exerted little influence on semiconductor design, technology standards, or chip selection for major product categories such as mobile phones, laptop computers, and LCD televisions. Most decisions about design and functionality come from global champions and reflect the preferences of consumers in Europe, Japan, and the United States. Local enterprises' R&D projects tend to be derivative—refining products developed in Japan and South Korea instead of developing fundamentally new products (Shanzhai products). Innovation based on careful study of consumer preferences is rare, especially when the consumers are outside of China. Chinese companies still place too much focus on expanding market share with just-good-enough products instead of creating markets with totally new products. In most cases, the skills and capabilities of these companies are oriented toward the domestic market which is so large, so even if they want to expand globally, they face high hurdles. Most of Chinese private entrepreneurs are uncomfortable doing business outside their own geography and language.

After 2000, the investment of R&D by Chinese enterprises exceeded 60% of the country's total R&D spending and increased rapidly. Some sectors experienced intensive development of R&D. For example, the top 100 domestic electronics and information enterprises spent on average about 3% of annual sales revenue on R&D, with telecom equipment manufacturers Huawei Technologies, Datang Telecommunications and Zhongxing Telecommunications (ZTE) leading the way, each devoting above 10% of the sales revenue to R&D. Nationwide, of the more than 10 million medium- and small-sized firms in electronics and information sector, 150,000 allocate more than 5% of sales to technological development. Although R&D expenditures, patent applications and high-tech exports have markedly risen, the overall technological capabilities of Chinese enterprises remain poor. Impressive absolute R&D expenditure growth fails to reveal the quality and efficiency of R&D investment of Chinese enterprises. In 2011, only 11.5% of all industrial enterprises carried out R&D activities, in which only 30.5% of large and medium – sized enterprises were active in R&D. The R&D intensity (R&D expenditure over sales revenue) was 0.71% for all industrial enterprises, and averagely 0.96% for large and medium – sized enterprises, much lower than the average 3-5% in developed countries, even though it has been increasing steadily since 2000 (see Table 3). It should be mentioned that R&D activities were very rampant in the State-owned sector. Although they had 14.6% of enterprise R&D budget, the State-owned enterprises counted 81% of total number of enterprises having R&D and 66% of national R&D personnel.

Table 3 Technology-Related Expenditure of Chinese Large and Medium – Sized Enterprises (RMB 100 million, 2004-2011)

	2004	2005	2006	2007	2008	2009	2010	2011
R&D Expenditure	954.4	1250.3	1630.2	2112.5	2681.3	3210.2	4015.4	5031
Technology Renovation	2590	2792.9	3019.6	3650.9	4167.7	3671.4	4293.7	4292.1
Technology Importation	367.9	296.8	320.4	452.5	440.4	394.6	449.0	449.4
Adaptation and Assimilation of Imported Technology	54.0	69.4	81.9	106.6	106.5	163.8	202.2	201.4
Purchase of Domestic Technology	69.9	83.4	87.4	129.6	166.2	174.7	220.5	222.1
R&D Expenditure / Sales Revenue (%)	0.71	0.76	0.77	0.81	0.84	0.96	0.93	0.96

Source: National Bureau of Statistics and Ministry of Science and Technology (ed.), China Statistical Yearbook of Science and Technology (Beijing: China Statistics Press, various years).

The limit of R&D deepening of Chinese enterprises is also reflected by the investment structure and outcome efficiency of R&D. The share of basic and applied research expenditure over total R&D spending is always small. It declined from 32% in 1995 to 17% in 2008, to 17.3% in 2009 and 2010, to 16.5% in 2011. The shares of fundamental research, applied research, experiment and development were respectively 0.1%, 2%, and 97.9% for the industrial enterprise sector. During 2000 and 2009, the R&D intensity of Chinese enterprises increased from 0.71% to 0.96%, while its ratio of new product over sales revenue increased from 11.1% to 12.1%, with less amplification effect. The share of "invention" patents over total domestic patents registered was 30.4% in 2000, dropped to 25.9% in 2004 and 22.7% in 2008. Encouraged by the government policy, the share of "invention" patents dramatically jumped up to 34.8% in 2009, but fell back to 27.3% in 2011. It is estimated that enterprises have now a share of 25% of patent applications in China. Even the most patented enterprises preferred to produce patents of utility new models and external design rather than "invention" patents. A check on the top 20 enterprises which registered biggest number of patents in 2011 shows that only 5 of them had more "invention" patents than other forms of patents (On the list they were: ZTE as number 1; Huawei as number 2; Hongfujin as number 5; China Chip International as number 17; and Hangzhou Huasan as number 18). Chinese R&D stagnated in bringing more auxiliary improvements based on design instead of coming out with product innovation based on core technology development. Except that several enterprises progress with strong integration capability from R&D to marketing, most of Chinese enterprises begin to invest in R&D but quickly find difficult to deepen their R&D fields, to increase the efficiency of projects, and to upgrade the quality of outcomes. They are stuck in the halfway of imitation to innovation. A survey in 2012 in the Pearl River Delta region (Guangdong Province) of 1201 industrial enterprises shows that 44% of these enterprises set up new R&D utilities after 2008 as a response to crisis, but still 55% of enterprises reported that their current R&D activities contained imitation of foreign technologies.

Since more than 10 years, the Chinese government has strengthened the patent law and legal protection of technologies to give bigger incentive to enterprises to innovate. One the other side, Chinese enterprises responded to government policies by increasing dramatically R&D investment and application of all forms of patents, as demonstrated by macro statistics. But why there is little sign of R&D deepening and why Chinese enterprises have tendency to continue their trajectory of imitation instead of indigenous innovation? The answer may lie in the fact that enterprises in China in general only have low levels of "absorptive capacity" for R&D. The absorptive capacity is, as defined earlier, a specific way that enterprise carries out its R&D activities. When an enterprise begins its in-house R&D projects and at the same time makes continuous effort to identify, assimilate, and exploit knowledge from outside knowledge such as basic research findings, instead of keeping every effort inward without external interaction, the enterprise is said to have "absorptive capacity". This open-door strategy of doing R&D will in return induce more R&D spending on future options, thus condition the success of on-going R&D projects. Otherwise, despite the domestic knowledge production at universities and research institutes, enterprises will fall short in absorbing this knowledge and its own in-house R&D will be lack of dynamic inputs. If innovation is an aircraft, indigenous R&D capability and absorptive capacities are like two wings. Missing either of them will make the aircraft unworkable.

Although Chinese enterprises begin to invest more in R&D, they tend to do it by closing the door, i.e., to cooperate less with other organizations. A survey research of 42 enterprises in the region of Central China in 2010 shows that the new ideas of R&D projects were mainly from three sources: first the end-users, then the enterprise itself, then the competitors. Suppliers, universities and research institutions were all of low importance as technology sources searched by enterprises (Liqin Ren, Deming Zeng, and Koos Krabbendam, 2010). The 2012 survey of 1201 enterprises in the Pearl River Delta region of Guangdong Province in the South China also demonstrates that compared with efforts of upgrading the in-house independent R&D capabilities (effort value of 6.17 of 10), enterprises made much less efforts to cooperate with universities, research institutes and other companies in R&D (effort value of 3.26 of 10). This survey also reveals that for the enterprises in the Pearl River Delta region, independent R&D and cooperation with customers who were generally foreign companies as clients constitute major sources of R&D projects. Only less than 14% of enterprises searched R&D sources through cooperation with universities and research institutes. Less than

10% of enterprises participated in joint R&D projects with other enterprises, universities and research institutes. In terms of searching and absorbing external knowledge for the R&D projects, Chinese enterprises are like isolated islands standing alone in the ocean of science and technology. Without nurture from this ocean, its R&D propensity will eventually fade away.

Table 4 Technology sources of R&D projects of enterprises in the Pearl River Delta (Guangdong)

Technological sources of R&D projects	Frequencies		Percentage (%)		Total number of enterprises giving responses
	No	Yes	No	Yes	
Independent R&D	368	808	31.29	68.71	1176
Cooperation with colleges and universities	987	148	86.96	13.04	1135
Cooperation with professional research institutes	985	149	86.86	13.14	1134
Cooperation with customers	428	735	36.80	63.20	1163
Cooperation with other enterprises	806	340	70.33	29.67	1146
Participation of multi-party R&D cooperation with other enterprises, colleges and universities, and research institutes	1032	102	91.01	8.99	1134
Purchase of technology patents and equipment	892	243	78.59	21.41	1135
Imitation of others' technology (without possessing private patent or purchasing others' patent)	970	164	85.54	14.46	1134

Source: Qiu, H., W. Zhao, et. al. 2012.

The development of absorptive capacity in enterprises depends on two things: enterprises' own efforts and orientations of R&D projects and external conditions which permit enterprises to establish various linkages with other organizations. A Chinese national survey of R&D resources in 2009 reported that in terms of R&D project expenditure, 69.4% of enterprise projects were accomplished by enterprises themselves independently, 10.3% of enterprise projects were accomplished by enterprises in cooperation with domestic universities, 5.6% of enterprise projects were accomplished by enterprises in cooperation with domestic research institutes, 4.5% of enterprise projects were accomplished by enterprises in cooperation with other domestic enterprises, 3.8% of enterprise projects were accomplished by enterprises in cooperation with foreign organizations, and 6.4% of enterprise projects were accomplished in cooperation with other organizations. From the perspective of industrial enterprises, since 2009, both private and State-owned enterprises decreased their expenditure part of external R&D projects in cooperation with universities, public institutes, and other enterprises. In private sector, the external R&D expense share decreased from 5.5% in 2009 to 4.7% in 2010; in State-owned sector, the share of external R&D decreased from 8.6% in 2009 to 7.3% in 2010. Chinese enterprises are not good in developing external cooperation in R&D, which is a sign of their weak absorptive capacity, but is also the cause of the low quality output of R&D projects with a "closed" management style. In 2011, there were 81615 projects of cooperation among enterprises, universities and research institutes. Though 30% of the project budgets were spent on external R&D cooperation, the Chinese enterprises didn't appreciate very much the role of these domestic R&D partners in developing innovation, especially domestic universities and research institutes. The 2012 Pearl River Delta survey shows that the 1201 enterprises gave a lower evaluation of the service provided by universities and research institutes in their innovation (average value of 4.77 of 9) than the evaluation of the service provided by public technology platforms of local government (average value of 4.87 of 9) and cooperation provided by other local enterprises (average value of 5.2 of 9). Regarding the frequency of contacts and level of trust with a series of other organizations in local environment, enterprises showed the second lowest level of trust to domestic universities and research institutes, and had fewer contacts with them than with other organizations.

Table 5 Assessment of external linkages by enterprises in the Pearl River Delta (Guangdong)

Type of organizations	Average contact frequency (evaluation scores between 1-9)	Average level of trust (evaluation scores between 1-9)
Competitors in the same industry	4.80	4.82
Local suppliers, supporting vendors and subcontractors	6.89	6.43

Type of organizations	Average contact frequency (evaluation scores between 1-9)	Average level of trust (evaluation scores between 1-9)
Local distributors, domestic traders and retailers	5.50	5.54
Overseas customers	5.81	5.93
Local governmental departments	6.07	6.71
Industry associations and chambers of commerce	5.55	6.18
Local centers of technological innovation	4.17	5.07
Domestic universities and research institutes	3.62	4.87
Local education, training and recruitment services organizations	5.12	5.52
Local financial services organizations	6.04	6.39
Local management consulting and information services organizations	5.01	5.53
Related local organizations to solve labor dispute	5.12	6.16
Mass media	3.22	4.66
Local exhibition and marketing organizations	4.62	5.39

Source: Qiu, H., W. Zhao, et. al. 2012.

In fact, Chinese enterprises lack interest in engaging domestic universities and research institutes with respect to R&D efforts. There was almost 16% of enterprise R&D budget spent on joint projects with universities and institutes in 2009 because either the projects were organized by government, if the enterprises were State-owned or the participant enterprises would get money from the State, if they were non-State enterprises. But the aversion of enterprises to universities and research institutes is also due to the situation of these science and technology organizations themselves. For the big R&D projects financed and coordinated by the government, State-owned enterprises and universities and research institutes which are also State-owned are under the same roof and obliged to cooperate for innovation. Besides this kind of imposed linkage, local Chinese universities and research institutes, except as suppliers of engineers, have contributed very little to R&D activities of enterprises, especially the non-State and private enterprises. The reforms in the science and technology system since the mid-

1980s have to some extent activated the enthusiasm of researchers in these institutions, but enterprises found soon that the coordination with universities and research institutes was even more difficult than negotiation with other enterprises. The academic mode of production is undermined and replaced by a profit-oriented mode of behaviour, where pecuniary incentives become more important. These science and technology organizations aggressively searched for profits and tried to maximize every single piece of their knowledge when they saw enterprises having potential to acquire technology from them.

The deeply-rooted problems of separation between R&D and the economy, and of organizational rigidity between enterprises and S&T institutions, have thus been overlapped by the new problem of marketization of research and industry cooperation. Such a problem may be due to the very unique Chinese model of capitalism in which the State itself behaves like a special interest group with lucrative objective in a market place, competing with other non-State groups for resources by elaborating all kinds of rules in favor of itself. If within the State-sector enterprises have to cultivate vertical relationships with bureaucrats and politicians for subsidies and other favors, outside the State-sector the Chinese society is like a pure laissez-faire market where non-State enterprises have to rely on traditionally inherited personalized trust and networks (the famous Guanxi) to establish links with research institutions, financiers, partners, suppliers and customers in transforming knowledge, capital, products and talent for innovation (Gilboy, 2004). The selfish State leaves beyond its own controlled system a free market absent of reliable legal framework that can be used to enforce contracts. If the Chinese State capitalism has greatly promoted the country's catch-up through coordinating the interactions between its production system with the national research and knowledge system, the remaining part of Guanxi capitalism in China finds it difficult for innovation to weave efficient linkages among organizations based on institutionalized trust.

4. Policy Implication: Exploiting Efficient Linkages of Innovation

To the Chinese government, how to mobilize the non-State sectors to develop more dynamic linkages with the State-owned sector of science, technology and knowledge seems still to be a big challenge. If the government is capable of making efficient and rapid technological catch-up in the domestic, monopolistic, and infrastructure sectors (artificial satellite, high-speed railway, grand airplane, nuclear station, etc.) through its research-based mega projects in mobilizing maximum financial, knowledge and organizational resources, it seems not so skillful in promoting further R&D investment and activity of non-State-owned enterprises in competitive markets (consumer electronics, automobiles, machine tools, food processing, textiles, fast moving consumer products, etc.). Whereas in these sectors, Chinese enterprises have accumulated enormous technological capabilities of manufacturing and distribution and the general technological level seems to be approaching the world frontier. But it is this distance of "last 100 yards" that constitutes the most difficult part of catching-up. The challenge in this sector is uniquely difficult because of the complexity of science-based design and engineering-based manufacturing. To create innovative outcomes, Chinese enterprises need to combine their operational excellence with high level research of science and technology, often under the form of formal and well planned R&D projects. Thus, contrary to the common feeling, Chinese enterprises in the mature, traditional and labor-intensive sectors still have a long way ahead of them to catch-up the world's technology and innovation frontier; even they are taking most of the market share in these fields. Chinese government shall support these indigenous firms in establishing more linkages other than those with customers, especially with domestic and foreign research institutions.

As a matter of fact, some Chinese domestic firms have been good in establishing strong linkages with customers, including both domestic consumers and foreign companies as clients. To adequately match customer needs from different regions, urban and rural users, and income levels, household appliance producer Haier offers over 400 refrigerator models in China. Haier developed a dual-use washing machine that can be used to wash vegetables in addition to clothes. This was driven by "listening" to the "abnormal" users of their products. Thus, Haier's innovation capacity is creating more product models to match different market needs rather than being technology-intensive. Lenovo, the Chinese company which bought the PC business of IBM in 2004, started by selling foreign computers such as AST, HP and IBM in Chinese market, while losing money in their own PC business till 1993. The boss Liu Chuanzhi then made Yang Yuanqing as the GM of its own PC production. Yang, as a top salesman in Lenovo Company, learnt from selling foreign brands such as HP that the key in Chinese market was to create a nation-wide network of sales agents. He fired all but 18 of the one hundred sales people in Lenovo. Then he reformed Lenovo's operation and asked the engineers to cut product costs in half. He purchased components in bulk from Samsung, used Intel and AMD CPU to cut price. He substituted heavy but cheap steel sheets for plastic computer cases. He even imitated the local small PC boutiques in assembling components to customerize PC products. By this strategy of imitation based on lowest price and customerization, Lenovo rose as number 1 in the Chinese PC market in 1997 and has kept this position till today. Huawei, the leading telecommunication company established in 1987, first started as a distributor of the HAX switch produced by a Hong Kong company. Huawei's first product of its own was the C&C08 switcher with 2,000 lines, and the customer was a small city in Zhejiang, a market neglected by the multinationals. In 1993, Huawei launched their C&C08 switchers with 10,000 lines, which were sold very well in rural areas. Ren Zhengfei, the boss of Huawei, always said that the user and customer are the source of innovation for Huawei. Later, Huawei set up a lot of joint laboratories with Texas Instruments (TI), Motorola, et cetera, and a joint venture with 3COM, thereby outsourcing more its technology from foreign companies buying than buying technology from university and research institutes.

As Huawei, some leading Chinese firms also have begun to expand in global market and search for developing indigenous innovative products abroad. By acquisition of foreign firms and R&D facilities and the establishment of R&D and design labs in technologically advanced countries, these enterprises hope to benefit from spillovers abroad. Through M&A or joint R&D, they expect to monitor new development trends and transfer new technology to China, and thus speed up inverse technology transfer and promote domestic upgrading. In 2010, 188 Chinese outbound M&A transactions worth 38 billion USD took place which is a 30% increase compared to 2009. Chinese M&A targets are widespread globally with one focus on the United States, but also on the European Union, Asia, Africa and developing countries with strong R&D infrastructure such as India. For example, Haier's global network consists of R&D, manufacturing, supply chain, marketing, and service. It has 15 industry zones, 30 oversea plants and manufacturing sites, 8 oversea R&D centers, and 58,800 sales offices. But the international R&D outsourcing of Chinese enterprises has its own constraints. The first is the investment destination of other developing countries, especially South Asian economies (Vietnam, Cambodia, and Laos), Middle, Russia and Africa. These markets cannot provide powerful information and technology inputs to high-level R&D projects. Chinese enterprises have little habit of making dynamic linkages with a variety of institutions in the environment and found it even harder in a foreign context. For the acquired R&D laboratories and competences, Chinese enterprises also have difficulty in finding pertinent organization to carry out inverse technology transfer. Thus in most cases, the overseas R&D activities of internationalized Chinese enterprises are mainly concerned of local product adaptation to consumer preference, collecting foreign technology and standard information for the home base, and assisting commodity manufacturing and marketing in the host country.

Other potential linkages of innovation can be found in exogenous firms in China. Chinese government has always policies to attract significant R&D activities of foreign companies. While previously most FDI was used for green-field investments or acquisitions in production and distribution facilities, today an increasing portion of foreign investments flows into the development of R&D facilities. China's universities graduate more than 10,000 science PhDs each year, and increasing numbers of Chinese scientists working overseas are returning home. Multinational firms are now to take advantage of these abundant supplies of low-cost skilled researchers in Beijing and Shanghai. The percentage of R&D expenditure of foreign-funded projects stays constant at around 27%. A large portion of foreign spending on R&D is concentrated in a few regional clusters in China namely Shanghai and Beijing. However increasing R&D investments in other provinces (Guangdong, Jiangsu, and Tianjin City) create a close link to the concentration of MNC investments in production capacities. The number of foreign R&D centers in China increased drastically from around 50 in 2000 to approximately 1,100 at the end of 2007, 1,200 at the end of 2009, and 3,300 at the end of 2012. 346 of the Fortune 500 companies have established R&D facilities in China. Many multinationals established in China one of their main centers of global R & D, which is the case of Microsoft and SAP (IT), Alcatel Lucent (telecommunications), BASF (chemicals), Novartis (pharmaceuticals), Matsushita, Sanyo (electrical equipment), and PSA (automobile), etc.

The strategic focus of foreign R&D activities has evolved during the years of rapid investment growth. The initial motivations of establishing R&D centers in China were to innovate by commercialization, as opposed to constant research, perfecting development, and critical designs which are controlled by multinational R&D headquarters. Multinational companies were to put a new product or service into the Chinese market quickly and improve its performance through subsequent generations. It was common for products to launch in a fraction of the time that it would take in more developed markets. While the quality of these early versions may be variable, subsequent ones improve rapidly. This approach of R&D is to focus on local product development in partnership with downstream players such as domestic manufacturing suppliers. This strategy helps multinationals meet local-technology requirements, but above all do research and applied development is close to the biggest market in the world. This kind of R&D projects in fact reinforces the multiple feedback process with the innovation chain. It helps multinationals have capabilities of domestic-market knowledge or relationships needed to apply R&D results effectively to adapt to Chinese domestic needs. The general idea is to be closer to Chinese customers and the network of institutions and universities from which multinationals source talent. The latest Buick GL8 minivan introduced in Chinese market is a good example. General Motor quickly developed the model through capability built in China, in using a combination of on-the-job mentoring, coaching, and expert assistance from overseas, as well as a very structured development process from their global team. The GL8 was an old GM architecture that no one else wanted, but it has turned into an unbelievably good-looking and highly desirable car in China.

Normally foreign R&D centers had the functions of technology monitoring and corporate R&D representation. But with the strong competition for talent, resources, and markets between foreign and domestic enterprises, foreign companies began to launch indigenous R&D centers with Chinese universities and institutes and to focus these facilities on developing technologies for unproven but promising next-generation domestic markets. There are even a few examples that some multinational companies developed through local R&D new models and incorporated some of the features they could transfer to other markets. Multinationals that participate in such ventures align themselves with China's goals while they have concerns about protecting intellectual property rights (IPR). Most of the foreign R&D labs in China are independent wholly foreign owned for better protection of intellectual property rights. These labs do not apply for patents to avoid disclosure of the technology know-how. Foreign R&D centers are reported to have limited interest in sharing knowledge with domestic firms and R&D labs. On the other side, since 2006 China has issued a variety of policies which allow Chinese companies to apply non-inventive patents (utility model patents, design patents) and impede foreign products from the Chinese market by compulsory testing, certification and standard requirements. The Chinese government even created a bigger web of interrelated policies by issuing requirements for the disclosure of foreign proprietary technologies. For example, China enacted an "Anti-Monopoly Law" in 2008 which exempts monopolies in sectors which are dominated by State-owned enterprises and in sectors where monopolies are deliberate by the state as they are critical to the Chinese economy. Chinese government also supports the "indigenous" innovation projects. To be eligible for the indigenous innovation catalogue (including computers and application equipment, telecom products, modern office equipment, software, new energy equipment and high-efficiency energy-saving products) to participate in public procurement, the product must, among other criteria, have full ownership of IP in China and have a trademark that is owned by a Chinese company registered in China. Chinese government seeks to use transferred IP and manufacturing methods to create its own champions that can compete with global countries around the world, not just in the local market. All these measures raise the concerns about the intellectual property rights of foreign R&D in China and impede the more aggressive investment decisions. Whether the foreign R&D activities are climbing from the focus on market feedback process to adding new process of more research and knowledge mobilization is now an open question. One thing for sure is that the majority of foreign R&D centers are not conducting indigenous technology R&D yet and the innovation capacity is rather in the downstream along the linked-chain process.

5. Conclusion

Some scholars such as William Baumol (2002) asserted that innovation as the capitalist growth engine was possible thanks to the free market mechanism, the laissez-faire competition and the body of rules guaranteeing private properties; while others see the State capitalism as compatible with creativity and innovation. China complies with neither. With the recent industrial upgrading strategy based on more R&D, China is positioning itself as a follower and adopted a pragmatic strategy in terms of increasing investment quantity of R&D to serve the restructuring of its industries. Contrary to the classic Schumpeterian entrepreneurial capitalism characterized by "creative destruction", its so-called State capitalism impedes the country's development of innovation capacity, though it accelerated enormously the technological catch-up process and industrial structural upgrading. With huge R&D investment, Chinese capitalism dynamics is still characterized by "imitative construction". Its rapid R&D quantitative expansion overwhelmed the quality improvement of R&D.

When market mechanism on an arm's length basis is no longer reliable, enterprises and organizations prefer to internalize their transactions instead of linking outside. Until now, most of Chinese enterprises rely on their linkages with customers or clients in the market as the main source of innovation, in the absence of dynamic linkages with research and knowledge institutions. The feedback loops from distribution activities and market demands become the most important inputs of the innovation process from market detection, to product design, and to development. Large quantity of small and medium sized enterprises count on American, Korean, European and Japanese enterprises as foreign clients to teach them how to employ technologies. The leading big companies adopt the strategy based on market-oriented product diversification and technology outsourcing (buying innovations of others) as their primary approach of innovation. The technology may come from anywhere, although most of the core, proprietary technology comes from the USA, Japan, Europe and Korea. The most famous Chinese multinationals such as Huawei, Lenovo and Haier grew up not because of their strong capabilities in in-house technology development, but thanks to their ability to survive market competition by understanding and responding to specific market needs. Put in another way, their success is not based on the technological capability of innovation promoted by the State, but on the emerging Chinese and global market opportunities. As these big three, many other big Chinese enterprises entered into the market first as distributors and sellers, not inventors or innovators in technology. This spirit of commercial trader is kept even in the following stages of enterprise development. During the last 10 years, numerous emerging Chinese enterprises such as Chery Automobile and Bird Mobile-phone announced that they made radical innovations but simply by buying various foreign developed technologies and putting them in a product shell designed for the Chinese or other under developed markets.

Now, the Chinese enterprises have got so used to the competitive and transaction-nature relations in market that they don't know what other kinds of linkage that they can have with other organizations in the economy. For example, the very popular form of organizing R&D activities through strategic alliance finds very few cases in the Chinese industry. When there is something like innovation network in China, it is always the relationship of competition which prevails over cooperation and communication among network participants. On the other side, Chinese economy has been rich of organizations of different natures, different levels, and different locations. It has well established universities and institutes, a variety of intermediate organizations, newly created science and technology parks and incubators, well financed State-owned enterprises with their R&D centers, accumulated FDI with their R&D facilities, emerging Chinese big companies with their overseas R&D hubs, and a large amount of private enterprises with regional public technology centers set up by local authorities. To make China a Schumpeterian innovation machine, the big challenge to the Chinese government is whether it can overcome its long traditional "paternalism over the State sector" in innovation policy and find an institutional substitute to correct the market failure effect in innovation capacity building of all Chinese enterprises. With almost everything has been done to promote innovation in China, it may still leave the dynamic linkages outside enterprises for R&D cooperation to be built.

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