Globelics

China's System and Vision of Innovation: Analysis of the National Medium- and Long-term Science and Technology Development Plan (2006-2020)

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China has been characterised by extremely high rates of economic growth for the last several decades. This growth originates from a transformation of the institutional set up giving more room for regional initiative, private ownership and use of market mechanisms. Regional political resources have been aligned to globally oriented market resources and this alignment has established a very specific and unique mechanism of capital accumulation resulting in extremely high savings and investment rates.

The downside of this growth model is its intensive exploitation of human and natural resources. While the rate of capital accumulation is extremely high (40-50% of GNP takes the form of gross savings and investment) non reproducible natural and social capital are suffering in the process of growth. Social and regional inequality has reached critical levels and so have ecological imbalances. The central leadership of China are aware of these problems and recent policy documents put strong emphasis on 'harmonious development' and 'independent innovation' (Gu and Lundvall 2006). In China the transformation of the national innovation system is now regarded as a major step toward a necessary renewal of the growth model. This paper presents a general framework for the analysis of national innovation system, a historical overview over the development of China's production and innovation system and ends up with a discussion of the National Medium- and Long-term Science and Technology Development Plan (2006-2020).

We conclude that the plan represents steps forward in important respects. This is true for the emphasis on need driven innovation policy with focus on energy and environment, the stronger role for enterprises as hosts of R&D-efforts and innovation, a more active role for public procurement and a more realistic understanding of the limits of science as source of innovation. But the plan has some weaknesses and needs to be complemented with other initiatives. There is exaggerated

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technology optimism and the need for institutional and organisational change at the level of the enterprise is underestimated. In some cases the policy instruments and tools seem to be inadequate when related to the very ambitious targets set by the plan. Especially problematic is the absence of an explicit analysis of the regional dimension and the need to upgrade working life in terms of skills and organisation. The fact that a knowledge based strategy, if left to itself, leads to further social and regional polarisation is not taken into account. Finally how the idea of 'indigenous innovation' will be implemented is crucial both for the success of the plan and for China's relationships with the rest of the world.

1. The National Innovation System[5]

The interest for the innovation system approach has grown remarkably over the last decade in China. The long term plan to be discussed in section 4 of the paper uses the national innovation system concept as explicit framework for presenting analysis and prescriptions. In the wake of this growing interest several of the 'classical' contributions (Freeman 1987, Lundvall 1992, Nelson 1993 and Edquist 1996) have recently been translated into Chinese. But as will be demonstrated in this section the concept may be given different interpretations that are more or less broad. A common weakness of much of the policy making that refers to innovation system is that it builds upon an implicit assumption that science is the major if not the only source of innovation. It is neglected that much competence-building crucial for innovation takes place within enterprises and in the interaction with customers. This kind of bias leads to policy strategies that underestimate the need to upgrade skills and to introduce elements of what may be referred to as learning organisations.

1.1 Innovation system – a focusing device

Theories in the social sciences may be regarded as 'focusing devices'. Any specific theory brings forward and exposes some aspects of the real world, leaving others in obscurity. That is why a long lasting hegemony of one single theoretical tradition is damaging both in terms of understanding and policy-making. In the field of economics, the dominating neo-classical paradigm puts its analytical focus upon concepts such as scarcity, allocation, and exchange, in a static context. Even if these concepts reflect important phenomena in the real world, they only bring forward some aspects of the economic system. The innovation system concept may be seen as signalling an alternative focusing device since it puts interactive learning and innovation at the centre of analysis.[6]

Table 1 illustrates how the analytical framework connected to innovation systems relates to mainstream economic theory. The theoretical core of standard economic theory is about rational agents making choices to which are connected well-defined (but possibly risky) alternative outcomes and the focus of the analysis is on the allocation of scarce resources. As illustrated by the following table the emphasis is different in the innovation system approach.

[5] This section draws upon Lundvall (2007).

[6] While the leadership in China is dominated by experts with engineering background a growing number of returnees from the US are economists with a strong training in neo-classical economics. The marriage between dogmatic Marxist economics and neo-classical economics in academic training does not make it easy for students to understand soft concepts such as social and natural capital.

Table 1: The two-dimensional shift in perspective

	Allocation	Innovation
Choice making	Standard neoclassical	Project management
Learning	Austrian Economics	Innovation systems

The analysis of innovation systems is based upon a two-dimensional shift of focus toward the combination of innovation and learning. While standard economics is preoccupied with specifying the institutional set-up that results in an optimal allocation of existing resources we are concerned with how different institutional set-ups affect the creation of new resources. While standard economics analyse how agents make choices on the basis of given sets of information and competences, we are interested in how the knowledge – including both information about the world and know-how of agents – change in the economic process.

This double shift in perspective has implications for innovation policy. Just to take one example, a policy analysis of patent races where 'winner takes it all' will, as far as it neglects the learning and competence building that takes place during the race, end up with too restrictive conclusions regarding the role of government in stimulating R&D.

1.2 The NSI-perspective is more complex – not less theoretical – than standard economics

What has been said obviously implies a more complex theory than standard neoclassical economics where it is assumed that all agents have equal access to technologies and are equally competent in developing and utilizing them. But it would be wrong to conclude that the theory behind innovation systems is 'less theoretical'.

Basically, the theory underlying innovation system analysis is about learning processes involving skilful but imperfectly rational agents and organizations. It assumes that organizations and agents have a capability to enhance their competence through searching and learning and that they do so in interaction with other agents and that this is reflected in innovation processes and outcomes in the form of innovations and new competences.

The methodological dictum within neo-classical economics that theory should be both general and abstract sometimes takes Occam's razor too far, leading to negligence of the concrete and historical. But the most important weakness of neo-classical theory is not that it is too abstract. *It is rather that it makes the wrong abstractions*. In a context where knowledge is the most important resource and learning the most important process neo-classical theory tends to abstract from the very processes that make a difference in terms of the economic performance of firms and for the wealth of nations.

Processes of competence building and innovation are at the focal point in innovation system analysis. The focus is upon how enduring relationships and patterns of dependence and interaction are established, evolve and dissolve as time goes by. New competences are built while old ones are destroyed. At each point in time discernable patterns of collaboration and communication characterize the innovation system. But, of course, in the long term these patterns change in a process of creative destruction of knowledge and relationships. A crucial normative issue is how such patterns affect the creation of new resources and to what degree they support learning among agents.

1.3 Standard economics favours narrow interpretation of innovation systems

Standard economics tends to stick to the idea that only quantitative as opposed to qualitative concepts can be accepted as scientific (Georgescu Roegen 1971). One reason for the bias toward narrow interpretations of innovation systems is that it is much easier to develop quantitative analysis of R&D and patents, than it is to measure organizational forms and outcomes of organizational learning.

Standard economics will typically focus on potential market failure and on choices to be made between different alternative uses of scarce resources. In the context of innovation policy the concern will be, first, if public rates of return are higher that private rates and, second, if the rate of return of public money is higher in investing in R&D than it would be in other areas of public investment.[7] The very idea that there might be organizational forms that are more efficient than the ones already in use cannot be reconciled with the basic analytical framework where it is assumed that agents, including firms, are equally rational and competent.

Standard economics will tend to see the market as the 'natural', if not optimal, framework of human interaction and economic transaction. This leads to biased conclusions when considering how to organize the economy (Nelson 2006). The concept 'market failure' reflects this bias since it indicates that other institutional set-ups should be considered only when it is obvious that the market cannot do the job.

In this section we argue that during the process of diffusion there has been a *distortion* of the concept as compared to the original versions as developed by Christopher Freeman and the IKE-group in Aalborg. Often policy makers and scholars have applied a narrow understanding of the concept and this has gives rise to so-called 'innovation paradoxes' which leave significant elements of innovation-based economic performance unexplained. Such a bias is reflected in studies of innovation that focus on science-based innovation and on the *formal* technological infrastructure and in policies aiming almost exclusively at stimulating R&D efforts in high-technology sectors.
Without a broad definition of the national innovation system encompassing individual, organizational and inter-organizational learning, it is impossible to establish the link from innovation to economic growth. A double focus is needed where attention is given not only to the science infrastructure, but also to institutions/organisations that support *competence building* in labour markets, education and working life. This is especially important in the current era of the *globalizing learning economy* (Lundvall and Johnson 1994; Lundvall and Borràs 1998; Archibugi and Lundvall 2001).

We see one major reason for this distortion in the uncomfortable co-existence in international organisations such as OECD and the EC of the innovation system approach and the much more narrow understanding of innovation emanating from standard economics (Eparvier 2005). Evolutionary processes of learning where agents are transformed and become more diverse in terms of what they know and what they know how to do are not reconciliable with the rational

[7] Within this narrow logic the neglect of learning effects from engaging in innovation will underestimate both private and public rates of return.

'representative agents' that populate the neoclassical world (Dosi 1999). Actually, we regard the neglect of 'learning as competence-building' as the principal weakness of standard economics and the narrow definitions of innovation systems as reflecting a negative spill-over from this misdirected abstraction.

Both Mode 2 knowledge production (Gibbons et al 1994) and the Triple Helix approach focus on science and the role of universities in innovation. When they present themselves or are applied by policy makers, not as analysing a subsystem within, but as full-blown alternatives to the innovation system approach (Etzkowitz and Leydesdorff 1995; Etzkowitz and Leydesdorff 2000), these approaches contribute to the distortion. These perspectives capture processes linking science and technology to innovation – below we refer to this as *STI-learning*. The fact that science and codified knowledge become increasingly important for more and more firms in different industries – including so-called low-technology ones – *does not imply that experience-based learning and tacit knowledge have become less important* for innovation. To bring innovations, including science-based innovations, to the market organisational learning, industrial networks as well as employee participation and competence building are more important than ever. We refer to the knowledge-creation that emanates from experience as *DUI-learning*. It includes learning by *d*oing, learning by *u*sing and and learning by *i*nteracting with users and suppliers. When assessing innovation policy strategies it is crucial to analyse their impact on both these forms of learning.

1.4 The weak correlation between strength of the science-base and economic performance

Over the last century there has been a certain focus on the European Paradox referring to the assumed fact that Europe is strong in science but weak in innovation and economic growth.[8] Similar paradoxes have been argued to exist in countries such as The Netherlands, Finland and Sweden. In a recent OECD-report a *general result* is that for the countries included in the study it can be shown that those that 'perform well' in terms of STI-indicators do not perform well in terms of innovation (OECD 2005, p. 29).[9] This indicates that what is registered is not so much a paradox as it is a systematic weakness in the theoretical analysis and the indicators upon which it is built.

We would argue that these apparent paradoxes emanate from a narrow understanding of the innovation process. They demonstrate that heavy investment in science in systems where organizational learning within and between firms is weakly developed and where there is a weak focus on user needs has only limited positive impact upon innovation and economic growth.

This can be illustrated by data on innovation performance at the firm level – see table 2. In a series of recent papers based upon a unique combination of survey and register data for Danish firms we have demonstrated that firms that engage in R&D without establishing organizational forms that

[8] This debate has triggered strong efforts to link universities to firms in Europe sometimes going as far as seeing the ideal university as 'innovation factory'. Dosi, Llerena and Sylos Labini (2006) raise doubts about the basic assumption behind the paradox that Europe is strong in Science.

[9] After comparing the performance of six countries it is stated that 'A striking feature is the apparent missing link between indicators A-E and the overall performance indicators in F. *This suggests that priorities and biases in the STI-policy system are weakly linked to general economic performance and policies*.' (OECD 2005, p.29, italics by us).

promote learning and neglect customer interaction are much less innovative than firms that are strong both in terms to STI- and DUI-learning (Jensen, Johnson, Lorenz and Lundvall 2007).[10]

Table 2 refers to the outcome of an analysis of survey and register data for almost 700 Danish firms and it presents different variables related to the propensity to introduce new products or services. We use sector, size and form of ownership as control variables but the focus is upon a variable indicating *the mode of innovation* in the firm. We distinguish between firms that are strong in science-based learning, firms strong in organizational learning, firms that are strong in both respects and we use those firms that are weak in both respects as the benchmark category. To construct this variable we pursue a cluster analysis grouping the firms in the four categories.

As indicators of strong science-based learning we use the R&D expenditure, presence of employees with academic degree in natural science or technology and collaboration with scientists in universities or other science organizations. As indicator of experience-based learning we take the use of certain organizational practices normally connected with learning organizations such as ‘interdisciplinary workgroups’ and ‘integration of functions’ together with ‘closer interaction with customers’ – to signal learning by interacting and a focus on user needs.

We use firms that only make weak efforts to support science-based and experience-based learning as benchmark and the odds ratio estimate indicates how much higher the propensity to innovate is among firms strong in respectively one or both of the modes of learning. The results reported in table 2 show that firms that combine the two modes are much more prone to innovate than the rest. It shows that the effect remains strong also after introducing control variables related to size and sector.

[10] The data in table 2 are from Jensen, Johnson, Lorenz and Lundvall (2007).

Table 2: The probability that firms develop a new product or a new service

Variables	Odds ratio estimate	Coefficient estimate	Odds ratio estimate	Coefficient estimate
STI Cluster	3.529	1.2611**	2.355	0.8564**
DUI Cluster	2.487	0.9109**	2.218	0.7967**
DUI/STI Cluster	7.843	2.0596**	5.064	1.6222**
Business services			1.433	0.3599
Construction			0.491	-0.7120*
Manuf. (high tech)			1.805	0.5905*
Manuf.(low and med. tech)			1.250	0.2229
Other services			0.747	-0.2923
100 and more employees			1.757	0.5635*
50-99 employees			0.862	-0.1481
Danish group			0.859	-0.1524
Single firm			0.521	-0.6526*
Customised product			1.378	0.3203
Pseudo R^2	0.1247	0.1247	0.1775	0.1775
N	*692*	*692*	*692*	*692*

** = significant at the .01 level
* = significant at the .05 level

The analysis and results reported above point to the need to develop our understanding of how different forms of knowledge and different modes of innovation are combined in different national innovation systems. The analysis also explains why narrow definitions of national innovation systems that focus only upon science-based innovation are of little relevance for the economic performance of firms and national innovation systems. This is not least important when it comes to analyse the barriers and opportunities for economic development in poor countries, another challenge for innovation system research (Arocena and Sutz 2000b; Cassiolato, Lastres and Maciel 2003).

1.5 National systems of innovation and economic development

While the modern version of the concept of national systems of innovation was developed mainly in rich countries (Freeman 1982; Freeman and Lundvall 1988; Lundvall 1992; Nelson 1993; Edquist 1997) some of the most important elements actually came from the literature on development issues in the third world. For instance the Aalborg version (Andersen and Lundvall 1988) got some of its inspiration concerning the interdependence between different sectors from Hirschman (1958) and Stewart (1977). Other encouragements came from Myrdal (1968). Applying the systems of innovation approach to economic development brings into focus other research issues of general interest such as the need to understand how innovation relates to sustainable development, economic welfare and the role of government in commodifying knowledge.

Most analysis of the innovation system regards it as an ex-post rather than as an ex-ante concept. The concept refers to relatively strong and diversified systems with well-developed institutional and infrastructural support of innovation activities. The perspective is one where innovation processes are evolutionary and path dependent and systems of innovation evolve over time in a largely unplanned manner. The system of innovation approach has not, to the same extent, been applied to system building. When applied to a country in transition such as China focus needs to be shifted in the direction of system construction and system promotion – something that was central in List's ideas for catching up – and to the fact that public policy is a conscious activity that needs to stimulate and supplement the spontaneous development of systems of innovation (Muchie, Gammeltoft and Lundvall 2003; Lundvall, Interakummerd and Lauridsen 2006).

Another weakness of the system of innovation approach is that it is still lacking in its treatment of the power aspects of development. The focus on interactive learning – a process in which agents communicate and cooperate in the creation and utilization of new economically useful knowledge – may lead to an underestimation of the conflicts over income and power, connected to the innovation process. In a global context where the access to technical knowledge is becoming restricted not only by weak 'absorptive capacity' but also by more and more ambitious global schemes to protect intellectual property this perspective gives a too rosy picture. The current focus on 'independent innovation' may be seen as making the global power game regarding access to knowledge explicit.

Furthermore, the relationships between globalisation and national and local systems need to be further researched. It is important to know more about how globalisation processes affect the possibilities to build and support national and local systems of innovation in developing countries (Lastres and Cassiolato 2005). In China the opening of the economy has taken place at a very high speed and one of the major effects has been regional polarisation. It is thus clear that the innovation system approach proposed here needs to be adapted to the situation in developing countries, if it is to be applied to system building. It is also clear that what is most relevant for developing economies is a broad definition of the NSI including not only low-tech industries but also primary sectors such as agriculture. Activities contributing to competence building needs to be taken into account and narrow perspectives that focus only on the STI-mode needs to be avoided.[11]

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[11] Several authors analysing the situation of less developed countries have been critical to the use of the concept 'national innovation system' and have preferred to work with concepts such as national technological systems (Lall and Pietrobelli 2003) or national learning systems (Matthews 2001;Viotti 2002). To some degree we see their alternative conceptual proposals as reactions to the use of narrowly defined innovation systems with focus on STI-learning. We strongly support the idea that understanding processes of experience based learning is a key to the understanding of the specificities of national innovation systems (Jensen, Johnson, Lorenz and Lundvall 2007; Arundel, Lorenz, Lundvall and Valeyre 2007).

1.6 Welfare and inequality in the context of innovation systems

A promising line of research is to link the perspective of Amartya Sen (1999) on welfare and inequality to the national system perspective. Sen presents a capability-based approach where development is seen as an expansion of the substantive freedoms that people enjoy. Substantive freedoms are defined as the capabilities people have to live the kind of lives they have reason to value. They include things like being able to avoid starvation and undernourishment, diseases and premature mortality. It also includes the freedoms of being literate, able to participate in public life and in political processes, having ability and possibility to work and to influence one's work conditions, having entrepreneurial freedom and possibilities to take economic decisions of different kinds. Enhancement of freedoms like these is seen as both the ends and means of development.

This way of looking at development refers to the capabilities people have to act and to choose a life they value, rather than to their level of income and possession of wealth. Poverty, for example, is in this perspective more a deprivation of basic capabilities than just low income. Human capabilities rather than resource endowments are the fundamental factors of development. Sen's approach fits well into a system of innovation approach. It is noteworthy however that learning and innovation capabilities generally do not seem to be explicitly included in this capability-based approach to development. Extending capabilities may be the result of changing the setting in which the agent operates, but even more important in the learning economy is whether the setting gives access to and stimulates a renewal and upgrading of the competence of agents.

We would argue that the learning capability is thus one of the most important of the human capabilities and it is conditioned by national institutions and forms of work organisation. It does not only have an instrumental role in development but also, under certain conditions, substantive value. When learning takes place in such a way that it enhances the capability of individuals and collectives to utilize and co-exist with their environment, it contributes directly to human well-being. Furthermore, to be able to participate in learning and innovation at the work place may be seen as 'a good thing' contributing to a feeling of belonging and significance.

China has developed a strongly meritocratic system where university education has become the key and almost the only legitimate entrance point for advancing in the social hierarchy. To offer wider segments of the adult population access to vocational training with theoretical elements might be a key both to reduce inequality and to enhance the capacity to innovate within enterprises. A more balanced understanding of the importance of experience-based knowledge in the education system as in society as a whole would benefit the efforts to build 'endogenous innovation capacity'.

1.7 On the sustainability of innovation systems

National Systems of Innovation may be regarded as a tool for analysing economic development and economic growth. It aims at explaining how systemic features and different institutional set-ups at the national level link innovation and learning processes to economic growth.

But such a perspective may be too narrow. As pointed out by Freeman and Soete (1997) the ecological challenge ought to be integrated in any strategy for economic development and here we will argue that in the learning economy not only intellectual capital but also social capital is an important element in the development process. The extended perspective can be introduced as in Table 3 below.

Table 3: Resources fundamental for economic growth – combining the tangible and reproducible dimensions

	Easily reproducible resources	Less reproducible resources
Tangible resources	1. Production capital	2. Natural capital
Intangible resources	3. Intellectual capital	4. Social capital

The diagram illustrates that economic growth is faced with a double challenge in terms of sustainability and that there is an immanent risk of undermining not only the material basis of material production (Segura-Bonilla 1999), but also the knowledge base. The creation of tangible capital may be threatened by a neglect of environmental sustainability. We will argue that the production and efficient use of intellectual capital is fundamentally depending upon social capital (Woolcock 1998). A development strategy that focuses only on production capital and intellectual capital is not sustainable.

This has become a key issue in China where the conflict between the current model of growth and sustainability has become obvious. But also in the rest of the world, including EU, there is a growing insight that linking innovation to environmental problems and energy shortage is fundamental for the future of the global economy. The fact that China has the potential to initiate a nation-wide strategy to establish this connection offers a major opportunity for China. But as we shall see in the following section radical change in this direction might not be easy to implement from the centre. The current governance model where local/regional alliances between political and economic agents are committed to the old accumulation model needs to be transformed through the introduction of new incentives and new forms of governance.

2. China's Production system and Growth trajectory[12]

Observers around the world are impressed by the rapid growth of China's economy. While outside observers tend to focus on the success story of unprecedented growth policy documents and recent domestic debates in China have pointed to the need for a shift in the growth trajectory with stronger emphasis on 'endogenous innovation' and 'harmonious development'.

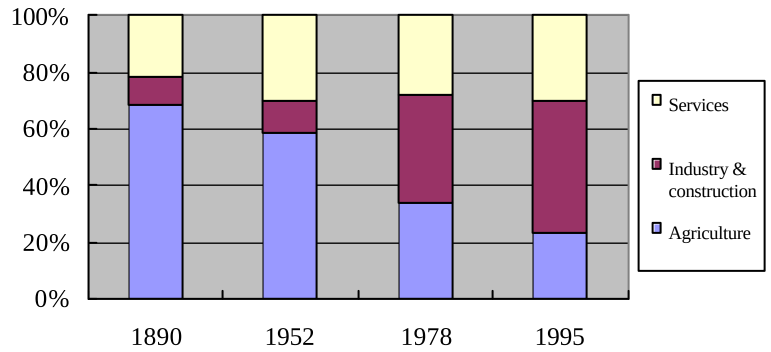
In this section we make an attempt to capture the current characteristics of China's production system and its mode of accumulation; how they were shaped by history and what major challenges they raise for the future. We show how the shift in policy toward decentralization, privatization and openness around 1980 established an institutional setting that, together with other factors such as the presence of a wide 'Chinese Diaspora', has resulted in extremely high rates of capital accumulation especially in export-oriented manufacturing.

2.2. The transition of China's economy

It is useful to distinguish between two periods in China in the second half of the 20th century. The crucial shift takes place in 1978 when DENG Xiaoping took over the political leadership after Chairman MAO and initiated economic reform and the opening of the economy to international trade. The first was a period of development under a centrally planned economic regime and the second a period with market-oriented reforms and economic transition.

12 This section as well as section 3 below draws upon Gu and Lundvall (2006b).

Figure 2 GDP Structure of China's economy at constant prices



Source: Maddison 1998: 56, Tables 3.1 and 3.2

At the time of the revolution the economy was still dominated by agriculture; in 1952 about 60 percent of GDP was generated by the agricultural (primary) sector, as shown in Figure 2. Both the first and the second period were dominated by industrialization, rather than "post-industrialization" that took place after WWII in developed and most less developed countries. As a result, China ends up being highly "industrialized" by the end of the century. In 2003, the GDP structure of China was 12.5 per cent primary, 46 per cent secondary and 41.5 per cent tertiary. The growth in manufacturing and the relative shrinkage of agriculture went on also in the 1990s, and the value added-share of the service sectors remained almost unchanged until the second half of the 1990s. But as we shall see below the economic structure looks quite different when the focus is employment rather than value added. The proportion of the labour force working in agriculture remains as high as 50% in the beginning of the new millennium. The growth in manufacturing value added reflects more than anything else a very high rate of accumulation of fixed capital accompanied by high rates of growth in labour productivity.

Behind the high growth rates and the restructuring of the economy in the second period lie extraordinary rates of savings and capital accumulation. In order to understand how these could be realized in a poor country like China it is necessary to look at the institutional changes that took place with the shift in the political climate.

2.3 Reforms and development performance in the 1980s and 1990s

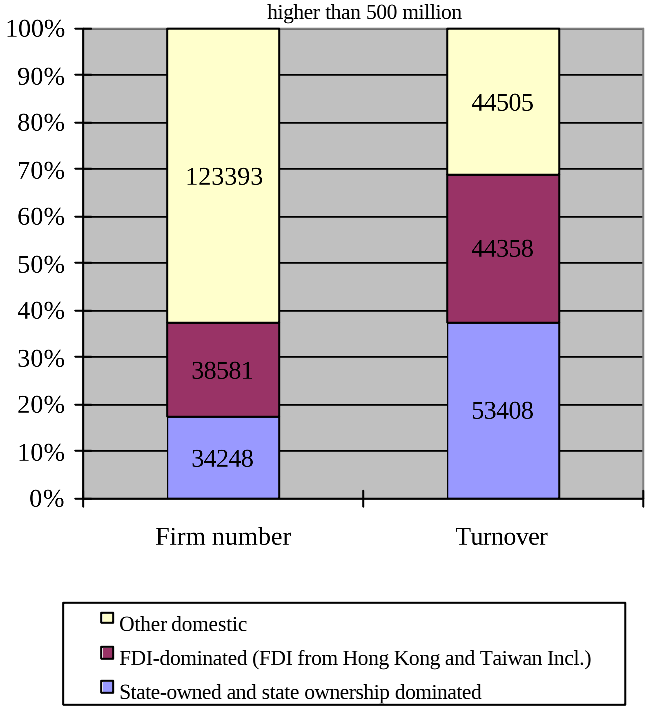
The policies transforming the economy from a centrally planned towards a market-oriented regime may be seen as following two parallel and mutually reinforcing lines of action aiming at decentralization and privatization (Wu 2003, Chapter 2).

The first line of action, "bureaucratic decentralization", began with increasing the autonomy of firms in decision-making on production planning, investment and acquisition of technology, marketing, pricing and personnel and with more autonomy to local governments in financial, budgetary and administrative issues.

The second line of action loosened the restrictions first for township and village enterprises in the early 1980s and later also for private initiatives in the mid-1990s. It included the creation of "Special Economic Zones" for FDI related investment with various favorable regulations. In provinces like Zhejiang this led to private initiatives by entrepreneurs.

But most importantly it gave the local governments bigger opportunities to engage in initiatives promoting the local accumulation of capital. They did so through establishing and expanding TVEs (Township and Village Enterprises) sometimes owned by the local governments, sometimes representing joint enterprises with private capital or through initiatives attracting private capital from local, national or international sources.

Figure 3 Ownership structure: Industry by 2003
Source: based on China statistical yearbook Table 14-2 2004http://www.stats.gov.cn/tjsj/ndsj/yb2004-c/indexch.htm
Note: the calculation is for all the firms which have annual turnover higher than 500 million



“Diaspora networks” played an important part in re-enforcing the rapid capital accumulation from foreign investment. Throughout the 1980s, the opening to FDI and international trade attracted partners mainly from the Greater China area—Hong Kong, Chinese Taipei, Singapore, and overseas Chinese from other continents. It was not until the second half of the 1990s that multinational companies from North America and West Europe came into China on a large scale.

The second line of action, also called “incremental reform”, opened up new spaces for economic activities outside the entities inherited from the central planning era. As a result, the ownership structure of industrial enterprises changed rapidly. As can be seen from figure 3, by 2003, each of the three types of ownership—the state-owned, FDI related and other domestic - were responsible for roughly one third of output.

2.4 Export led growth

International trade was initially pushed by favourable policies and gradually pulled by FDI and intra-trade within global value chains. Today China’s economy has reached a much higher level of openness than all other large economies in the world, developed or developing. Figure 4 shows that

the sum of exports and imports as share of GNP has grown from 10% to more than 50% in 2003. The corresponding openness indicator is 25-30% in the US, Japan Brasil and India.
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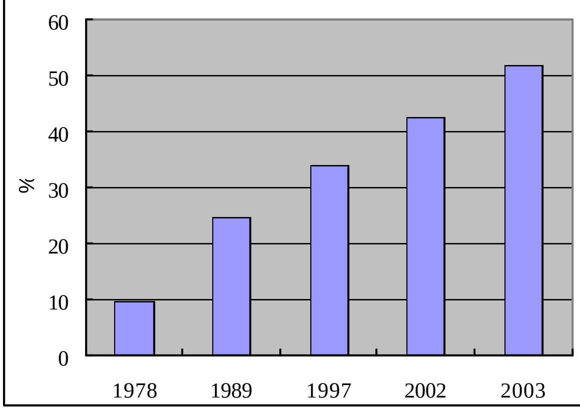
Figure 4 Openess to Global Economy



Export structures have been upgraded (Figure 5). The share of primary products, such as foodstuffs, agricultural products and mineral fuels, have been reduced from half of the total in 1980 to less than 10 percent by 2002, while the share of manufactured goods increased to more than 90 percent. In manufactured exports, electric and machinery products including electronic products, demonstrated the fastest growth rate. But light and textile products and apparel increased considerably as well.

Beyond quantitative growth, qualitative or structural change has been radical but the most strongly knowledge based activities take place in the foreign-owned firms. In industries such as computer and IT products exports are mainly manufactured in factories owned by Western and Taiwanese investors. For 2003 it is reported that 61.9 percent of high-tech export was produced by fully foreign-owned and 21.4 percent by partly foreign-owned firms; altogether FDI-related manufacturing produced more than 80 percent of high-tech export from China (China S&T Indicators 2004). This reflects overall trends of the innovation system of China characterized by easy access to foreign technology, while remaining weak in local and domestic clustering.

2.5 A unique pattern of economic growth

In about a quarter of a century China's economy has been characterised by high rates of economic growth and capital accumulation. Some of the mechanisms behind that growth pattern are unique while some have parallels with the institutional set up that promoted capital accumulation in England in the 18th century (Qian 1996).

The reforms that were initiated more than 25 years ago unleashed restrained material needs. It was explicitly argued that getting some concentration of wealth among the few was a first step toward making everybody better off; this made the strife for material wealth ideologically legitimate. Slumbering entrepreneurship was awoken to engage in production and trade both within and outside the public sector. *The most important driver behind capital investment and economic growth was a specific local fusion of political and economic interests.*

Foreign direct investment initially emanating primarily from overseas Chinese investors and subsequently from wider sources should be added to this as an important factor. Joint ventures offer good opportunities for public and private rewards for local policy makers. The same is true for attracting direct investment in purely foreign-owned enterprises to the locality. Building infrastructure and supplying cheap labour, energy and land has become a key concern for local administrators.

The dynamics of reform has also been driven by the competition between localities to offer the most attractive framework conditions. This sometimes takes the form of offering cheap resources and lax regulations in relation to environment and workers' safety. But there are also examples of forward-looking ideas developed locally and then spread nation-wide.

2.6. Limits to growth

The development trajectory behind the high speed of growth is now confronted with barriers for further growth. Some of these are external and refer to potential trade conflicts. Others reflect domestic problems with social and ecological sustainability. There are indications of serious weaknesses of the innovation system. The call for 'harmonious development' may be interpreted as an attempt to give new direction to the recognized unsustainable growth patterns.

Gaps between the urban and the rural, between regions, and between the rich and poor in the same region are widening. Working conditions and workers' safety have been largely neglected. Negative externalities also include environmental degradation such as pollution of air and water and exploitation and wasteful use of other non-renewable resources. The current development mode entails intense consumption of non-renewable raw materials and energy sources. Especially when these inputs are under the control of local groups with vested interests there may be a tendency to set prices too low and to be lax in terms of safety regulations.

The industrialization process has not resulted in building a widespread and robust indigenous innovation capability in Chinese firms. After twenty years of being the origin of manufactured goods "made-in-China", China's economy has not been able to embark upon the track of competence upgrading. This contrasts with the catch-up history of the US and Japan where "made-in-US" and "made-in-Japan" were preludes to the two countries, within a time span of one generation, reaching the world frontier in innovativeness and competitiveness. China remains specialized in low value-added products with profit margins trapped at meager 2-5 percent, or in some areas even lower.

Recent policy documents and the general debate have pointed to these problems and contradictions, and to the need for a shift in the development strategy with stronger emphasis on 'harmonious development' and 'endogenous innovation'. What adjustments of the development strategy are needed to realize the intentions signaled by these concepts? Does the new long term plan represent an adequate response to the current problems?

Before we discuss this issue in Section 4, it is necessary to analyze the reform of the innovation system that accompanied decentralization and privatization. The analysis of the reform and its outcome points to weaknesses of the current innovation system and it helps us to specify what reforms are required in order to make innovation endogenous and to make it contribute to harmonious development.

3. The Transformation of China's Innovation System

China is an old civilization and historically it has made important contributions to global science and technology (such as the compass, gunpowder and paper). In the older history of China, however, science and technology as it evolved in Western Europe was not regarded as important or as carrying social status. While Confucious' heritage gave high prestige to intellectuals, it was to those engaged in humanistic science and in political and administrative affairs. Scientific and technological knowledge was seen as based upon practical experience, rather than as a modern type of scholarship. Whereas Research and Development (R&D) establishments started to be organized in the 1920s to 1930s, China only began the process of institutionalization of modern science and technology nationwide in the 1950s.

3.1. The weakness of sector institutes

The R&D system established in the first period of development was designed in accordance with the centrally planned regime. One prominent feature was the huge size that was a reflection of the Marxist idea of science as a societal force of production and also a result of the self-reliance development strategy in the centrally planned period (see Table 4).
The second feature was the separation of industrial R&D centres from productive enterprises. The centrally planned regime had introduced particular mechanisms to link up R&D activity with production: All the R&D institutes, except those belonging to the Chinese Academy of Sciences (which was assigned to be the national top organization for comprehensive natural and engineering science) were organized under the jurisdiction of sector specific ministries or bureaus, independently outside enterprises. The ministries or bureaus took the responsibility for planned production tasks as well. They were hence in command of both R&D and production (Gu 1999: 151-176).

The institutional setting was reflected in innovation characteristics. For example, the machinery industry of China was apt at "general purpose" machinery, and weak in technologies fulfilling particular machining tasks since these could only be developed through interactive learning and close producer-user communications (Gu 1999 127-135). The low degree of *effectiveness* of the centrally planned institutional settings was well acknowledged at the end of the 1970s. This became one important motive for the launch of reforms.

3.2. The 1985 reform

The crucial event for R&D system reform came in 1985, slightly lagging the agricultural and industrial reforms, which were started in 1978 and 1984 respectively. A 1985 Decision made by the Central Committee of the Communist Party of China initiated the reforms in Science and Technology System Management. The central theme for the reform was to rearrange the relationship between knowledge producers and users and their relationships with the government. In a context where demand, supply and coordination factors were changing, reform of the S&T system was seen as essential.

The then Prime Minister Mr. Zhao Ziyang interpreted the reform as the following:

> *The current science and technology institution in our country has evolved over the years under special historical situations. …………. One of the glaring drawbacks of this system is the disconnection of science and technology from production, a problem, which is a source of great concern for all of us....*
>
> *By their very nature, there is an organic linkage between scientific research and production. ………. The management system as practiced until now has actually clogged this direct linkage, so that research*

institutes were only responsible to the leading departments above, in a vertical relationship, with no channels for interaction with the society as a whole or for providing consultancy services to production units. ………..This state of affairs can hardly be altered if we confine ourselves to the beaten track. The way out lies in a reform (Zhao Ziyang 1985).

3.3. The adaptive policy process and the recombination of competences

For reforming the S&T system, a two-pronged policy was designed. On the one hand, "technology markets" were established to function as distributive institutions for R&D outputs (Decision: Section III). On the other hand excellence-based allocation mechanisms were introduced for the allocation of public R&D funds (Decision: Section II). It was expected that by push and pull, the previously publicly funded R&D institutes would move to serve their clients via regular and multiple linkages.[13]

The actual process of S&T system reform, as the reforms of the overall economic system, unfolded through trial and error and entailed continuous adjustment of policies (Gu 1999). *The technology market solution,* central in the initial design, was soon recognized as being difficult to realize in its original form. The users were not capable of absorbing transferred technology, and the market was too small to secure R&D institutes with enough earnings. As a response, in 1987 reform policy began to promote the *merger of R&D institutes* into existing enterprises or enterprise groups.

In the next year (1988) the Torch Programme was launched to encourage organizations akin to *spin-off enterprises* — called *NTEs* (New Technology Enterprises) - from existing R&D institutes and universities. And by the early 1990s, reform policy included another solution to change *individual R&D institutes into production entities.* This, as well, was an adaptation to an actual evolution already realized by many industrial R&D institutes.

Adaptive policy evolving though trial and error characterized the "gradual reforms" in the process of economic transition in China. The great uncertainties associated with foreseeing the impact of major political reform made adaptive policy learning necessary. Only policy-making that was responsive and adaptive to the feed-back information on the impact could preserve the feasibility for success of any radical social innovation program (Metcalfe 1995, Gu and Lundvall 2006).

3.4. Remaining weaknesses

The transformation was constructive in safeguarding and recombining technological capabilities in the context of market reform and opening to the global economy. It has supported the rapid growth in the economy as a whole. For example, a number of NTEs like Huawei, Datang and Linovo, grew to become key ICT enterprises and this led to a fundamental restructuring of China's ICT industry (Gu and Steinmueller 1996/2000). The achievements are especially impressive when comparing with Russia where scientific and technological capabilities were destroyed on a huge scale. It nonetheless leaves the system with some prominent weakness.

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[13] Note that the Decision recognized the diversity of R&D institutes in terms of their function. It divided them into "technology development type", "basic research type", and "public welfare and infrastructure services type". The reduction of public funds was mainly applied to the technology development type and it was done gradually to be complete in a time span of five years. Consequently by 1991, the 2,000 plus, out of the 4,000 in total, technology development institutes had had their public "operation fees" entirely or partly cut. Roughly the sum of the reduction accounted to slightly less than RMB 1 billion (or USD 200 m), or about one tenth of the overall government S&T budget in 1985.

First of all, the resulting system developed weaker domestic links and interactions than international links, although the mastery of the latter links remains rather passive, dominated by the import of foreign technology embodied in machinery and other process equipment. The *capital goods industry* has not played a role as an innovation centre for the whole economy by providing appropriately advanced production means for various users; they were instead largely integrated into the respective global value chains. In general *potential local or domestic links along and between value chains* have been slow to develop and hard to expand. Small firms in traditional manufacturing sectors, and agriculture and rural development have received inadequate support from national and regional technological infrastructure, showing a *separation between the modern and the traditional part* of the system (Tylecote, this issue).

Second, the transformation ignored the development of technological infrastructure and supportive institutions. The remarkable aspect of the reform is that the initial intention - to establish markets for technologies for existing R&D institutes and existing enterprises - was not realized. Instead other unforeseen adaptations ‘saved’ the reform. A general tendency was *vertical integration of R&D and design with production activities* - either through merger into enterprises or through the establishment of downstream production. This has resulted in a weak capability to provide S&T inputs and supportive services to innovation in firms; a capability that is fundamentally important for knowledge based growth (Nelson 2004, David 2003).

There were several reasons for the drive toward vertical integration. One reason was the peculiar pattern of division of labour for R&D institutes inherited from the centrally planned system in which they had already been involved in many “down-stream” activities. Weak absorptive capacity and less developed social capital were other reasons for the difficulties in establishing markets for technology.

China’s technology policy has yielded impressive results in a number of areas, such as telecommunications and nanotechnology. International scientific publications have increased significantly, as have patents, the latter of which grew by around 40 % in 2005 (albeit from a low level), even if they still account for a small share of total patents registered with the World Intellectual Property Organisation (WIPO). Compared to the Soviet Union the Chinese transformation of the innovation system has been highly successful. While the scientific and technology infrastructure in Russia has been ruined by the crude transformation toward a marked economy this has not been the case in China. The transformation has resulted in a strong infrastructure with stronger couplings to the production system. The policy has been pragmatic and involved on-going adjustments when original approaches did not work out as expected.

Nonetheless the major source of growth has been intensive use of physical capital, natural resources and labour. Productivity growth in the manufacturing sector has not been linked to an upgrading of the production structure or to a growth in the service sector. A specific problem has been the reluctance of the big state-owned enterprises to become active in terms of building R&D and innovation capacity in house. Easy access to capital and low-priced labour and - until recently - foreign technology has led to passive management strategies where imitation has been more attractive than innovation. A classical example is the automotive sector where only recently some new players are beginning to build their own design and innovation capacity.

Attempts to compensate and bring innovation into the domestic economy through attracting foreign direct investments on a large scale have not been as successful as expected. China attracts more foreign direct investments than any other country in the world with the exception of the USA and the UK (UNCTAD 2005). During the past five years, hundreds of new R&D centers have been established by foreign companies in China and in several recent surveys, executives from multinational companies rated China as the most attractive country for future R&D investments (see, for example, UNCTAD 2005). China has become a large exporter of high technology products, which accounted for one fourth of China's total exports in 2005.

Nonetheless, China's strategy of attracting foreign technology and knowledge has only partially been successful. A large share of China's high tech export still consists of the import of high-tech components which are assembled in China and then exported abroad (Cong, 2004) and as we have seen no less than 80% of high technology exports emanates from firms that are wholly or partially owned by foreign capitalists. This is the background for the emphasis on 'independent innovation' in the new plan.

4. China's 2006-2020 Science Technology Development Plan[14]

On February 9th, 2006, the State Council presented its strategy for strengthening China's scientific and technological progress in the coming 15 years (State Council 2006a). The plan reflects China's clear and strong ambitions to make the country one of the world's most important knowledge bases. In addition, it contains an explicit target to reduce China's dependence on foreign research and development as well as to use public procurement as a way of strengthening its domestic industry. The aim of this section is to provide a critical assessment of the plan. First, we identify and provide a summary of key components of the plan. We also examine the actors, processes and driving forces explaining its development. Second, we analyze the plan in the context of China's larger socio-economic challenges. Finally, we assess how the 15-year plan reflects some of the principal weaknesses in China's innovation policy and its innovation system. We conclude by some policy recommendations.

4.1 The general targets of the plan

The plan sets eight major objectives to be reached over the 15-year plan horizon:

1. Industries producting manufacturing equipment and information technology, important for the country's national competitiveness, should develop and master core technologies at world class level.
2. The scientific and technological base of agricultural production should become one of the most advanced in the world, the production capabilities of agriculture should be improved and food safety ensured.
3. Breakthroughs should take place in energy exploration, energy-saving technology and clean energy technology, in order to promote more efficient energy use, with energy consumption of major industrial products brought down to the standards of the advanced economies.
4. Scientific and technological efforts should support modes of production pointing toward a recycling economy in major industries and key cities to support building of a resource-efficient and environment-friendly society.
5. Major progress should be achieved in fighting major diseases and in epidemics prevention, for diseases such as AIDS and hepatitis. Breakthroughs will be acquired in R&D of new

[14] This section draws upon Ju LIU's analysis of the original planning documents and it has also been inspired by Schwaag Serger and Briedne (2007).

pharmacies, medical equipments, and apparatuses. Technological capabilities will be built up for industrial development.

6. The development of S&T for national defense should support R&D of modern weapons and equipments, for informationalization of the army, and for safeguarding national security.
7. Scientists and research teams should reach world class level and a number of important breakthroughs in science should be achieved. Specifically, technologies in the frontier fields of information, biology, materials and space should reach world advanced level.
8. World-class research institutions and universities as well as internationally competitive R&D institutes owned by companies will be built. A relatively complete national innovation system with Chinese characteristics will be built.

Some of the key priority areas refer to societal needs some of which emanate from the currently dominating growth trajectory. First priorities are the development of technologies that can solve problems with energy and water resources and developing environmental technologies. Furthermore, China is to promote the development of IPR-protected technology based on IT and material technologies. Biotechnology, aerospace, aviation and marine technologies continue to be prioritized sectors. Finally the plan emphasizes the importance of increasing investments in basic research, particularly multidisciplinary research.

The plan lists sixteen key projects that are to be launched. The common criteria for these projects are that they address significant socioeconomic problems, they are to be found in areas where Chinese technology already possesses sufficient competence in relevant technologies, their cost should not be too high and the results shall be suitable both for civilian and military applications. Examples of key projects are one to put a Chinese on the moon and another to develop the next generation of jumbojets. Others focus on the development of fast processors, high-performance chips, oil and gas extraction or exploitation, nuclear power technology, water purification, development of new drugs, fighting AIDS and hepatitis, and developing the next generation of broad band technology.

The plan addresses new technologies that are likely to be significant for the next generation of high technology. Among these, biotechnology is at the top of list, followed by IT, advanced materials, production technology, advanced energy technology, oceanography, laser and space technology. These priorities are not radically different from what has been behind earlier generations of science and technology programs. But the urgency in relation to finding solutions on environmental and energy problems is stronger and the ambition to build ‘independent innovation capacity’ is more explicit. There are also some major differences in the tools proposed for implementing the plan. Public procurement and and tax subsidies are given a stronger emphasis and in general there seems to be a new kind of mobilisation around the strategy.

One of the most noteworthy and novel methods suggested in the plan is the introduction of tax incentives for small and medium-sized enterprises (SMEs). These incentives are intended to encourage companies to invest in R&D and even to establish R&D activities abroad. The latter is particularly interesting and it might be unique for China. It signals that 'independent innovation' does not aim at decoupling Chinese firms from global sources of knowledge and innovation.

4.2 The preparation and implementation of the plan

It is noteworthy that the development of the new plan was coordinated at the highest political level. The prime minister, Wen Jiabao, has been actively involved in the development of the new plan and chaired a steering group which led the process (MOST 2004). Many ministries have been involved in the drafting of the plan (Cao, 2005). The preparation and drafting of the plan, took around three years.

The process was initiated in 2003 with the commissioning of 20 strategic studies which focused on key R&D issues, both from a scientific and socioeconomic perspective. 2000 researchers were involved in the preparation of these 20 studies. Once the reports were finished, they were reviewed by the Chinese Academy of Science (CAS), the Chinese Academy of Engineering (CAE) and the Chinese Academy of Social Sciences (CASS). After that, the Ministry of Science and Technology (MOST) took 12 months to draft the plan, in consultation with other actors, such as the Ministry of Finance, China Academy of Sciences and China Academy of Engineering.

The plan was presented in February 2006 and in June 2006 the State Council presented the a "Consolidated List of the Rules for Implementation of the Supporting Policies for the Outline of the National Medium- and Long-term Planning for Development of Science and Technology Formulated by the Relevant Department" (State Council, 2006b). The list contains 99 supporting policies or tasks. For each task, one ministry or government institution is assigned a lead role or overall responsibility. Within the lead institution, a person is identified by name as bearing main responsibility for each task, with the designated person being in general at Vice-Minister Level. In addition, it is also clearly indicated which other institutions, should participate in the task and when the task is to be completed. The tasks vary in terms of scope or level of detail. Overall, however, they all aim at providing concrete policy tools or action plans for implementing the overall objectives defined in the plan.

The National Development and Reform Commission (NDRC) has been assigned lead responsibility for 29 tasks, followed by the Ministry of Finance 21, the Ministry of Science and Technology (MOST) with 17 support policies and the Ministry of Education with 9. NDRC and the Ministry of Finance have been given lead roles in implementing what could be argued to be some of the pillars of the new long-term plan. Thus, NDRC has been put in charge of strengthening innovation in SMEs and presenting a plan for special projects on promoting national independent innovation capabilities, while the Ministry of Finance has the responsibility for designing fiscal incentives for increasing R&D and innovation in enterprises, and for drafting public procurement policies aimed at promoting independent innovation.

MOST maintains the responsibility for incubators and science parks, as well as implementation measures for supporting research and development in the area of scientific technologies, both of which continue to be key areas of China's science and technology policy. However, it is clear the MOST is only one of several important players in the new long-term plan. Overall, there are several indications that the influence or weight of MOST in China's latest 15-year plan is reduced when compared with previous plans. The new emphasis on enterprises as the engine of China's innovation system is one explanation for why ministries such as NDRC and the Ministry of Finance, are given large responsibilities for implementing the plan. Two other focal areas, namely public procurement and the emphasis on independent or indigenous innovation, also point towards ministries and agencies in charge of enterprise and industrial policy as well as government purchasing regulations, again NDRC and the Ministry of Finance, taking on a greater weight when compared to earlier plans.

In the light of our discussion of different ways to define the innovation system we might argue that this shift in responsibilites among strategic agents signals a shift in the perspective on the innovation systerm. In mechanistic STI-dominated perspective where it is assumed that there is a simple connection from investments in science to innovation it is natural to leave the minister of science in charge of innovation policy (this is the Danish case). The latest long-term plan indicates that China is moving away from a science and technology policy towards an innovation policy where it is realised that organisations and markets need to be taken into account. In this new arena, MOST's leadership is no longer self-evident or guaranteed.

Having presented the main components of the long-term plan as well as the process that led to it we will now focus on some of the main features of the plan and on some of the policy instruments that the plan builds upon.

4.3 The main features of the plan

A NSI-perspective

According to the documents presenting the plan it is the first time the concept of *national innovation system* is used to structure a mid-and-long-term plan (SOURCE). The plan defines national innovation system as a social system where government is in a guiding position, market plays a fundamental role to deploy resources, and various sources of S&T innovation link tightly and interact effectively. It is referred to 'a national innovation system with Chinese characteristics' and argued that it consists of three sub systems. The first is technological innovation system in which enterprises are main force and industries, universities, and research institutes are integrated. The second is knowledge innovation system in which scientific research and higher education are integrated. The third is national defense S&T innovation system in which military and civilian S&T activities are integrated. To these are added regional innovation systems with various characteristics and differentiated comparative advantages. Finally there is a reference to an 'intermediate service system' where processes of socialization and networking are important.

As we read the plan almost all the attention is given to the three sub-systems and little is said about regional systems and about the intermediate service system. It is obvious that the plan sees the stimulation of R&D-efforts as the single most important step toward innovation. But the weight the plan gives to procurement shows attention to the demand side. With this exception the emphasis is on what we referred to in the first section as STI-learning. There are some references to vocational training but very few to how enterprises are managed and workplaces are organised.

Governance

A general problem with any kind of planning document is that it presents intentions and instruments while the capacity to realise the plan will depend both on the degree of shared commitment and on the institutional set-up with its specific distribution of power. There are some reflections in the plan documents on how to improve governance.

To promote and improve the national innovation system building, institutional reform will take place in the country's S&T system. According to the plan, " the national S&T decision making system and macro coordination mechanism for S&T policy will be improved. General planning and administration of the development of S&T by the government will be strengthened. S&T policies will act as the country's fundamental public policy. The system for examining and appraising S&T quality, and as the system for assessing and rewarding S&T achievements are to be reformed. Justice, fairness, openness, and innovation-friendliness will be embodied into the system".

Especially the last measure is important since it indicates shortcomings in the current system when it comes to fairness, openness, transparency and innovation friendliness. Corruption, favoritism and authoritarian rule especially costly when it comes to promoting innovation.

The Purpose of the Plan and the Brave Target Numbers

The plan sets some explicit and rather ambitious quantitative targets to be reached over the 15 year period. First, the proportion of R&D expenditures of GDP will be raised from 1.3% to 2.5 percent of GDP. Second, more than half of economic growth should emanate from 'technical progress' – i.e. not from the extended use of labour and capital. Third the reliance on foreign technology should be reduced from 60% to 30%. The use of some of these numbers – especially the one on technical progress - might appear naïve since the basis for the calculation is highly uncertain and dubious. But they may also be seen as strong and clear signals for actors in the national innovation system.

The objective of raising R&D-expenditure to 2.5 % of GDP can be compared with the 3% goal set for the EU set for 2010 (the EU-goal has proven to be unrealistic). In the case of China the 2.5% requires a very steep expansion of the resources engaged in R&D (about 20% per annum) since it is assumed that GDP will grow four times between 2000 and 2020. To avoid that such high growth rates become mirages produced by false statistics rather than real change is a major challenge. It should be noted that nominal R&D expenditure grew by around 24% per year on average 1999 and 2006, or from around 0.8% of GDP to 1.4% of GDD (China Statistical Yearbook, various years). If this trend continues, China is more likely to reach its goal than the EU.

Enterprises as main force for innovation

As indicated by the basic definition of the 'system of innovation' it is assumed that the national government has a lead role but it is also argued that markets play a major role. The plan states that enterprises should be seen as being at the very core of the innovation system. But little is said on the governance, organisation and management of enterprises. The focus is more on how government through tax subsidies and procurement policies can stimulate firms to invest more in R&D and engage more in developing new products and services with the public sector as customer.

According to the plan, an innovation-friendly tax policy will be adopted. For instance, 150% of R&D expenditure can be deducted from taxable income of the same year. Companies will be allowed to accelerate depreciation of the equipment used for R&D. Income tax will be remitted for new startups in national high-tech industrial zones for two years once they become profit-making and after these two years the income tax rate for these companies is 15% which is 10 percentage points lower than that for ordinary companies. Donations from companies, civilian organisations, social associations, and individuals for enterprise technological innovation foundations will also be deductable from taxable income. Furthermore, favorable tax polices will be applied to venture capital investment companies, S&T intermediate service agencies, S&T incubators, and national university S&T parks. Stronger financial support will be given to companies for innovation. Commercial financial agencies will be encouraged to invest in innovative companies and innovation projects.

Government procurement is to be used as an important tool to encourage indigenous innovation. The system of procurement of innovative products will be enhanced. The government is to purchase the first vintage of innovation products created by domestic enterprises or research institutions when the innovative products have significant market potential. A control and evaluation system giving guidelines for procuring domestic and foreign products will be set up. Normally, in the purchasing process, domestic products have priority over foreign products. Only products not available in China can be purchased from abroad. When government procures products from foreign companies, those companies that are willing to transfer technology to local companies will be given priority over other candidates.

Tax incentives and public procurement play a key role in raising R&D- and innovation-efforts in the enterprise sector. It is a general problem in all countries applying tax rebates for R&D that it is difficult to control that the enterprise's expenditure is actually addressed to this purpose. In order to make tax rebates effective it is crucial that the tax system is reasonably well-functioning and reliable and this might not always be the case in China.

The procurement policy leaves quite a lot of leeway for administrative judgement and can be undermined by corruptive behaviour in the central and especially in the local administration levels. Without a major effort to establish 'good governance' in the private and public sector the two sets of instruments might not be successful.

Indigenous innovation

One of most interesting feature of the new plan is the declared intention to strengthen 'independent' or 'indigenous' innovation. Policymakers have identified a low innovative capacity as the most important explanation for why China's efforts to upgrade its technological capabilities have not yet resulted in the world-leading products 'made in China' that the Chinese government had hoped for.

Indigenous innovation is defined as a value-creating process resulting in new products based upon core technologies and upon IPR. The plan defines three types of indigenous innovation. One is the *original innovation*, out of which there emerge core technologies; another is *integrated innovation*, which refers to the process of incorporating and combining various domestically controlled technologies into new products; and the third is developing new products on the basis of advanced foreign technologies.

Several different policies aim at IPR creation and protection. Government will strongly support the IPRs of core technologies and key products. The national S&T departments, comprehensive economic departments, and other relevant departments will jointly and regularly issue a catalog of core technologies and key products for which China should seek to obtain the IPR. The technologies and products listed in this catalog will be given strong support by the national S&T

plan and capital investment. IPR information service platform will be set up by national S&T departments and IPR administration departments. According to the plan, China will actively participate in international standard establishment and will promote domestic market-centered technological standards. The plan calls for the government to support research on standards of core technologies, it will guide joint research by industries, universities, and research institutes on technological standards, and it will promote the integration of R&D, design, and manufacturing.

It is important to note that a key element in the definition of indigenous innovation is self-owned IPR and that the target to raise the share of patents owned by domestic firms has been given very high priority in this context. This calls for a radical change in the institutional set up but also in the behaviour in the enterprise sector in China. It goes against what might be referred to as the 'imitation syndrome'. A question is how far public regulation and legal procedures can eradicate this weakness of the system. Changing corporate culture may be seen as a more difficult and long term way of changing the actual behaviour of firms in this respect.

International cooperation for S&T development is highlighted.

While there is a strong emphasis on strengthening the domestic capacity to innovate there is no general intention to reduce international cooperation on knowledge production. There is a strong emphasis on the potential for drawing upon global sources of knowledge through international cooperation and through attracting expertise from the rest of the world.

The plan envisages that various forms of international and regional cooperation and exchange on S&T will be expanded. Research institutes and universities are encouraged to set up joint laboratories or R&D centers with overseas R&D institutes. International cooperation projects under bilateral or multilateral frameworks of cooperation agreements for S&T will be supported. In particular a cooperative institution for S&T cooperation between mainland of China and Hongkong, Macao, and Taiwan will be set up. Companies are encouraged to "go global". Export of high-technology and products are to be increased. Companies that set up overseas R&D institutes and industrialization bases will be encouraged and supported. Multinational companies will be encouraged to set up R&D institutes in China.

Scientists and S&T institutes will be encouraged to join major international scientific projects and international academic organisations. They will also be supported to participate in or lead major international or regional scientific projects. A training system will be set up to improve the capability for domestic scientists to take part in international academic exchange. Chinese scientists will be supported to hold leading positions in major international academic organisations. Favorable policies will be offered for setting up major international academic organisations or agencies in China.

A fundamental question is how the balance between national objectives and international knowledge sharing will be established in practice in enterprise strategies. If Chinese laboratories operating abroad were to act primarily as national agents not fully committed to the local knowledge networks' knowledge sharing they would not get access to critical local capabilities (cf. the analysis by Alice Lam of Japanese biotech firms located in the Cambridge region).

Dual use of scientific research in defense and civilian sector

One of the areas where national priorities as well as secrecy are important is of course scientific and technological research for military purposes. The plan aims to form a dual-use technological and industrial base that serves both military and civilian needs. So far government investment in science and technology development has been divided into two parts, one for military use, and the other for civil use. According to the plan document, over half of all the military R&D projects overlap with civilian ones and it is argued that this has resulted in a lack of investment and a waste of human resources in both areas.

To make full use of economic and social resources the two systems will be integrated. Military research institutes will be encouraged to shoulder tasks of scientific research for civilian use. At the same time, civilian research institutes and enterprises are allowed to take part in national defense research projects. The purchase of military articles will also be expanded to more areas of civilian research organizations and enterprises.

Here the critical question refers to the implications for national knowledge protectionism. The US has used military arguments to keep secret important elements of its technology base and it has defined a very wide set of sensitive technological areas where foreigners are not welcome to join research and development efforts. Does the reference to dual use imply that China is moving in the direction of extending the technological fields that will be pursued in more closed environments?

Efforts to train talented people and foster world-class experts and scholars

The plan is to speed up the development of world-class experts based on major S&T projects and construction projects, key disciplines and S&T bases, as well as international academic cooperation and exchange projects. Development of scientists of strategic importance, experts in S&T administration, leaders of different disciplines, and construction of teams for innovation are emphasized. Special policies will be issued for experts in core technological domain. Institutions and rules for training and selecting talented people, especially top level experts, will be improved.

The role of education in developing innovative people is recognized. Postgraduate students are supported to participate in or take up the task of S&T projects. Undergraduate students are also encouraged to do S&T projects and to develop their research interest and scientific spirit. Universities are required to set up subjects of cross-discipline and emerging disciplines, and to restructure their specialized subject according to the need of the national strategy for S&T development and the need of serving a market for innovative people. Efforts to upgrade vocational education, continuing education and training should be made to stimulate the development and use of applied science.

Enterprises will be supported to train and attract S&T talents. Government will encourage companies to hire top level talents by giving favorable policies. Scientists and scholars from research institutes and universities are encouraged to innovate and to start their own businesses. They are also allowed to do part time R&D job in companies. Companies, universities and research institutes are encouraged to cooperate for technological talent training. Companies are supported to recruit foreign scientists and engineers. More effective measures will be taken to attract and employ high level personnel from abroad and to encourage Chinese students overseas to return home and work in China.

While emphasis is given to education the objectives set are related almost exclusively in quantitative terms and in relation to academic education. There are no reflections on the need to reform the university education system in ways that could promote creativity among students or link the formal knowledge to problem solving in the real world. It is mentioned that there should be efforts to upgrade vocational education, continuing education and training but it seems to be a secondary concern. Also, the plan places no emphasis is placed on secondary or primary eduction and addressing needs for reforms of the education system even at these lower levels to promote creativity and innovative thinking. While China's R&D expenditure as a percentage of GDP is much higher than for example in Brazil, India, Mexico and Russia, its public expenditure on education as a percentage of GDP is much lower (Lv, 2007). Furthermore, government expenditure on education is strongly concentrated in tertiary education, especially when compared with countries such as Japan, South Korea or India (Mei and Wang 2006). The strong emphasis on knowledge rather than learning and the bias of government expenditure and policy focus on higher education has resulted in an education system that is "unfit for the innovation needs" (Lv 2007). The plan does not sufficiently address these issues.

The President of the Chinese Academy of Engineering (CAE), Xu Kuangdi, points to a mismatch between the knowledge taught to engineering students at universities and the skills required in the workplace, arguing that engineering education in China does not prepare students to meet industry's and society's needs and demands (Xu 2008). This view is confirmed by Mu and Qu (2008) who point to a shortage of highly skilled technical labor at the same time as graduates struggle to find employment.

In its latest five-year plan, the Chinese government has targeted education as one of the prioritized areas, and announced its intention to increase China's budgetary expenditure on education to four per cent of GDP by 2010.

4.4 Discussion

The Plan presents adequate responses in several respects

In the light of the frustrating outcomes of attempts to build a strong innovation capacity in Chinese controlled firms and the costs involved when licensing foreign technologies it is not surprising that the plan shows tendencies towards so-called 'technonationalism'. But it is a delicate balance between realising the legitimate objective to build 'endogenous innovation capacity' within enterprises and protectionist approaches undermining knowledge sharing and resulting in a more closed and less dynamic innovation system.

Second, it is a natural lesson from the current growth process that people carry a too heavy burden both in terms of the high saving ratios and in terms of their work effort. It is attractive to establish innovation-driven growth that results in firms producing more highly valued products with less effort. The problem here is to find the right instruments and the measures defined in the plan may be too much focused upon STI- rather than DUI-learning.

Third, it is obviously a good idea to establish innovation strategies that aim at solving some of the major problems that have been created by the current growth model. Finding ways to reduce the use of energy and turning the system toward low-carbon technology use and developing technologies that are less polluting not only offer important solutions for some of China's problems. They may also lead to world leadership in technology fields where global demand will be growing very rapidly.

Fourth, the strong role given to the National Development and Reform Commission (NDRC) and the Ministry of Finance when it comes to realising the plan implies a new understanding of innovation as having other critical components than the science base. The emphasis given to public procurement shows an understanding of the importance of the demand side. This insight can be further developed into a more conscious exploitation of the Chinese domestic market. In the field of telecommunication and automobile industry there are examples of the creation of technologies that address specific needs in China and that later on can be exported to other parts of the world with a lower GNP per capita than the one found in the rich part of the world.

But while the plan represents progress and may be seen as being in some respect an adequate response to the problems that China faces, it remains biased in certain dimension and there are some important missing elements.

Technology Bias?

Of the nine men who make up China's Politbureau, seven are engineers. Normally either the Prime Minister or the President of China is recruited among the Faculty of Tsinghua, China's leading university in Technology and Management. Among Chinese economists with a standard economics background this is seen as the main reason why there is so (too) much talk about innovation in China's public sphere. It is interesting to see a parallel to the strong role of engineers (MITI) in Japan's post-war industrial policy and the weak position of economists (Bank of Japan). As illustrated by the Japanese growth success the overweight of engineers may be an advantage especially for economies that are on a catching-up trajectory.

While the focus on innovation may be rational in the current context it is not sufficient to focus on 'technical innovation' in isolation from the social and institutional environment. As argued in the first section the capacity to transform technical innovation into economic performance depends upon market orientation, human resources and organisational learning. Engineers, as well as standard economists, may tend to underestimate the importance of the wider setting of the national innovation system and the result may be exaggerated expectations regarding what technology can bring to the solution of social and economic problems.

One of the problems that the plan aims at remediating is the lack of domestic innovation capability. As already indicated this reflects that it has been too easy for the big State Owned Enterprises to mobilise low cost capital (through privileged access to funding from state-owned banks) and labour and to combine it with technology licensed or copied from abroad. To break such habits there will be a need for quite radical managerial reform giving the managers a stronger incentive to promote the economic performance of the firm. Another important factor has been lack of competition in sectors related to defense and electrical power where firms have been offered monopoly positions.

But the imitation syndrome has roots further back in history and it is reproduced in the education system. The tradition in some of the most favoured disciplines was that the apprentice should be able to copy in detail the work of the Master before he/she was allowed to develop his/her own style. The current education system tends to reproduce similar patterns where evaluation systems tend to give emphasis primarily to the capacity of students to replicate what they have been taught by the professor. Individuals' deviation from the collective are sanctioned and the incentives to engage in creative activities are weak. To reform the education system so that it becomes more problem oriented and so that it promotes critical thinking and creativity may be seen as one of the most important challenges for a strategy that aims at 'independent innovation'.

A recent analysis by the Development Research Center of the State Council examined the criteria applied by the Ministry of Education, the National Natural Science Foundation, the Chinese Academy of Sciences and the Commission of Science, Technology and Industry for National Defense for identifying, evaluating and funding so-called 'Sci-tech innovation teams', i.e. teams of researchers whose work is considered to play an important role in advancing science, technology and innovation in China (Lin and Liu 2008). The identification of teams, as opposed to individuals, might be interpreted to acknowledge the importance of interaction and learning in the innovation process. The authors claim that the criteria currently used are too strongly focused on short-term quantitative results, such as publications and patents, rather than applying process-based indicators. It could also be argued that the selection criteria focus on academic merits of the team leader and members rather than seeking to promote a mix of relevant backgrounds from industry, academia, and policy, and from diverse disciplines. Greater emphasis should be placed on teams' ability and proclivity to interact with potential innovation users, thus enhancing DUI learning processes.

Mu and Qu (2008) identify insufficient mobility of human capital, from universities and research institutes to companies and from developed to less developed regions, as an impediment to increasing China's innovative capacity.

Where are the regions?

It is obvious that China has become very skewed in terms of regional economic development and that the unevenly distributed capacity to absorb and use new technologies is crucial for the future regional development in China. To some degree the growing regional inequality was not only tolerated but even seen as a driver of uneven growth in China.

But as there is more emphasis on intellectual resources and innovation in the strategy regional inequality tends to become so strong so that it might become difficult to keeping the national system together. According to research organised by UNU Wider, China's inequality in regional innovation capability has increased from 1995 to 2004. Location, industrialization and urbanization and human capital are significant contributors to the inequality in innovation capability. Unbalanced development in high-tech parks exerts a growing explanatory power in driving innovation disparity, which implies that institutional factor plays a direct role. In a recent study, Hong (2008) found that the administrative decentralization of China's university system and economic reforms have increased the differences in rich and poor regions's access to knowledge resources, thus further exacerbating regional inequality.

There is also a strong link between globalisation and regional inequality in China. FDI may have a significant positive impact on the overall regional innovation capacity. The strength of this positive effect depends, however, on the availability of the absorptive capacity and the presence of innovation-complementary assets in the host region. The inflow of foreign direct investment has further reinforced regional inequality. It has stimulated regional economic growth in China's coastal regions but not in the inland regions.

Against this background it is noteworthy that there are few references to the regional problem in the long term plan. We found five lines in section 7 related to building regional innovation system. But there is no mentioning of the regional dimension neither in section 8 on policy measures nor in the detailed document from August 17 2006 on policy. While the plan responds to the other major challenges that originate in the growth model the regional problem is given little attention. It is also striking that there is little room for regional initiative in implementing the plan. We believe that a strong investment in knowledge infrastructure, education and efforts to modernise traditional sectors in the lagging regionsmay be a key not only to address the problem of regional inequality but also to implement the general objectives of the plan.

The silence on the regional dimension contrasts with the new EU-strategy where the structural and regional funds increasingly address the promotion of regional innovation systems and competence building. As indicated above, regional fusions of political and commercial interests have been major drivers behind the old growth model that the new plan tries to substitute with a new kind of growth trajectory. Therefore it is difficult to see how the ambitious objectives set in the plan can be reached without finding ways to mobilise these strong regional interests in favour of the strategy. Perhaps a stronger element of local and regional participation in decision making for ordinary citizens is a key to the necessary realignment of local interests to the new strategy?

Conclusions

China has made impressive advances in science, technology and innovation in recent years (see Mu and Qu 2008 for an overview). The latest long-term plan for science and technology sets out clear goals and addresses important issues in China's development. However, several challenges remain: Increases in inequality, both intra- and inter-regional, are limiting innovation capability. Another challenge lies in the education system and in the emphasis on knowledge rather than learning. There are abounding examples of highly innovative Chinese firms, many of them private, which succeed in developing products and services that meet or even create market demand. However, innovation capacity is still very limited in a large share of China's firms. DUI learning is underdeveloped, with little interaction between producers and potential users of new technology and knowledge.

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