Enhancing technological progress in a market-socialist context:China's national innovation system at the crossroads

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Enhancing technological progress in a market-socialist context: China's national innovation system at the crossroads[1]

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Abstract

This paper analyzes the available evidence of China's S&T, R&D, and innovative capabilities, to provide an assessment of the effectiveness and potentialities of its national system of innovation (NSI)), and to formulate some preliminary policy suggestions aimed at improving China's overall innovation strategy. Our approach focuses particularly on the evolving relationship between China's NSI and the country's overall market socialist social and economic system - both of which are developing fast and undergoing deep qualitative changes - and on related policy challenges.

China's innovation strategy aims at embodying world-class best practices from technological world leaders and successful late industrializers, but is also peculiarly Chinese in at least two crucial aspects. The first is China's sheer size, which has allowed her to leapfrog to rank 2 worldwide in terms of the absolute quantitative magnitude of its NSI, at a stage when it still far lags behind all technological leaders in terms of per capita educational, technological, and research achievements. The second is China's specific form of market socialism, which has the potential of conferring her leaders an outstanding advantage in the crucial area of strategic planning, i.e. the capability to master national resources and to earmark them towards key goals accordingly to a clear set of priorities.

China's goal is to engineer in a relative short period a decisive qualitative leap in her NSI, developing a systemic ability to generate world-class indigenous innovations. In addition to fostering technical progress, China's development strategy shall also take into account the challenge of establishing a model of innovation compatible with an equitable pattern of income distribution and environmental sustainability, thereby paving the way to the eventual evolution towards a higher and more developed form of socialism. This is the expressed aim of the Chinese leadership. However, the simple NSI approach is not necessarily sensitive to these strategic requirements, and therefore there is a need for more advanced analytical and planning tools. In this context, we propose to consider the utility of nonlinear models of the POLIS (positive feed back loop innovation system) class, which are suitable to chart strategically the market socialist course, as their internal logic is consistent with China's unique catch up strategy.

[1] We are grateful to Francesco Schettino, University of Ancona, Italy. This paper has not been previously published in any form.

1. Introduction

The aim of this paper is to provide a BROAD assessment[1] of the effectiveness and potentialities of its national system of innovation (NSI), and to formulate some preliminary policy suggestions aimed at perfecting China's overall innovation strategy. Our approach focuses particularly on the evolving relationship between China's NSI and the country's overall market socialist social and economic system - both of which are developing fast and undergoing deep qualitative changes - and on related policy challenges.

By the turn of the century[2], China's R&D sector was growing rapidly in size and effectiveness, yet a major reorientation of resources towards research activities had not materialized yet[3]. Major policy changes had been taking place in the 1980s and 1990s, and China's R&D system was undergoing two main and apparently contradictory, but in fact potentially complementary transformation trends. On one hand, there was a powerful drive towards commercialization and decentralization. On the other hand, the government was earmarking large resources and according an increased degree of priority to a new generation of national research programmes. The innovative capacity and the technological level of Chinese productive enterprises were improving, particularly so in the state-owned sub-sector, where managing practices and property relations were undergoing major changes (Gabriele 2002). In the late 1990s and early 2000s China has kept investing heavily in its R&D and S&T sector, and reforming its NSI. Similar patterns, on a lesser extent, were observed in other semi-industrialized developing countries.

In the meantime, further evidence is accumulating on the key role of R&D in boosting economic growth (see David et al. (2000), Arora et al (2007)) and on global technological trends, which point towards an ever-increasing divergence between developed and developing countries. Only China and (possibly)[4] a very small group of other semi-industrialized countries are beginning to close the technological gap separating them from the world leaders (see Fagerberg, Knell, and Srholec (2007)). However, there are also signs of a sort of "research and innovation fatigue" which appears to be emerging in the developed world.

The rest of the paper is organized as follows. Section 2 reviews some of the recent contributions stemming from an ever-expanding literature. Section 3 presents and comments the most updated statistical indicators on China's S&T and R&D inputs and outputs. China's 15-year Science and Technology Plan. Section 4 discusses whether China is actually overinvesting and the need to shift towards an increasingly intensive and innovation-led form of growth. Section 5 discusses present opportunities and challenges Section 6 concludes.

2. China's NSI and the linkages between industry and science

China's NSI has witnessed remarkable advances since the early 1980s, as a result of a series of reforms aimed mainly at improving its effectiveness and closing the excessive gap which traditionally separated university-based research activities from the technology absorption and innovation needs of the enterprises system. The main thrust reforms has been to diversify the country's NSI and to strengthen its market-orientation (or market-compatibility), but the role of centrally-managed large, long-term research programs has also been enhanced. These reforms, along with the ever-expanding availability of financial resources made possible by economic growth and by the strong role of the national state, have allowed achieving remarkable advances. As a result, for instance, China's NSI is far superior to that of the other Asian emerging giant, India, in virtually every aspect (see Dahman (2007), Schmitz and Stamm (2007), Kash, Augur, and Li (2004), Hung (2008)).

Several organizational and institutional structures which proved their validity in the context of developed market economies are also being studied, experimented, and in some cases adopted in China, but such a pragmatic approach does not amount to an attempt to ape western examples. Actually, "It is far from clear that evolving into an innovation system similar to that found in developed market economies is a possible or even advisable objective for China or other countries emerging from central planning regimes and Soviet-style industrial organization…." On the contrary, "it is necessary to accept the possibility that fundamentally different but equally viable national innovation systems could emerge in China, other formerly centrally planned economies, or other nations with similarly very different legacies of industrial organization and social systems ….Policymakers would then be able to better evaluate which system structure is most appropriate, given the particular characteristics of their national context and the costs and likelihood of successfully introducing changes to move towards an alternative system structure" (Liu and White (2001), p.1112).

The most visible change in China's NSI is probably the progressive shift of the bulk of R&D activities away from universities and specialized research centres and towards industrial enterprises (see Section 3). However, universities participate too many of the most ambitious basic research endeavours, and often play a crucial role in their implementation. For instance, universities carry out about 1/3 of the "863 projects" and 2/3 of the projects founded by National Natural Science Foundation (NNSF) (Wu (2007) , Hu and Jefferson 2004). In order to re-balance the roles of the different actors in the R&D scene in favour of the academia, the Chinese government is earmarking increasing funds to elite universities, mainly through the Ministry of Education (MOE). Elite universities are expected to lead in national R&D programs and projects, facilitate technology diffusion and spillovers, promote spin-off companies, incubation centres, and open laboratories for R&D sharing, to bridge-in foreign technology and partners. This emphasis on the role of universities in engaging directly in the development, production, and commercialization stages of their research results has been dubbed "forward engineering " by Lee. According to this scholar, forward engineering is a peculiarly Chinese component of the "Beijing Consensus", a comprehensive and proactive catch-up strategy very different from the "Washington Consensus" and partly, but not fully similar to that followed before by other successful Asian latecomers such as Korea and Taiwan (see Lee 2006a, b and Lee, Hanh, and Justin Yifu 2002). Among other initiatives, a very important one was project 211, aimed at funding the construction of campuses and developing new academic programs in key scientific areas all over the country (Hsiung 2002) during the 1996-2000 5 year plan period. Other programs promote specifically university-industry links. The first one of this kind was launched jointly in 2001 by the State Economic and Trade Commission (SETC) and the MOE to set up state technology transfer centres in six universities, in order to promote the commercialization of technological achievements. Another directive issued by MOE in 2002 encouraged the development of university start-up enterprises, after a long debate that concluded with the official position that universities have a threefold mission: research, teaching, and commercialization. Research and technological innovations are seen as crucial channels through which universities contribute to national and local economies (see Ma 2004, Zhang 2003, (Haiyan, Yuanlong and Kaiyuan 2006, Hong 2006,. Motohashi 2005).

As mentioned above, however, the bulk of China's R&D is presently being carried out by enterprises, many of which are large SOEs. These firms have managed so far to resist and even to thrive after over a quarter-century of market-oriented reform, in the framework of a complex, ever-changing and opaque institutional environment, characterized by a weak and ambiguous -albeit increasing- degree of protection of property rights in general and of intellectual property rights (IPR) in particular5. Shedding light on this apparent (for orthodox economics) paradox, most studies on innovation among Chinese productive enterprises found that substantial progress was going on, and that SOEs were capturing the bulk of S&T resources, but exhibiting a less-than-satisfactory capability of translating them into true production improvements. The innovative capability of SOEs, however, appears to have been further enhanced in the mid-2000s6, thanks at least partly to the economies of scale and scope made possible by the "grasping the big, enlivening the small" policy. The combined profit of the 150 or so companies controlled by China's central government reached Rmb1,000bn (USD140bn), more than 200% higher than five years earlier. By end- 2007, the list of the world's 10 most valuable companies contained four groups controlled by the Chinese state7. The behaviour of Chinese SOEs is also becoming more modern and effective in a number of areas, including their ability to attract top executive talents (Dodson (2008)).

In China as elsewhere, R&D expenditure is positive and significantly correlated with firm productivity. Government R&D contribution to firm productivity works mainly through an indirect channel, via the promotion of firms' own R&D, which appears to be a more effective policy tool than direct R&D grants. Other key sources of production improvement and innovation growth are each firm's absorptive capacity, the production network, openness, and managers' education. Market-oriented, competition-enhancing innovation system reforms are improving the effectiveness of the incentive structure and fostered S&T linkage activities. With respect to the impact of ownership type, SOEs perform worse than collective and private firms in terms of production performance, but not in terms of innovation capabilities grants (Guangzhou Hu (2001), Guangzhou Hu and Jefferson (2003), Motohashi and Yun (2007)). The choice of innovation types among Chinese SOEs depends on the turbulence in the environment, and on the organizational resources, with market forces and internal governance simultaneously influencing SOEs' innovation patterns (Li, Liu, and Ren (2007)). In many SOEs, managers apply the technical innovation audit tool for benchmarking, thereby improving their ability to choose among different types of innovation mechanisms.

Due to the influence of the two main stakeholders (government and end-users), firms with a higher degree of government involvement companies and a correspondently lower degree of openness to the market exhibit a more widespread use of innovation mechanisms, thereby apparently contradicting the positive relationship between market focus and innovativeness traditionally posited by

“Western” innovation management theories. Therefore, "entering an open market abruptly may not be the solution for SOEs, which are rooted in a socialist economy, to become more competitive and more innovative" (Ren, Krabbendam, and de Weerd-Nederhof (20069. SOEs tend to prioritize the fulfillment of administrative tasks and "empire-building" ventures, whereas non-state firms tend to be more profitable in the market (Li and Xia (2008)). With the term "empire-building", Li and Xia refer to SOEs' managers' propensity (which they attribute to "agency problems"), to pursue "long-term investment and meeting new product output target, at the cost of high level of slack and inefficiencies…"(p.41). SOE's managers are "less concerned with the lack of legal protection of property right. Thus, compared with their non-state counterpart, they are relatively more likely to invest in projects with a longer payback cycle" (p.45). This phenomenon is due largely to strong government interference in SOEs' behavior: in a context of relatively weak IPR protection the government puts a paramount emphasis on long-term investments and makes a great effort to promote technological innovation, targeting them as important indicators of SOE performance and awarding resources to SOEs accordingly). SOEs, rely more on government-allocated resources, and therefore tend to perform better in areas that are encouraged by the government, such as new product development. As new product output is an important indicator of SOE performance, SOEs are incentivated to operate at the frontier of new product development (Li and Xia (2008) ,MOST, 2005). In our view, in spite of the relevance of static inefficiencies and distortions, SOEs' much "distorted" behavior implies extremely relevant dynamic advantages in terms of innovative capacity and technological progress, with major spillovers benefiting the national economy as a whole - taking also into account the existence of virtuous synergies with the non state-owned sector.

Notwithstanding China's NSI remarkable strengths, remaining challenges are huge. For instance, Wang (2006) identifies a dualistic pattern in China's of technological development, with the export-oriented segments of the economy being relatively isolated from those producing mainly for the domestic market. Zeng and Wang (2007) stress the weight of constraints such as an insufficiently developed institutional framework, relatively low overall educational attainments, the lack of a large pool of world-class talents, the embryonic stage of indigenous innovation capacity, and insufficiently developed linkages between R&D and industrial enterprises. Other researchers point towards China's and the persistent weaknesses in technological cooperation between universities and industry, the inadequate integration of the country's NSI into the global innovation networks, and the need to develop a comprehensive , more refined technological strategy is to be developed to achieve effective technology transfer from foreign technological leaders, while at the same time maintaining an appropriate balance between indigenous innovations and technology imports (see Li-Hua (2007), Haiyan, Yuanlong and Kaiyuan (2006), Li-Hua and Simon (2007)).

3 Recent evidence on China's innovative capabilities

3.1. Indirect and comparative evidence on China's technological progress

Growing quantitative evidence is becoming available on various aspects of China's economy, institutions, and innovative capabilities, and they broadly converge towards suggesting that China is in fact climbing fast the economic and technological development ladder. Figures on economy-wide and industrial GDP, export, and labor productivity growth are too well known to be worth mentioning here. S&T, R&D and high-tech trade indicators are discussed in Section 3.2. Various other sources mention statistics bearing indirect relevance to gauge China's technological power. Fortune's 2007 list of the top 500 global corporations includes 24 Chinese firms, four more than in the previous year. This figure is still far from that of US global companies (162), and also quite lower than Japanese, French, and German companies, but it's higher than the number of Korean, Indian and Taiwanese companies (Yoshida 2007).

Intriguing comparative evidence on companies' productivity growth and propensity to innovate appear to show that Chinese firms are doing pretty well, European firms are maintaining their positions and (surprisingly) US firms are losing ground (see Suh 2008). Productivity growth in China is more than three times the rate of that in the US and Europe. A survey carried out on more than 500 chief information officers (CIOs) in the US, Europe, and China provides even more striking results. Only 32 % of US executives and 41% of Europeans said they wanted to be early adopters of new technologies, compared to 70% of Chinese CIOs (Mayberry, Wang, and Suh 2006. see also Accenture 2007, 2008). Consistently, 70% of companies in China are committing most of their business to web services, against 42% in Europe and 38% in the US: "As companies use these new standards for communicating with other systems, people and companies, they cut manual business process costs to one-10th of current levels and can flexibly change features and services in less time for substantially less money….. Newer systems, during this second wave of web-based innovations, outperform older technology. These technologies have improved substantially in the past five years, making them easier to implement. As a result, more business processes will be online, driving higher levels of productivity" (Suh 2008). Moreover, many indicators on productivity, revenue and profit growth show that US companies are doing significantly worse than what conventional data on productivity growth might suggest. Among US S&P 500 large companies, employee growth was faster than both revenue and profit growth in 2001-2005. Thus, the growth of average revenue gains per employee was 58% lower than total average revenue growth, and profits per employee growth were only 75% of total profit growth. In contrast, among US S&P 350 companies recorded revenue and profit growth rates higher than employee growth rates.[8]

Further indirect evidence of major advances in the areas of governance, management, and technology in China's industry is provided by the very marked improvements in SOEs' economic and financial performance. In the aftermath of the 1997 Asian financial crisis China's SOEs sector, long plagued by the traditional deficiencies common to most publicly-owned productive enterprises, saw its average profit margins fall close to zero, with many firms reporting big losses. The prevailing wisdom, even among many Chinese observers, was that "since good performance does not guarantee that the incumbent manager will stay long, the manager does not have long-term incentives…. these built-in problems of state ownership cannot be solved by state-dominated corporatization…To ensure that only high ability people will be professional managers and that managers can be well disciplined, the authority of selecting management must be transferred from bureaucrats to capitalists. This calls for privatization of both state enterprises and state banks "(Zhang 1998).

After ten years of restructuring, which implied a dramatic decrease in employment and in enterprise numbers but also massive injections of capital and technology and a major leap in managers' and workers' education and skills, the SOEs sector is in good financial health. In 2007, the profits of the core 152 firms controlled by the central government was about Rmb 1000 bn (USD 140 bn), more than 30% higher than in 2006 and over 200% higher than five years earlier. The rate of return was 11.7%, 1.3% higher than in 2006. 139 enterprises (more than 90 percent of core SOEs) increased their profits year-on-year… period, and 18 of them recorded profits of more than 10 billion yuan, against 14 a year earlier" (Chinaview 2007). Shipbuilding, automotive and shipping enterprises are becoming significant profit earners, along with petroleum, power generation and telecom companies.

In this respect, there is a sub-sector that of cellular phones, where Chinese enterprises might soon achieve global leadership, thanks inter alia to their unique technological change pattern. Domestic producers' competitiveness in the world's largest cell phone market has been buoyed by the Chinese government's October 2007 decision to eliminate all licensing requirements to manufacture and sell mobile phones in the country, thereby opening the gate for newcomers, some of which have been selling phones in the black market. Differently from Japan, which has been quite innovative in the past but mainly produced models sold only in the local market, China is presently using the same technologies as the rest of the world. This important difference could induce Chinese manufacturers to launch fast-forward innovations with the goal of increasing their domestic market share, thereby ending up producing phones that result ex post competitive also in foreign markets. New Chinese brands are making progress in the areas of brand name, research and marketing development, and appear on the way to close the gap with foreign brands. They might be particularly successful in the huge and fast-growing rural market, Rural customers are price-sensitive than in the cities and "do not have strong brand loyalty, so they buy things which can give them the best value. To cater to such values, home-grown brands pack more features into their phones, making people think they can get more value from these products…Among the new entrants of home-grown handset vendors, Beijing-based Tianyu is a rising star. It expects to sell 13 million mobile phone units in 2007, a 113.1% growth year-on-year to become the third biggest domestic handset vendor in China. …" (Chung 2007). Other strong and innovative firms are CECT (which has launched a model with biometric security features) and Meizu. These companies "seem to be building up a global customer base attracted by the feature sets of the phones, which aren't provided by the global brands…. It's also pretty inevitable that there will a breakthrough product, one that just happens to meet an unexpected demand, and that will really bring Chinese phones to global attention"(Trigram.wordpress.com 2007).

In sum, China is trying to create a group of larges leading SOEs in highly competitive sectors, where technology, design and marketing capabilities are key for ultimate survival, thereby overcoming a traditional weakness of public enterprises worldwide (Dyer and McGregor (2008). The ultimate outcome of this major upgrading and restructuring exercise in China's public industry will clearly play a crucial role in shaping the country's development model.

3. 2. R&D and S&T indicators

. Input indicators show that China not only earmarked huge and ever-increasing resources towards research, science, and technology, but also intensified its efforts in relative terms, thereby exposing a strong and effective pro- R&D and S&T bias in both government and business sector policies (See Table 1). Gross Domestic Expenditure on R&D in nominal terms almost tripled (in nominal terms) in the early 2000s, reaching 300 bn yuan by 2006. In a period of very fast economic growth, the GERD/GDP percentage ratio also increased markedly, from .95 in 2001 to 1.42 in 2006. This figure is beginning to approach the 2% benchmark which is commonly considered a rule-of-thumb indicator signaling that "a country is sufficiently technologically sophisticated to help ensure technology-led economic growth." (OECD 2007). The business sector is the main contributor to total R&D expenditure (almost 70% in 2006), with most of the remainder being provided by the government. Sector-wise, over 70% of China's R&D is carried out by the business sector, which also employs almost 2/3 of the country's R&D personnel and about 19% by research institutes. 70% of China's R&D workforce focuses on experimental development, 20% on applied research and almost 10% on basic research (see Tables 1.1 and 1.2). Roughly a half of total R&D is concentrated in the manufacturing industry, representing about 2% of its total value added. However, the latter indicator is more than twice as much in the high-tech industries, and reaches almost 14% in the aircraft and spacecraft sub-sector (see Table 1.3). Government S&T appropriation reached 168.8 bn yuan in 2006, more than twice the correspondent figure for 2001. Government S&T appropriation also increased as a percentage of total government expenditure (3.7 in 2001 to 4.2 in 2006), with a high level of priority being accorded to special projects and operating funds. S&T personnel reached over 4 million, and R&D personnel (mostly scientists and engineers) 1.5 million (see Table 1.4).

. Patents granted by SIPO (State Intellectual Property Office of the People's Republic of China) in 2006 were over 280000, more than twice the corresponding figure for 2002 and six times that of 1996. Over 22000 patents were granted to Chinese nationals (up from about 17000 in 2005) and 44000 to foreigners. However, most domestic patents were granted for utility model and design innovations. In the subset classified as true "inventions", successful foreigner applicants outnumbered Chinese nationals, although the share of invention patents granted to the latter (43%) increased from that of the previous year (39%). Over half of all domestic service invention patents were generated in the business sector (see table 2.1). China's published over 400 thousand S&T papers in 2006, almost twice as much as in 2001. More than half were produced by universities, but the fastest rate of increase was recorded by publications stemming from medical institutions. Chinese S%T papers indexed by SCI, EI, and ISP were 172 thousand in 2006, two-thirds more than in 2001. The share of Chinese S%T papers indexed by the main international specialized institutions also rose significantly, reaching more than 42% by 2006.

. China's high-tech trade expanded at an extremely fast pace. Exports increased twenty-fold in 1996-2006 period, reaching 2.8 USD bn by the end of the period. Their relative weight also rose, and by 2006 it had climbed to about 30%, both with respect to manufacturing exports and to total exports[9]. High-tech imports increased at a slightly slower pace, and as a result the high-tech trade balance turned positive in 2006 for the first time (see Table 3.1.). China's high-tech trade is heavily concentrated on the computers & telecom sub-sector, with over 2.2 bn exports and a 1.5 bn surplus in 2006.

Available, simple international comparative indicators of R&D inputs and outputs confirm the basic features of an overall scenario in which China has undoubtedly joined the worldwide Ivy League, pouring towards the research sectors enormous and ever-increasing human and financial resources, far outpacing other large, semi-industrialized countries such as Brazil and India, and leapfrogging far ahead of many countries formerly seen as among the most industrialized ones, such as Italy. However, they also show that China still lags behind the US and the other members of the small group of world technological leaders in the most advanced areas.

In dollar terms, China's Gross Domestic Expenditure on R&D appears to be only slightly over one tenth of that of the US, one fifth of that of Japan, and half that of Germany (still, it is over four times higher than Russia's and Brazil's). However, in this case the MOST data, albeit formally correct, are misleading, as they might induce to unduly underestimate China's true strength vis a vis the rest of the world:" While the dollar figure on China's R&D spending is dwarfed by that of Japan and the U.S., the real value of its expenditure is higher, thanks to lower costs – putting China third globally, on the basis of purchasing power parity" (HIKPA 2006). In fact, the international R&D expenditure figures expressed in purchasing power parity (PPP)[10] estimated by the OECD terms show a dramatically different picture. Having been growing at an exceptionally high annual rate of over 20% (more than five times that of any other major industrial country), China's R&D expenditure reached 136 bn USD in 2006, the second largest in the world, surpassing that of Japan [11] and equivalent to more than one third that of the US (see Table 4.2).

In terms of R&D intensity of the national economy, measured by the GERD/GDP percentage ratio, China has clearly left behind Italy, Russia, Brazil, and India, but still lags behind the four world R&D leaders: US, Germany, Japan, and Korea. The two Asian countries, in particular, lead the field in terms of R&D intensity with GERD/GDP ratios close to or larger than 3%, more than twice China's ratio. Data on the distribution of GERD resources confirm the findings reported in paras 1 and 2 above, i.e. that China's R&D activity - consistently with its present level of technological development - is much less focused on basic research than that of any other major player, including Russia. The absolute size of China's R&D personnel army (over 1.5 mn) far outnumbers that of any other country, yet in relative terms (R&D personnel per 10,000 labor force) it is less than one tenth that of Japan, Germany, and even Russia (see Table 4.1.).

Basic comparative indicators of international R&D outputs appear[12] to show that China - having reduced rapidly its relative backwardness, especially in the early 2000s - figures among the global leaders, as it ranks 4th worldwide in terms of domestic invention patents granted, 2nd in terms of indexed papers published, and 5th in terms of SCI-indexed papers published. Table 4 data, however, are not adequate to provide firm evidence on a much-discussed issue, i.e. whether China's ability to translate R&D inputs into output is structurally lower than that of world technological leaders.

4. Accumulation and technical progress

Felipe et al. (2008) apply a Classical analytical framework to analyze in a comparative fashion the diverging patterns of capital accumulation, profit rates, investment rates, capital productivity, and technological change of China and India between 1980 and 2003. Their findings can be propedeutic to a deeper discussion on the relationship between China's pattern of economic development and its unique socioeconomic structure.

China's accumulation process has been much faster than India's, thanks to China's investment rate (i.e., investment/GDP ratio), due in turn mainly to the fact that China has been reinvesting almost all her surplus, while India invested a much lower share.. In fact, as a World Bank study has recently pointed out, corporate sector saving – including by SOEs – is a key contributor to China's high rates of saving and investment: "At about 20 percent of GDP – double the share in the U.S. and France – retained earnings finance more than one-half of enterprise investment." (Kuijs, Mako, and Zhang 2005, p.3). Another important, and apparently contradictory finding, is that profitability has been rising constantly in India, but declining in China, so that the profit rate was much higher in the latter by the late-1990s. More worryingly, capital productivity[13] declined in China, while it rose in India[14], and - consistently - technical change was Marx-biased (i.e. of the labor saving, capital consuming type) in China, while it was broadly Hicks-neutral in India.

In sum," India differs from China in terms of how much profit has been plowed back into investment. In China virtually all profits are reinvested, with the consequence that actual investment has outstripped the capacity provided by profit and has led to the creation of overinvestment and overcapacity. Why is so much profit reinvested in China? A large part of these profits come form State Owned Enterprises. These companies do not pay dividends and face incentives that are biased toward investment, as local officials are promoted largely on their success in generating economic growth, which comes through investment. Thus, a large part of these profits is used for capital expansion (as much as 20% of all investment in China comes from local governments) without efficiency considerations…" (p.752).

The policy - initiated in 1994 - of non-payment of dividends was initially justified by the feeble and declining profitability of public enterprises, and by the need to recapitalize SOEs in the framework of a deep reform process aimed at streamlining and strengthening state industry, but by the mid-2000s it had been made obsolete by its own success. Actually, "The current non-payment of dividends implicitly assumes that there is no better use of SOE profits other than re-investment back into SOEs. Clearly, however, China faces urgent challenges in refocusing its public spending to improve key services. " (Kuijs , Mako and Zhang, 2005, p.7)[15]. It is also clear that, as a result of this policy, SOEs have been investing more than they would have had otherwise. The Chinese government has acknowledged this problem[16], and began in 2008 to enact a cautious and still experimental policy change, collecting a modest (5-10%) share of the profits of state firms under its direct control. The destination of these dividends has not been clearly specified yet, but they are expected to be channelled to both social consumption (i.e., financing social security funds) and investment in high technology sectors (see China Daily 2007, China.org.cn 2007, Shanghai daily 2007, Naughton 2008). This development surely goes in the right direction, but is still probably insufficient even to achieve the simple goal to curb excessive investment (see Chan 2007).

Felipe et al 2008 attribute their findings largely to India's unfavourable institutional investment climate, and to China's bureaucratic push towards wasteful and inefficient investment. SOEs' bias towards wanton and inefficient expansion of investment, in particular, appears to constitute a major weakness of China's economic system. In our view, however, it also important to see this issue in another perspective. Following Gabriele and Schettino 2008, we introduce the term "socialistic". Assume, as a mental experiment, a theoretical continuum of conceivable mixed socioeconomic systems, where on one hand there is a pure free-market, private-property based model of classical capitalism, and on the other hand a fully publicly-owned, centrally-planned socialist model. In this theoretical framework, the term "socialistic" indicates the property of being characterized by crucial systemic features in the domain of ownership, class, and other social relations of production and exchange which are relevant enough to position a specific socioeconomic formation rather strongly towards the socialist side.[17]

Our reasoning is crucially based on a proposition which we consider a relatively self-evident stylized fact, but which by its very nature cannot be demonstrated formally. The important differences in the patterns of accumulation and technical change found in the two Asian giants are in turn the product of another key difference, which is stemming from the very structural nature of their respective socioeconomic formations. Simply put, in India, but not in China, there is a full-fledged capitalist bourgeoisie structured and organized as the dominant class[18] (see, for instance, Tsai 2008). Thus, China can be considered as one of the two presently-existing members[19] of a very small club that of a market-socialist or "socialistic"[20] countries. India, conversely, is a "normal" capitalistic country.

A very important corollary of this crucial systemic difference is that the share of surplus which finances the bourgeoisie's conspicuous consumption in "normal" capitalistic countries is virtually non-existing (or more precisely, carries a much lesser macroeconomic and strategic[21] weight) in China, and almost all the profits are reinvested.

In a capitalistic economy, the shadow price of potentially investible financial resources in the framework of a long-term social welfare function to be maximized by policy- makers is likely to be lower than private capitalists' implicit discount rate. Therefore, taking for given the wage rate and hence workers' consumption[22], there would be room left for other investment projects, which would imply a relatively low but still positive rate of profit .Thus, it is usually the case under "normal"[23] circumstances that the actual share of invested surplus in a capitalistic economy is lower than the one which would be optimal from a long-term social welfare viewpoint[24] (See Appendix).

What happens, conversely, in an economy that is "socialistic", even if only in a weak sense, such as China, where the state is strong enough to effectively command (via direct appropriation and/or via institutional, administrative, legal, and informal mechanisms) the allocation of a major share of the surplus? Ceteris paribus, a country with such "socialistic" characteristics should invest a share of the surplus higher than that of a capitalist country. It is reasonable to argue that this is in fact the case in China - largely because a large share of total profits is earned by SOEs[25], which are mandated by the state to pursue a number of objectives different from profit maximization, among them investment expansion.

According to our view, therefore, a socialistic society can exhibit a lower marginal productivity[26] of investment than an otherwise similar capitalist one, and still exhibit an overall superior behaviour with respect to the determination of both the quantity and the quality of national investment.[27] Whether this is in fact the case or not depends on the specific characteristics of the institutional framework shaping investment decision in a concrete socialistic economy, and can only be analyzed empirically on the basis of available data. Going back to the China-India comparison, it is known that the share of surplus that is plowed back to investment (which could also be called the investment/surplus ratio) is higher in China than in India. How much of China's additional (with respect to those which would be channelled towards capital accumulation in India, or another "normal" capitalist country[28]) investment resources are rightly earmarked towards socially profitable projects - resulting in a lower marginal and average productivity of investment, but in a better long-term allocation of resources - and how much are totally or partially wasted (see Appendix)?

A related but different question is as follows. The recent decision to let SOEs start paying a significant (even if still very small) share of their profits as dividend to the state is to be welcome. The destination of these dividends is still not very clearly defined, as there would be good economic and social reason both to earmark them to social consumption and investment (i.e. public health care and education), but also to keep prioritizing investment in infrastructure, key high-tech sectors, and R&D. Given the suboptimal state of China's basic public services, and the very long-term unsustainability of an already very high and permanently rising investment rate, it is plain that a high degree of the priority in the short term should be accorded to enhance social public consumption and investment. In the long term, however, assuming a stable and sustainable rate of accumulation is achieved, a more complex issue arises. For any modern socioeconomic formation, it is clear that the only way out of Marxian's law of declining profit rates is not to slow down accumulation per se, but to shift progressively more and more resources towards the development of high-tech sectors and towards R&D and S&T activities in particular, striving to accelerate the rate of technical progress and to improve its nature. Actually, the pattern of technical progress should be made less and less Marx-biased, capital consuming in nature, and become increasingly Hicks-neutral, or even capital-saving. Such a major drive towards the quantitative and qualitative improvement of technical change patterns must be pursued, at least in part, independently from a key price-based signal such as the expected market-measured profitability of individual investment projects, in a market-compatible framework based on a modern and advanced form of planning. We refer to a form of resources allocation where a significant share of aggregate investment is allocated according to shadow prices based on a long term planning framework. This framework should internalize to the maximum possible extent those needs and externalities which do not stem from the price structure emerging spontaneously from the market - i.e. the "real" long-term social value of education, health, the environment, R&D itself, etc. An important component of this overall planning framework might be an embodied mechanism to shape in a dynamically optimal fashion the evolution of the price structure itself.[29]

5. Opportunities and Challenges: from NSI to POLIS?

Since the late 1990s, the Chinese Government has approved a number of crucial strategic decisions to build up a world-class National Innovation System, seen as " a networking system composed of institutions involved in knowledge innovation and technology innovation (which)… includes the following: knowledge innovation system netted with the state research institutions and key universities; technology innovation and technology application system with industrial enterprises; knowledge dissemination system with schools and universities. In 1998 the government instructed the Chinese Academy of Sciences (CAS) - a vast network of research institutes that are presently undergoing feverish expansion and reorganization - to initiate the Pilot Project of Knowledge Innovation Program (KIP)" (CAS 2008). An action plan was carried out for rejuvenating education in the 21st century, in addition to a national meeting on technology innovation and a working conference on basic science research, in order to further enhance the reform of the scientific research system. Plans are also drawn to open a second-board stock exchange in the securities market, similar to the American Nasdaq. The KIP piloted at CAS is a major component of the National Innovation System (see CAS 2008).

In January 2006 China launched the "National Medium- and Long-Term Program for Scientific and Technological Development" (2006-2020), commonly known as the 15-year Plan for science and technology. The Plan's long-term goal is to allow China to become a pre-eminent global economic and technological power, relying on "independent, indigenous innovation":[30] "By the end of 2020, we should establish an improved scientific and technological innovation system. . . We will strive to leapfrog the development of China's information science and technology and to acquire core technologies with proprietary intellectual property rights in the IT sector."(quoted in AeA 2007).

Not all the details of the plan were made public, but its main tenets are clear. China is foreseen to raise R&D spending from the current 1.4 percent of its economic output to 2 percent by 2010 and 2.5 percent by 2020:"these commitments would put Chinese R&D investments above $100 billion annually, placing it in the same league as Japan and the United States (RTM 2007). Acknowledging that China's high-tech industry is growing fast but is still largely dominated by multinational companies and centred on low-value-added, labor-intensive manufacturing, "the 15 Year Plan intends to change that equation by investing heavily in such cutting-edge areas as nanotechnology and biotechnology to spawn indigenous innovation." (RTM 2007).

Table 5 The 15-year Plan's 12 priority sectors

Advanced Storage Technologies
Alternative and Renewable Energies
Biotechnology/Genetics
Electronic Components
Environmental Technologies
Integrated Circuits/Semiconductors
Manned Space Exploration
Materials Technology
Nanotechnology
Network and Communication Technologies
Optical and Biological Computing
Software and Related Services

Source: AeA 2007

According to American Electronics Association (AeA), which carried out a synthetic assessment of the plan in 2007, (AeA 2007), the Plan's goals are ambitious, but not unrealistic[31]. China has a leadership mainly composed by engineers, who are in a favourable position to understand the nature and the strategic centrality of research and technology, and has already built up has remarkable elements of strength in the S&T and R&D area. For instance, it has being pouring huge societal investments into higher education and research (state financing for higher education more than doubled in 1998-2003, reaching over USD10bn by the end of that period; China's number of researchers increased by almost 80% in 1995-2004, and is now second only to the US). Large SOEs are also investing heavily in technological upgrading and human capital formation, and there a number of start-up innovative firms, some of them already established in international markets (such as Lenovo, Haier, and Huawei), and others active in crucial areas such as the provision of Internet services for the domestic market.

Yet, China also faces a number of challenges. Its high-tech industries are growing extremely fast, but at they are mostly owned by foreign TNCs and still usually concentrated on low value-added stages in the value chain. In this respect, AeA 2007 quotes Daniel Rosen, a senior researcher in the Institute for International Economics, who half-jokingly remarked: “China’s high-tech exports turn out not to be so very high tech - nor, indeed, very Chinese.” Another key area of concern is constituted by weak IPRs protection - although the AeA rightly notes that the Plan acknowledges that China's own development interests are already shifting in favour of strengthening the IPR protection regime, and calls for action in this domain.

AeA 2007 argues that it is also urgent to take decisive measures to reform capital markets, encourage risk taking, and let ideas flow more freely, to stimulate truly innovative thinking and research. To our view, many of these challenges are in fact crucial - a significant exception being, probably, capital market reforms. However, it is not straightforward that the remedies should always go in the direction of following the US model (as AeA appears to suggest), taking into account the strong arguments in favour of fostering a smooth reform path towards a specifically Chinese

NSI consistent with the country's history and its market-socialist socioeconomic system (see, for instance Liu and White (2001), Keun Lee (2006)).

Finally, it is important to locate China's 15-year S&T Plan in the framework of the worldwide scenario shaped by the converging trends of key frontier technologies. As the APEC (2005) workshop on this topic has made clear, the convergence of information technology, biotechnology and nanotechnology (the so-called superconvergence) might be the most significant technological event of the 21st century (see khan 2005). The process of convergence is already underway. All the major national and regional players including USA, EU and Japan have already taken significant steps in order to maintain and gain further advantage in these technologies. China is a latecomer.

What can China do in order to be in the same league as the three major players mentioned above? Taking into account the challenges posed by a very competitive international environment where the other major players still hold a significant advantage, China can achieve superconvergence only through the creation of a self-sustaining innovation system that can move forward over time, This paramount strategic goal must be properly seen as the logical evolution of the present S&T strategy, basically centered around the perfectioning of China's NSI, towards a qualitatively superior, self-propelling innovation system. The 15-year Plan, if successful, will complete the catch up process by 2020. Between 2020 and 2050, the strategic goal will become should be to build up autonomously advanced technological capabilities in the three crucial areas, with a view towards moving towards superconvergence. Regional cooperation with Japan, Korea and Taiwan can play an important role in this strategy. Ultimately, a Pan-Asian regional innovation network including India and the ASEAN countries might also be established. China's National Development and Reform Commission (NRDC) can start the process of national capacity building and regional cooperation by supporting key strategic ventures. Increasing the number of competent staff in the areas of planning for high technology development should be given serious consideration. In Khan (2008a, c, 2004a, 2002, 1998) the overall planning framework is presented as part of a system-wide effort to create a positive feedback loop for innovation, which is at the same time distributionally progressive, equitable, and environmentally sustainable. The term used by Khan to refer to such a mechanism is that of nonlinear positive feed back innovation system, or POLIS. (see Appendix 2). The POLIS framework can be applied through quantitative economy-wide modeling techniques, in order to analyze the challenges for transition from now to 2020 and then from 2020 to 2050.

The POLIS approach is based on a somewhat novel theory of innovation in the economy wide setting. Its first and most important feature is that the analysis of a POLIS can be thought of as part of the institutional turn in economic theory. However, in contrast with much institutional literature, its propositions can also be expressed in a formal language, through models that can be estimated quantitatively for both rigorous, empirical scientific testing and for policy making purposes. The starting point of the POLIS theory is the creative destruction process at the firm and industry level. However, an extension to an economy-wide setting requires the explicit theorization of the role of the state as well as an interacting nonlinear market process. The direction in which the theory leads is a complex interaction between state policies and market processes that influence the decisions taken by specific firms in particular areas of innovative activities. The key concept that is developed in this context can be called a Managed *Creative Destruction* (MCD) process. In a national (or regional) MCD, the creative destruction process characterizing innovation is structured more consciously by the state (or the states in a particular region). It can be argued that China is now going through this process. Following Schumpeter, we assume that innovation in specific firms can have economy-wide effects. As models based on this approach have multiple equilibria, the concept of a positive feedback loop innovation system or POLIS is formalized by picking an appropriate sequence of equilibria over time. It can be also shown that POLIS has empirical relevance by applying the formal model to an actual economy. Ultimately technological transformation — in particular the creation of a positive feedback loop innovation system - is what makes the difference between sustained growth and gradual or sudden decline.

In addition to the system wide approach to innovation over time, the POLIS theory offers two other distinct advantages. One is the linkage between micro and meso or macro levels. One can start with firm level data on innovation activities and link these to sectoral and intersectoral information flows. In this way, what happens at the firm level can be seen from a larger, economy wide perspective. At the same time, the impact of firm level activities on overall level and pace of innovation can also be ascertained qualitatively and quantitatively.

The third aspect of POLIS is distributional. Since the complex system dynamics of POLIS is holistic, it integrates production with distribution. Thus the distribution of value added in production at both the factorial and household levels can be formulated as part of a general equilibrium (or, under circumstances of internal or external shocks, disequilibrium) frame work. Given the levels and distribution of income among households, the consumption patterns and effective demand feedback mechanisms complete the formulation of a system wide model.

6 Conclusions

While acknowledging the impressive progress achieved so far, a comprehensive recent OECD on China's innovation system (OECD 2007) concluded with a sobering warning: "China needs a better return on its fast-rising investments in research and development (R&D) and higher education if it is to meet its goal of becoming an 'innovation-oriented' economy by 2020…China still has a long way to go to build a modern, high-performance national innovation system.".

This statement is realistic, as it stresses the uncertainties on the future without underestimating Chinese government's firm strategic determination to achieve the 15-year Plan's goals. China's leadership is fully aware of the centrality of science and technology, not only for economic growth, but also with respect to other crucial challenges, such as the ultimate environmental sustainability of its market socialist development model[32] and for the sake of enhancing China's relative place among the world leading nations. Consistently, it has being earmarking towards research and the broader S&T sector an increasing share of China's fast-growing GDP. Therefore, China has now achieved a substantial critical mass in the area of research and innovation, second only (according to some estimates) to that of the US, and growing four times faster than of any of the major world technological leaders, among which there are signs that the enthusiasm for ever-increasing investment in R&D might be someway declining, both in the public and the private sectors. There is by now plenty of evidence showing that the over the last decade China has witnessed major efficiency-enhancing institutional and organizational changes, including in the area of property rights, a massive accumulation of human capital, and a very sustained rate of scientific and technical progress. Labor productivity has been rising fast, and a major part of the improvement is likely to be due to the aforementioned factors, even taking into account China's extraordinary rate of non-human capital accumulation. All R&D input indicators have being rising fast, and so did output indicators, such as patents and scientific papers. Yet, a closer look shows that China is doing an excellent job at absorbing, adapting and developing existing technologies, but is still lagging significantly behind world technological leaders in terms of capability to generate state-of-the-art, world-class innovation proper, as is shown for instance by data on basic research and inventions patents[33].

With respect to state industry, the assessment of available evidence on SOEs' performance is more complex. Most sources indicate that, until the end of the past century, SOEs have been were absorbing a major share of investment funds while exhibiting efficiency and profitability levels lower than enterprises belonging to other forms of ownership. Yet, their propensity to innovate (not always in an effective way) was high, and their productivity climbed dramatically, especially during the late 1990s. Latest available evidence appears to show that, during the present decade, the policy of concentrating huge resources on a small number of large and advanced SOEs, while letting smaller and less efficient state enterprises to fence more or less on their own (recurring increasingly to extreme measures such as closures or ownership changes) has begun to bring significant qualitative fruit, as testified by core SOEs' increasing profitability and international competitiveness and by the embryonic emergence of some world-class state-owned TNCs. Both SOEs and large industrial enterprises operating in China under different forms of ownership - such as joint ventures and private (national and foreign) firms - manifest a very strong willingness to innovate, at a time when their counterparts in the US and - to a lesser extent - other OECD countries appear to show a sort of innovation fatigue.

The economic sustainability of China's historically unprecedented S&T effort does not presently appear an issue, at least in the short-to-medium term, taking into account the leadership's determination in prioritizing the S&T sector and the resilience of China's GDP growth rates, even in presence of diverse unfavorable exogenous phenomena such as the Sichuan earthquake and the overall slowdown in the international economy triggered by the US subprime crisis.

As a result, China's NSI is undergoing major quantitative and qualitative changes. The latter are those which bear the most crucial weight. The main features of the 15-year plan appear to show that the basic tenets of the two-pronged S&T strategy outlined in Gabriele (1992) still hold. On one hand, the relationship between most R&D activities and the market is becoming closer and closer. Most of the R&D is already being carried out inside the enterprise sector, while universities and research institutes are intensifying their contacts with firms, and generating themselves start-up ventures to develop, produce and commercialize their innovations. The IPR protection system, in particular, is evolving towards a higher level of protection, partly to respect China's WTO obligations, but mainly to suit the present development stage, characterized by an increasing degree of commercialization of the bulk of technological knowledge (essentially, the one stemming from applied research and development activities). On the other hand, in order to tackle the crucial weaknesses mentioned above, vast financial, human and institutional resources are being channeled towards a long-term basic research endeavor, concentrating on a limited number of strategic high-tech sectors. This major effort is articulated institutionally in a decentralized fashion, yet operates in a broadly consistent organizational and financial framework set up as a key component of China's specific form of strategic development planning.

The challenge, at the present stage, is to engineer in a relative short period (10-15 years) a decisive qualitative leap in China's NSI, developing a systemic ability to generate world-class indigenous innovations. In addition to generating technical progress, China's development strategy shall also take into account the challenge of establishing a model of innovation compatible with an equitable pattern of income distribution and environmental sustainability, thereby paving the way to the eventual evolution towards a higher and more developed form of socialism. This is the expressed aim of the Chinese leadership. However, the simple NSI approach is not necessarily sensitive to these strategic requirements, and therefore there is a need for more advanced analytical and planning tools. An example is constituted by the models introduced by Khan (1998, 2002, 2004a, b,c and 2008a,b,c) within the context of nonlinear positive feed back innovation systems or POLIS. These models are sensitive to many of the above-mentioned concerns, and can be used to chart strategically the market socialist course, as their internal logic is consistent with China's "walking-on-two-legs" catch up strategy. Actually, this strategy aims at embodying world-class best practices from technological world leaders and successful late industrializers, but is also uniquely Chinese in at least two crucial aspects. The first is China's sheer size, which has allowed her to leapfrog to rank 2 worldwide in terms of the absolute quantitative magnitude of its NSI, at a stage when it still lags far behind all technological leaders in terms of per capita educational, technological, and research achievements. The second is China's peculiar, "socialistic" version of market socialism, which - along with many, mainly static inefficiencies - confers her leaders an outstanding advantage in the crucial area of strategic planning, i.e. the capability to master national resources and to earmark them towards key goals accordingly to a clear set of priorities.

APPENDIX The investment decision-making process in capitalistic and socialistic economies

In a "normal" capitalistic country each of the various capitalists forming the bourgeoisie must decide individually what to do with their respective share of surplus. This decision-making process essentially takes place in a rather uncoordinated, atomized fashion. Individual capitalists, using their limited information, try to maximize their respective welfare functions. The most important argument of such functions is capitalists' own present and future conspicuous consumption of (mostly luxury) goods and services. Capitalists' propensity to consume, in turn, is shaped by a risk- averse time-preference schedule characterized by a relatively high implicit rate of discount. Each capitalist ends up investing a share of (past) profits[34] that is positively correlated with the expected (risk-weighted) profit rate, setting aside a non-zero, non negligible amount for his own present consumption.

A major consequence of capitalists' decision-making process at the aggregate level of the national economy as a whole is that the reinvested share of surplus tends to be lower in capitalistic context than in a socialistic one, due mainly to two factors. First, capitalists' degree of preference for present consumption (which would presumably be lower or nil if the agent responsible for the investment decision where not a capital owner, and were not historically used to a certain level of conspicuous consumption). Second, individual capitalists can be expected to exhibit a degree of risk aversion higher than that of a hypothetical public agent. The latter, in fact, should be endowed of superior information, and her subsistence consumption consumption - which, in any case, is lower than the capitalists conspicuous one. - should also be relatively shelved from the possible negative outcomes of a failed.

A socialistic mechanism of investment decision-making, however, can lead to irresponsible overinvestment on the part of public agents, unless a proper system of incentives and risk balancing is put in place. Let us assume that there are three sets of feasible investment projects. The first set is constituted by those projects which are expected to generate a rate of profit high enough to be invested in by the bourgeoisie in capitalist society, along the lines sketched above. These projects will be carried out also in the "socialistic" society, with a degree of efficiency that might be higher, lower, or equal to the corresponding one that would prevail in a capitalist society[35] A second set is constituted by investment projects that are socially, but not privately profitable - or better said, not profitable enough to be funded by capitalists. Some of them might even carry a negative rate of profit if evaluated individually according to the actually-existing structure of prices, due inter alia to well-known phenomena such as spillovers, imperfect capturability of benefits and externalities. Yet, they might in fact result socially profitable, and hence worth undertaking, if evaluated on the basis of shadow prices stemming from a long-term social welfare function maximization exercise. Investment projects belonging to the second set are bound to be carried out in a socialistic society, but not in a capitalistic one.

Finally, a third set is constituted by bad projects, which have a negative social present value and would only represent a waste of resources. Of course, they should be discarded by both types of society, but they might have a relatively higher chance to be carried out in a socialistic one if the system of incentives and checks and balances for enterprise managers, economic ministries and local governments is excessively biased in favour of a blind expansion of the quantity of investment per se.

The argument developed in this brief appendix has implicitly assumed a static closed economy scenario, with a given state of available techniques. In our view, these apparently restrictive assumptions do not seriously undermine the relevance of our comparative discussion on aggregate investment in China vis a vis India (or other semi-industrialized capitalist countries). In a dynamic scenario techniques change, and the speed and direction of technical progress become largely endogenous (mainly via the share of investment earmarked to R&D and S&T activities). Path-dependency and cumulative effects thereby tends to reinforce divergences in accumulation and technical change patterns over time. However, the fundamental difference in the mechanism of investment decisions between a capitalist and a socialistic country can be essentially captured also in a simplified static context. With respect to the closed economy assumption, as is well known China's and India's economies are actually quite open and international trade plays a large and increasingly relevant role in both of them. However, they are also very large. As profitability conditions are (or at least are perceived to be by foreign investors) more favourable in China, this country receives much more FDI than India. This huge FDI flows contributes (but not in a decisive way, at least from a quantitative viewpoint) to increase China's investment rate with respect to India's. However, neither in China or in India FDI and international financial flows plays a crucial role in fuelling aggregate investment. The main engine of accumulation, both in China and India, is constituted by domestic savings and investments.

Source: MINISTRY OF SCIENCE AND TECHNOLOGY OF THE PEOPLE'S REPUBLIC OF CHINA

CHINA SCIENCE & TECHNOLOGY STATISTICS DATA BOOK

http://www.most.gov.cn/eng/statistics/2007/200801/P020080109573867344872.pdf

TABLE 1 CHINA R%D INPUT INDICATORS

TABLE 1.1 GERD Gross Domestic Expenditure on R&D

	2001	**2002**	**2003**	**2004**	**2005**	**2006**
GERD (100 mn yuan)	1042.5					3003.1
GERD/GDP	0.95	1.07	1.13	1.23	1.33	1.42

2006	
By source	
Business	GOV
69.10%	24.70%
By sector	
Business	Research institutes
71.10%	18.90%

Source: MOST 2007

TABLE 1.2 R&D personnel by sector 2006

Sector

Business	**Research institutes**	**Higher education**
65.7	15.4	16.1

Type of activity

Basic R	**Applied r**	**Experimental D**
9	20	71

Source: MOST 2007

TABLE 1.3 **2006 High-technology industry expenditure on R&D and as a percentage of value added**

	R&D exp 100 mn yuan	% of value added
Total manufacturing	1551.4	2.14
High-tech industries		4.54
Aircraft spacecraft		13.82
Computers office equipment		3.45
Electronic&telecom eq		5.41
Medical eq and meters		2.67
Pharmaceuticals		2.91

Source: MOST 2007

TABLE 1.4 **Government S&T Appropriation**

		2001	2006
Government S&T Appropriation	100 mn y	703	1688
% in total gov exp		3.7	4.2
Special project funds		359	780
operating funds		223	483
S&T personnel	10000	314	413
R&D personnel	10000 person-years	96	150
Scientists & engineers		74	122

Source: MOST 2007

TABLE 2 CHINA R&D OUTPUT INDICATORS

TABLE 2.1. Patents granted, 1996-2006 (10000)

	1996	2000	2003		2005				2006			
Total		**Total**	**Total**		**Total**	**Domestic**	**Foreign**	**Domestic/Total (%)**	**Total**	**Domestic**	**Foreign**	**Domesti Total/%**
	4.4	10.5	18.2		21.4	17.2	4.2	80.2	26.8	22.4	4.4	
				Invention	5.3	2.1	3.3	38.8	5.8	2.5	3.3	
				Utility model	7.9	7.8	0.1	98.5	10.8	10.6	0.1	
				Design	8.1	7.3	0.9	89.5	10.3	9.2	1.0	

Domestic service invention patents, 2006			
	Business	9433	51.3%
	Research institutes	2553	13.9%
	Higher education	6198	33.7%

Source: MOST 2007

TABLE 2.2 **S&T papers**

Domestic S&T papers, 000s

	2001	**2006**	**Change (%)**
Total	203.2	404.9	99.2
Business	14.5	13.3	-8.2
Research institutes	29.1	42.4	45.6
Higher education	132.6	243.5	83.6
Medical inst	19.7	91.3	362.5

Chinese papers indexed by SCI, EI, and ISTP, 000s

	2001	2006	Change (%)
Total	64.5	172	166.7
Share of domestic S&T papers	31.7	42.5	33.9

Source: MOST 2007

TABLE 3 HIGH-TECH TRADE

TABLE 3.1 CHINA HIGH-TECH TRADE 1996-2006, USD 100 mn

	1996	2000	2001	2006
Exports	127	370	465	2814
% in total exports			17.5	29
% in manufacturing exports			19.4	30.7
Imports	225	525	641	2473
% in total importsexports			26.3	31.2
% in manufacturing imports			32.4	40.9
Trade balance HT	-98	-155	-176	341

Source: MOST 2007

TABLE 3.2. HIGH-TECH TRADE BY FIELD 2006, USD mn

	Exports	Imports	Trade balance
Aircraft spacecraft	24.4	131.6	-107.2
Computers & telecom	2249.0	706.9	1542.1
Electronics	360.0	1301.9	-941.8
life science tech	63.4	51.4	12.0
Computer-integrated manuf	26.8	196.3	-169.5

Source: MOST 2007

TABLE 4 **INTERNATIONAL COMPARISONS**

TABLE 4.1. **R&D INPUTS**

GERD **Gross Domestic Expenditure on R&D, 100 mn USD**

	China	US	Japan	Germany	Korea	Italy	Russia	Brazil	India
Basic R	5.2	18.7	13.3						
Applied Research	16.8	21.3	22.4						
Experimental D	78	60	64.3						

Source: MOST 2007

TABLE 4.2. Gross Domestic Expenditure on R&D -- GERD (billion current PPP $)

	1996	2000	2001	2005	2006	RANK
Japan	83	99	104	123	**129**	3
United States	198	268	278	325	**338**	1
EU-15	139	176	188	223	233	
China	19	45	52	113	**136**	2
Germany	41	52	53	61	63	4
Growth rates:	**average 1981-2006**					
Japan					4.5	2
United States					3.9	3
EU-15					4.8	
China					**20.4**	1
Germany					3.5	4

Source: OECD 2006, Fig.1.

TABLE 4.3. R&D PERSONNEL

	China	Japan	Germany	Russia
	2006	**2005**	**2005**	**2005**
1000 person-years	1502.5	921.2	473.7	919.7
R&D personnel per 10,000 labor force	19	139	115	124

Source: MOST 2007

TABLE 4.4. R&D OUTPUTS

		China	US	Japan	Germany	Russia	Korea	UK	Italy
Patents granted (domestic, 2005)		20705	74637	111088	13084	19447	53419	3751	na
S&T papers indexed (SCI, EI, ISTP)		171878	590807	148887	134557	41316	na	138678	78166
	Rank	2	1	3	4	13	na	4	7
	%	8.4	28.8	7.2	6.6	2.01	na	6.8	3.8
S&T papers indexed (SCI)		71184	378690	88486	88850	23033	na	97942	50546
	Rank	5	1	2	3	14	na	2	8
	%	5.9	31.2	7.3	7.3	1.9	na	8.1	4.2

Source: MOST 2007

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[1] The elaboration of a more thorough and formal assessment, designed also to be further developed as a practically usable policy tool, will be the ultimate object of a larger research project, of which the present paper is to be seen as an introductory and propedeutic working document.

[2] Gabriele (2002) is based on Chinese and foreign sources of the mid- and late 1990s.

[3] In the remainder of the paper it will be showed that at present, less than about a decade later, such a resources reorientation is actually taking place, and China's R&D sector has probably reached a critical mass. The crucial issues, therefore, are becoming more and more of a qualitative, rather than a quantitative, nature.

[4] If Korea and Taiwan are considered as already developed, it is not obvious that any developing country, apart from China, is really closing the technological gap.. Emerging industrial and technological powers such as India and Brazil, for instance, are very far from engaging in a sustained R&D effort comparable to China's.

[5] It has been argued such a peculiar societal and institutional environment is conducive to a rather high level of corruption. However, as it co-exists with a high level of public trust, such a corruption is relatively ""efficiency-enhancing" rather than purely predatory (Li 2007). On the concept of ambiguous property rights see Gabriele 1993.

[6] See below, sections 2 and 4 2.2.

[7] Chinese industrial conglomerates' strong capitalization was due to some extent to the high valuation of the Shanghai stock market in 2007.

[8] According to Suh (2008), this alarming trend among US companies is due mainly to two factors. One is to a structural phenomenon favouring followers over technological leaders: the former have nothing to lose in earmarking most of their new investment towards the newest technologies, while the latter tend to channel most of their fresh capital to fortifying old technological systems. The second factor, related to the former but qualitatively different, is a subjective (and possibly conjunctural) increase in risk aversion among American top executives. However, it is also conceivable that increasing risk aversion might be at least partly a rational response of very well-informed informed agents to a real economy-wide increase in the riskiness of investment in the US. One major culprit is the long-term impact of the mess caused by deregulation excesses in the US financial system. In this respect, Suh observes that "US companies may be spending more but they are not spending better. Spending on the Sarbanes-Oxley compliance law and mergers and acquisitions integration is consuming most discretionary capital. This has delayed crucial new projects and left old systems to sup- port ageing processes". Another factor is probably constituted by unfavourable geopolitical trends, which are leading towards a deterioration of US control on energy and other primary resources worldwide..

[9] The vast majority of China's exports is constituted by manufactures.

[10] As is well known, PPP estimates are tentative, and should not be read straight-forwardly as the "true" figures as opposed to the "wrong" one expressed in current USD. By their very nature, PPP estimates (specularly to ordinary data expressed in current USD) relatively overestimate to some extent poorer countries' GDP and other economic magnitudes with respect to richer ones, mainly because they tend to underestimate the weight of traded goods. For instance, a country's ability to obtain advanced weapons is better approximated by its GDP in current USD than by its GDP in PPP terms. This bias might be particularly relevant in the case of R&D. for instance, an average engineer's salary in current USD is much lower in China than in the US or Japan. However, it is possible (albeit not at all certain) that a Chinese engineer's "true" skills are lower than those of her/his American counterparts, to an extent that, in practice, cannot be gauged in a precise manner. If this were the case, China's R&D expenditure in PPP would end up being overestimated relatively to that of the US and Japan.

[11] 2006 figures are projections..

[12] Different countries' synthetic indicators of international R&D outputs, even more so than R&D input indicators, are not always fully comparable and/or less than straightforward to interpreter properly. For instance, country A might publish more indexed R&D papers than country B, yet the quality of country B's papers' might be higher. The latter information is not carried out by the parsimonious indicator "number of indexed R&D papers".

[13]The productivity of capital is the inverse of the capital/output ratio.

[14] India's capital productivity surpasssed China's in the early 1990s, and by the early 2000s it was about 30% higher (see Felipe et al 2008, figure 8).
[15] The World Bank report also observes that "… if 50 percent of SOE profits, estimated at 6.5 percent of GDP in 2004, were distributed to the budget, this would support an 85 percent increase in government spending on education and health" (Kuijs , Mako , and Zhang C., 2005, p.7.)
[16] Li Rongrong, director of the state-asset regulator body in 2006 that the dividends from SOEs would likely be used to fund public works projects and support the development of select industries (Shanghai Daily 2007 September 14, 2007).

[17] Two caveats are warranted.. The first is that, in our view, neither extreme model system could practically exist, let alone prosper, in the real world, so that - at least, during the present historical time - only intermediate, hybrid socioeconomic formation can be sustainable, even if crucial differences among the more "socialistic" and the more "capitalistic" ones do exist. Second, the term "socialistic", even if its genesis is related to a mental experiment, is meant to be an analytical tool referring exclusively to the scientific, positive observation of objective features of really existing socioeconomic systems. On the contrary, per se, it does not imply any value judgement on whether one or another socioeconomic system is performing more satisfactorily than the others (or might be better equipped to do so in the future) in the realm of achieving the normative goals traditionally pursued by the socialist movement (such as universal satisfaction of basic needs, social justice, and an end of workers' exploitation).

[18] This remains true even taking into account phenomena such as widespread corruption and the conspicuous consumption of a newborn "new rich" class in China, as the latter lacks some of the typical crucial social and political attributes of a ruling capitalist class. This statement constitutes an informed, yet heuristic judgement based on the interpretation of available historical, sociological, political, and economic evidence. By its own nature, it cannot constitute a scientifically proven proposition, and we are aware that many observers legitimately disagree with us on this important point.
[19] The other member is, of course, Vietnam.
[20] As explained above, "the term "socialistic" does not imply any value judgement in teleological, normative terms.
[21] The public sector holds a commanding leadership position in controlling China's overall investment process, not only in quantitative, but also in qualitative terms. In this respect, one often underestimated reason explaining the higher profitability of China's) private enterprises vis a vis SOEs is that the latter have been according a significant priority on infrastructure, R&D and investment in advanced sectors, thereby also creating major positive externalities. Conversely, the investment of domestic capitalists (and, to some extent, of TVEs) is in a certain sense of a residual nature, as it concentrates on reaping the ample money-making opportunities in traditional sectors, where a relatively small investment can generate high profits in the short term.
[22] If, more realistically, we were assuming that workers also save a share of their income, the story would not differ substantially, as the capitalist class is the only one which has the power to decide about the allocation of the surplus (see Pasinetti 1962).
[23] Capitalists as a class might end up overinvesting under particular circumstances due to factors such as asymmetric information , irrational exuberance, herd behaviour, financial and real estate bubbles, etc., leading to crises.
[24] Of course, this rather strong statement implicitly assumes a ceteris paribus condition with respects to the efficiency of investment.
[25] For the sake of our argument, it is sufficient to assume that the share of profits which is reinvested is significantly higher than in a "normal" capitalist country. In practice, of course, a sizeable share of China's profits is earned by TNCs and national capitalists. According to our interpretative approach, there is no reason to believe that their investment behaviour should be much different from that of capitalists operating in any other country. However, it is possible that some aspects of Chinese national culture could be conducive to a relatively high propensity to save and invest on the part of China's capitalists.
[26] Of course, if - as it is the case in China - the marginal productivity of investment is not only lower than, for instance, in India, but also progressively declining, the existing pattern of growth is not

sustainable in the long run. It is therefore necessary to put a brake to the excessive rise in the rate of accumulation and - more importantly - accelerate the rate of genuine technical progress and shift its bias away from the ultimately unsustainable Marxian one, which is labor-saving but capital-consuming.

[27] This is the virtuous case where all, or most, of the additional investment (with respect to that which would prevail in a capitalist setting) is earmarked towards the privately unprofitable but of socially useful projects. The opposite, of course, is true if, on the contrary, most of the additional investment goes towards bad projects of the third type.

[28] There are a few examples of capitalists countries planned countries which reached accumulation rates similar to that of China. However, they were strongly atypical, due to the depth and effectiveness of government intervention in the economy. Classical examples are Singapore and Korea.
[29] An example would be to earmark more resources to all levels of education, in order to increase the supply of skilled labour and highly-skilled labor via human capital formation. Besides boosting technical progress and economic development, such a policy would help to lower the skilled/unskilled wage premium, thereby diminishing wage inequality in a market-compatible fashion.
[30] The United States Information Technology Office in Beijing translated the Chinese term used in the Plan as "independent, self-reliant, and indigenous" and "combining three distinct elements: yuanshi (original, or genuinely new); jicheng (integrated, or combining existing technologies in new ways); and yinjin (assimilated, or making improvements to imported technologies)". (AeA 2007).
[31] Thus, "the United States and other global powers should not underestimate China's ability to follow through on them and become an economic and technological equal." (AeA 2007)

[32] On energy and sustainability in China's development strategy see Khan (2008c,1997)
[33] As shown in section 3, China has being climbing the international ranking ladder in all categories of patents, but the relative weight of invention patents is still comparatively low.
[34] Besides using his own retained profits, each capitalist can have access to part of the society's existing profits (i.e. potentially investible surplus) through the credit mechanisms. Ex post, however, for the economy as a whole, the mass of profits (surplus) does not change.
[35] According to our approach, there is no a priori reason to believe that the efficiency with which "capitalistically profitable" investments is carried out should be lower in a socialistic society.