STABLE INSTITUTIONS & NOVEL TECHNOLOGIES: A COMPARISON BETWEEN CHINESE AND INDIAN BIOTECHNOLOGY SYSTEMS

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Comparing and contrasting the two giant economies, China and India, is gaining increasing attention in the literature, and rightly so because of their gargantuan economic share in the global space. However, because of the lack of empirical support, these literatures tend to overemphasis one's prospects over the other. As a result, there are more questions than answers in these literatures. One of the questions is the focus of this study: how the national innovation systems (NIS) China and India contribute to their biotechnology capabilities. The evidences based on patent granted, patent citations, level of R&D and investment indicate that Chinese annual growth in biotechnological capability is 18% (patents) and 28% citations versus Indian growth about -.4% (patents) and 1.5% citations over 12 years (1994-2005). These findings are contrary to the views asserted in the emerging literature that China as a system potentially lags India, so China should learn from India. Conversely, the evidences show that, provided high technology innovations are resources for economic growth and competitive advantage, China has a clear and substantial lead over India in both current resource endowments and potential capabilities in biotechnology systems.

Keywords:

China, India, Biotechnology, National Innovation Systems

1.0 INTRODUCTION

China and India are emerging two technological and economic actors in the global space. Together, China and India contain 40% of the population in the world, and they drive 18% of global purchasing parity (Economist, 2006). Deutsche Bank estimates that China is likely to surpass the USA, and India is likely to surpass Germany by 2020 in terms of their economic sizes. In technological capability, McKinsey Global Institute estimates that life science based capabilities are increasing at increasing rate in both China and India and are likely to growth 30% by 2008. This sets the importance of these emerging actors in the global space. Following from their significance in the global space, some research- and practice-oriented literatures are paying increasing attention to understand the underlying institutional systems and governance mechanisms that are driving their technological and economic capabilities. Although there is general consensus that the two institutional governance systems differ from each other, there is an increasing debate on the sustainability and the long term prospects of each.

One stream of the literature accentuates that the integrated institutional governance that defines Chinese system is likely to sustain the innovative capabilities and economic growth in the future. Some authors observe that China efficient infrastructure, manufacturing technological base and internal market size are some of main potential drivers. Since China has competence in infrastructural development and economic dynamism (Becker, 2004; Lal, 2005; Shenkar, 2006), the underlying assumptions imply that the integrated market structures, top-down governance structure, and social cohesion are some of the major knowledge drivers and therefore are the economic determinants.

In contrast, the other stream accentuates that the liberal (disintegrated) institutional governance that defines Indian system is likely to sustain the innovative capabilities and economic growth in the future. Some authors note that India has competence in basic research, professionalism in software technologies, and office support systems (Huang & Khanna, 2003). Since India has the advantages in terms of highly developed financial institutions, established legal system, and democratic political systems, the underlying assumptions imply that the liberal market structures, bottom-up governance structures, and democratic culture are some of the major knowledge drivers and therefore are the economic determinants.

Encountering both ends on the this spectrum, in the analysis of India versus China, a theoretical stream of literature has raised some intriguing questions: China versus India, who wins the battle of ideas (Girdharada, 2006; Lal, 2005); can India overtake China (Huang & Khanna, 2003); and will China again become a viable great power, while India will remain a great democracy? (Desai, 2003). Although this generic questions seem to suggest differences between China and India innovation systems, there are some similarities between the two systems. On the one hand, both are diverging from their dirigisme past, and they are converging to the some level of the liberal institutional governance mechanisms. On the other hand, both are building high technological innovation systems the high technological capabilities to exploit potential economic opportunities in the global space. Hence, they are converging towards nationally bounded coordinated market systems (Hall & Soskice, 2001).

Generally, Chinese are associated with hardware engineering technologies and Indians are with software engineering technologies. For future technological capabilities, the former (China) is climbing towards upstream for creating innovative environment adjacent to the existing physical infrastructure; and the latter (India) is descending towards downstream by enhancing physical infrastructure adjacent to its existing features of the capital market economy. In the this convergence-divergence dilemma, on the one hand, Chinese economy is often modelled as a transitional economy between central planning and market economy (Qian, 1999); and its a hybrid in another sense (Jin *et al.*, 2005). Like German civil law, the structure of the corporation is fixed by law. Conversely, like Anglo-American model, there is no centralized ownership by the banking system. On the other hand, the Indian economy is transitional in terms of liberalization and the shift from upstream software technology to downstream manufacturing.

Which of the two is likely to be more innovative in the future technologies (biotechnology) is an outstanding question in the biotechnology innovation systems of India (Katrak, 2002; Ramani, 2002; Sikka, 1998) and China (Yam *et al.*, 2004; Zhou & Leydersdorff, 2005, 2006). The past categorizations that one may have competitive advantage over the other may be a valid assumption. Nevertheless, empirically, these claims are insufficient and systematically unsupported. In particular, biotechnology is a different and important source of future economic development. It has the explicit attributes of the generic knowledge in terms of generic technology (Nelson, 1994), and it has tacit attributes of specific knowledge in terms of interactive management (Pisano, 1990). These attributes of biotechnology require two types of activities and therefore two types of institutional mechanisms. The activities refer to the explorative for knowledge discoveries and the exploitative routines for knowledge capitalization (March, 1991). The supporting institutional mechanisms refer to the feed-forward for knowledge innovation and feedback for knowledge diffusion (Crossan *et al.*, 1999). The measurement of such innovations may highlight the policy patterns; the R&D focused investment (resources allocation); and the performance (recourse generation) in terms of patented innovations. The existing literature has theoretically debated some issues on the two institutional governance mechanisms of China versus India, but it has not yet provided with concrete studies to support either or both systems.

Using R&D investment, patents generation (quantity), patent citations (quality), and contextual data, this paper provides some insights to the level of the exploration and exploitation. In turn, it will explain the argument whether one kind of institutional pattern or the other may lead to technological novelties. Currently, we understand that India's path-dependent capabilities lie in the service industry (e.g. back offices support and software engineering). In contrast, China's path-dependent capabilities lie in its efficient manufacturing. What we are unable to determine is which system is more effective in shifting from the old paths to new technologies i.e. biotechnology. This in turn will enable us to understand what kind of institutional governance mechanisms are effective novelties in biotechnology. To explore what kind of institutional structures are more likely to contribute to the biotechnological capabilities and eventual innovation, the structure of the paper consists of five sections.

The next section outlines theoretical framework, the following section describe methods, the fourth section reports results and the last section offers an elaborated discussion, which is followed by a brief conclusion.

2.0 THEORETICAL CONTEXT

This study is drawn on National Innovation System (NIS) framework. The rationale for NIS is based on at least three reasons. First, although the focus is on the knowledge at various levels in the two systems, the cross-national systems are comparable at the aggregated levels (Casper, 2000; Hall & Soskice, 2001; Whitley, 1999). Second, biotechnology is a new phenomenon, and the conventional linear style approaches are partially applicable (Pisano, 1990). So, biotechnology may not be viewed as a transacted snapshot product but are codified (patens) forms of complex knowledge (tacit) (Mowery *et al.*, 1996). Third, in the high technology and knowledge based economies, there is an increasing consensus on the integrative structures of the relevant institutions for research and practice in the knowledge based systems. These integrated innovation systems are being emulated across Asia (Datamonitor, 2004) in the context of biotechnological innovation systems (Batholomew, 1997).Thus, innovation system is a recognizable theoretical framework from the perspectives of the supplier and adopters of the technology (Rosenberg *et al.*, 1992). To draw a specific research framework, three steps are fundamental in a logical process: concepts, constructs, and assumptions (Poole & Van de Ven, 1989). Some of the conceptualizations of the NIS are outlined blow.

Freeman (1987) views an NIS as "... [t]he network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies." His focus remains on the concept of the institution on the one hand, and their enabling and formalizing role on the other. In abstract terms, this view is proximal to the institutions that enable as well as pattern behaviour (Hodgson, 1988). This definition is not precisely focused on the national boundaries of a system. Similarly, Lundvall (1992) emphasizes "... [t]he elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge ... and are either located within or rooted inside the borders of a nation state." This view highlights the relational aspect of the interaction that efficiently contributes to the knowledge as an innovation output. It is a narrower definition in the sense that, on the one hand, it selects relational parameters as the focus; and on the other hand, its focus lies within national boundaries.

Nelson & Rosenberg (1993) cut across the two by suggesting that NIS is "... a set of institutions whose interactions determine the innovative performance ... of national firms." On the one hand, it is proximal to the institutional based as a starting point, so it is akin to the first view in the above. On the other hand, it is precisely focusing on the national firms, so it is akin to the second view in the above.

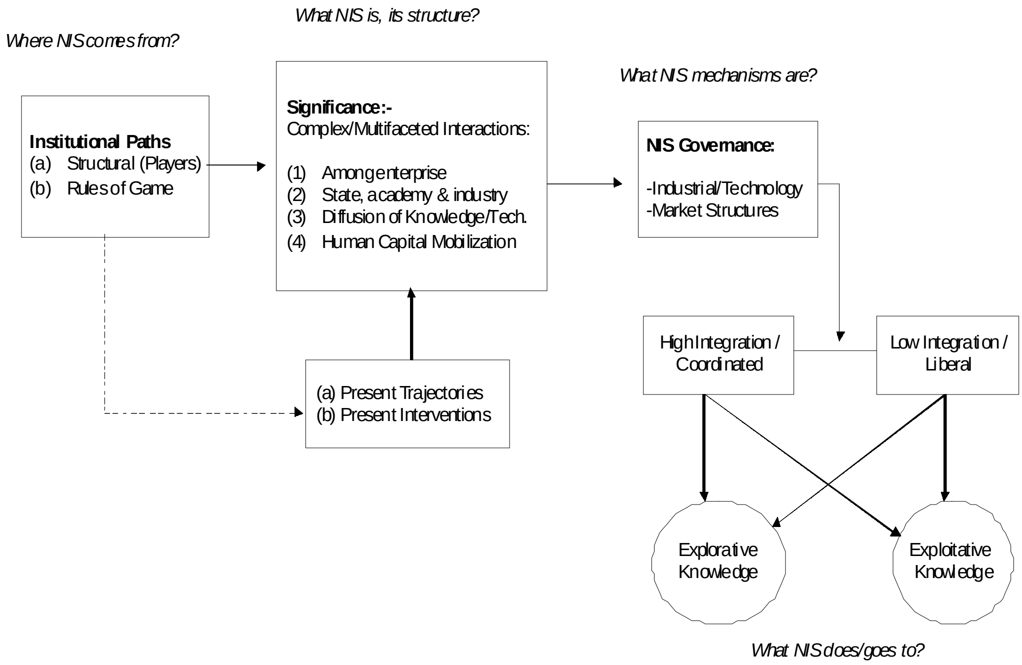
Patel and Pavitt (1994) see an NIS as, "... [t]he national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country." This definition cuts-across three of the above. First, it emphasises the importance of institutions. Second, it highlights the governance structures for certain incentives structures for better resource mobilisation for learning and innovation. Third, it delimits the governance within the national boundaries.

The above definitions are feed-forward views by linking the frame-to-actions. Metcalfe (1995) follows a feedback definition by linking actions-to-frame for policy making: "... [t]hat set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies."

These and a plethora of other concepts, constructs and assumptions constitute an NIS framework. Although concepts and constructs may differ because of the varying dimensions of the arguments, the sources, the formation and the functional roles of NIS framework are converging to four questions that hinge upon their respective assumptions. The first question seeks the sources of an NIS by asking "where they come from." This is based on the assumption of path-dependent institutions and technological trajectories (Dosi, 1982). The second question seeks to understand the formation and configurative complexities of the interactive structures buy asking "What the NIS structure is". This is based on the assumption that the less complex knowledge, the low complex structures; and the more complex knowledge, the high complex structures (Birkinshaw *et al.*, 2002). Along this assumption, the configuration of the institutional structures highlights the governance mechanisms through which these complexities operate. This need for the operational mechanisms highlight the fourth question "what the NIS mechanisms are". This question is based on the assumption that there are two competing mechanisms. On the one hand, there are less integrated governance mechanisms in an NIS or in some of its elements. On the one hand, there are highly integrated governance mechanisms in an NIS or in some of its elements (Hall & Soskice, 2001). The last question seeks the outcome of an NIS by asking "where do an NIS' activities go." This question is based on the assumption that some governance structural mechanisms lead to an explorative knowledge (innovations), while others to the exploitative (innovation). Putting together, some NIS may lead to one kind of technological innovation, while the other may lead to another kind of technological innovation. Figure 1 below captures the main elements of the configuration of an NIS relevant to a high technology in a knowledge based economy. Each is further explored in its respective importance.

Figure 1

Conceptual Model



2.1 Path-dependent Institutional Trajectories

Most of institutional economists (Greif, 1998; Menrad & Shirley, 2005; North, 1990; Williamson, 2000), sociologist (DiMaggio & Powell, 1983; Granovetter, 1985; Hall & Soskice, 2001; Stinchcombe, 1965; Whitley, 1992) and organizational psychologist (Cohen & Levinthal, 1990; March & Olsen, 1989; Weick, 1979) more often than not agree that institutions are path-dependent trajectories. These trajectories are usually system specific, or country specific, which result from the past national policies on the knowledge-resources acquisition and allocation. Some of them are likely to be the results of structural paths, and some others may be the results of the rules-paths (Bebchuk & Roe, 1999). The former may be informal source, and the latter a formal source of the resulting institutional technological trajectories. These trajectories lead individual national systems to different technological competitive advantages, which in turn constitute a national innovation system (Whitley, 2002). Together, the three streams see the innovative activities representing deliberate as well as inadvertent patterns of the past. Although these disciplines apparently converge to NIS, they take a different reference points on the formation of an NIS.

2.2 Configurative Formation of NIS

The institutional economists premise on two types of institutions (North, 1990). One refers to the players of the game. These are formal organizational actors. A university can be an example of such formal entities. The other type refers to the rules of the games that define the framework of the law for these institutions. These institutions function as a transaction mechanism (Williamson, 1985). The intra-institutional exchanges may refer to vertical transactions knowledge, and the inter-institutional may refer to the horizontal transactions of knowledge. Hence, to the institutional economics, the past structures and rules of these institutions define the current state of the institutions for transactional purposes in an NIS.

Sociologists propose that systems are based on the relational dimensions. These dimensions may result from norms and social habits (DiMaggio & Powell, 1983; Myers & Rowan, 1977; Stinchcombe, 1965). According to this view, the underlying mechanisms of the normative institutions refer to isomorphism and cultural norms. In comparison, the economist tend to follow exogenous role of the rules of law, the sociologists tend to reflect on the endogenous mechanisms of the institutions (Dyer & Singh, 1998). In this sense, the economic perspective views the institutions as patterning behaviour; and the sociologist perspective views the institutions as enabling conditions for knowledge flow. The latter perspective is consistent with the organizational psychology of the system approach.

The organizational psychological perspective views that the cognitive patterns of a system in the present are in fact the result of the past routines. Since behaviours precede as well as follow cognitive patterns (Gavetti & Levinthal, 2000), each affects and reflects the other. Therefore, the current actions may be the result of some deliberate and inadvertent cognitive activities of the past (Cohen & Levinthal, 1990), and in turn, the current is likely to define the further trajectories. Putting together, the literature on these perspectives seem to converge on at least three aspects of an NIS.

First, institutions determine structural complexities, and the complex structures define the technological complexities. In turn, the knowledge and technological complexities constitute innovations that are behind the economic progress of an economic system. Second, the knowledge has two main dimensions: explicit or codified and tacit. The former is attributed to the market transactions, and the latter is attributed to the relational transactions. Third, the institutions are the central mechanisms for the knowledge flow. Therefore, the importance of an NIS can be attributed to its ability to produce and disseminate knowledge. The more the knowledge complexities, the more the structural intricacies required. However, structures may continue to persist along their path-dependent trajectories. The old frames may crowd out the new reality (March & Olsen, 1989). Accordingly, the economists (Greif, 1998; North, 1990; Williamson, 1985), the sociologists (Dobbin, 2004; Hall & Soskice, 2001; Stinchcombe, 1965; Whitley, 1999), and the cognitive organizational psychologists (Cohen & Levinthal, 1990; Gavetti & Levinthal, 2001; March & Lavitt, 1999) tend to agree that path-dependent beliefs may crowd-out the objects of the new reality (Weick, 1979). So some deliberate policies and strategic actions on the formation and configuration of the structures seem imperative for influencing those historical paths.

These two dimensions an NIS are structural complexities and current endowments, and they represent the second stage on the conceptual model in figure 1. In terms of the interaction, the literature on NIS and technological capabilities had identified four common types of fundamental activities (OECD, 1997). These activities constitute the actors, the interaction and the purposed dimensions, representing the linkages.

The first link refers to the inter-firm links in the intra-industry context (Gulati *et al.*, 2000). In biotechnology, it implies to the biopharmaceutical industry in its upstream and downstream dimensions (Gambardella, 1995). The second interaction refers to the state, academy, and the industry (Rosenberg *et al.*, 1992). Some literature has referred these elements as “triple-helix” (Benner & Sandstrom, 2000; Etzkowitz & Leydesdorff, 2000). The third refers to the diffusion activities of the knowledge and innovation. This implies that for patents and publication as the diffusion mechanisms, other institutions come to the fore in an NIS. The last factor refers to the knowledge carriers and therefore the tacit knowledge base (Colyvas *et al.*, 2002; Nelson *et al.*, 2004). This means the human and social capital mobilization. Together, these four elements of interaction in the structure are not necessarily a random phenomenon, functioning on its own. They are part of the deliberate policies and strategic structures for future path-setting. For the management of the structures, a governance system is fundamental.

2.3 Governance Structure

In general terms refer to the ownership of the technologies, enterprises and some broader institutional entities (Freeman, 1999). In specific terms, the governance is defined by the purpose it serves. More concretely put, the governance of a system represents the stakeholders it serves. The direct stakeholders in an NIS are the government, the research institutions, the industrial enterprise and the other socio-political entities. In broader terms, the authority and control stems from the ownership structure (Pisano, 1989; Williamson, 1996). These structures represent two levels of interaction, ranging between high-integration to low-integration. Between the two ends on the spectrum, there are ranges of other interactive disposition on the spectrum. Two common dispositions in the literature on NIS can be recognized.

2.4 Integrated vs. Disintegrated Markets

The first one refers to the direction, and the other refers to an activity. For instance, in term the direction, an NIS may have high integration in the upstream along the value chain and low integration in the downstream or vice versa. The other one refers to the activities attributed to the system. An NIS may have high integration in one type of interactive activity but low integration in another type of activity and vice versa (Powell *et al.*, 1996). Putting together, the level of integration in a governance system constitutes and diagnoses technological innovation as output. (Dyer & Singh, 1998). Interchangeably used, an innovation in high technology may be referred to two types of knowledge on the value chain in an NIS. The upstream is called explorative knowledge, while the downstream is called exploitive knowledge (March, 1991). Together, the system loops in a pattern of feed-forward and feedback (Crossan *et al.*, 1999; Rosenberg *et al.*, 1992).

In particular to biotechnology industry, the upstream innovations are captured in patents, publications and designs, and the downstream innovations are captured in the development of therapeutics for pharmaceutical applications. As a whole, this NIS framework configuration, its sources and its functions are likely to enable the exploration and the explanation of the technological competitiveness of the national innovation systems in the knowledge based economies. In the current study, the exploratory focus is on the NIS of China and India in their biotechnological industries.

Following the existing paths, India will continue to be competitive in the information technology (software engineering), and China will continue to be competitive in hardware engineering. However, the evidences strongly support that both are striving to develop capabilities for the future technologies such as biotechnology (Mahmood & Singh, 2003) by some resonance to their path-dependent routines (Kimberly & Bouchikhi, 1995) and some divergence from their dirigisme past to the future directions (Amburgey & Rao, 1996). So, the resonance refers to the institutionalization of knowledge in stable institutions, and divergence refers to creating conditions for novel technologies.

Some literature refers this framework of stability and divergence to an admixture of the old and the new knowledge (Bourdieu & Coleman, 1991; Katila & Ahuja, 2002). Synthetically, it is proximal to the combination of knowledge capabilities (Kogut *et al.*, 2002) and routines (Winter, 2003) Paradigmatically, it is proximal to the co-evolution between physical and social technologies (Nelson & Nelson, 2002), facilitating two contextual questions. Whether biotechnological innovation is better explained by the technological proximities to paths routines; and whether climbing to basic technologies from the applied ones (Chinese case) are more or less effective than those descending from the basic technologies to the applied ones (Indian case). The answers to these issues lay in the explication of the evidences and the transitional phenomena in the two systems of innovations. The methods for the exploratory effort are outlined in the following.

3.0 METHOD

The method section delimits various types of data, their respective relevance, and their techniques of analysis. Following the theoretical framework outlined in figure 1, there are four sections of the NIS framework used for investigation. Each segment requires specific data patterns. Hence, the components of NIS are organized in four sections for the respective data. (i) Institutional sources, (ii) formation and configuration of the two systems, (iii) the governance mechanism and market structures, and (iv) the innovative performance in terms of knowledge as output and learning as capabilities.

3.1 Sources of NIS

The institutional dimension seeks history description, the interactive structural dimensions maps the system design, the governance reflects the ownership, and the outcome refers to the performance of the system. These are generic and anecdotal elements of the two national systems. In concrete term, the data refer to approaches. On the one hand, a conventional approach focuses on the R&D investment on biotechnology. On the other hand, a non-conventional approach focuses on patents and publications. In contrast, an NIS approach refers to the structures and their performance. The current method triangulates three techniques. It captures general patterns from the scientific as well as popular literature. It examines R&D investment patterns, and it refers to the innovation based performance.

3.2 Formation Focus

The qualitative evidences on the configuration of the two systems were gathered from published documents such as professional magazines, institutions, and daily publications. The magazines were ‘The Economist’ and ‘Business Week’. The institutional publications were the World Bank, UNDP (United Nation Trade & Development), McKinsey Quarterly, and Morgan Stanley Institute. The daily publications were ‘The Wall Street Journal’, Business Standard’, and ‘International Herald Tribune’. These variegated sources constitute the differences and similarities between the two national innovation systems (Friedman & Gilley, 2005; Hall & Soskice, 2001).

3.3 Governance Mechanisms Focus

The Chinese governance is attributed to hybrid governance structure (OECD, 2005; Qian, 1999), which is nationally bounded integrated. The Indian is hybrid governance structure which is nationally bounded, but more liberal market system. These categories were adopted from the established understanding in the existing literature (Farrell *et al.*, 2004).

3.4 Performance & Capability Focus

Biotechnology consists of multiple sub-classes in biotechnology industry. Three of them have been recognized as standard measures by research institutions, R&D, regulatory institutions and industrial applications: *Nucleic acid, proteins and tissues/cells* (Burnand, 2005). For patents and citation, the IPC (international patent classification) codes were analysed for both cases. The performance based data is measured in terms of innovations in patents owned by Chinese and Indian firms as well as research institutions. Three characteristics of these data are important to mention.

First, these data are delimited to therapeutic biotechnologies. To collect these patents, the SIC (standard industrial codes) were used. So on four technologies represented by four SIC were: A61K (Medical, dental, etc), C12Q (Methods of testing Enzymes or micro-organisms), C07D (Organic Chemistry Structures), and C12N (Micro-Organisms or Enzymes, compositions thereof). The data were collected from European Patent Office from the IPC (international patent classification) database. Second, these data were gathered over 12 years, from 1994 to 2005. Third, these data codes were consistent and internationally accessible to the two innovation systems at equal levels. To supplement these data, WIPO's (World Intellectual Property Organization) sources were used to support the national level technological capabilities.

The evidence gathering was followed by the techniques for analysis. There are two perspectives on an analytical technique. The first one is informal and descriptive, and the second is more formal. In this context, both are used respectively. The descriptive aspect focuses on the data organization and tabulation over twelve years (1994 to 2005). This includes R&D spending related to basic science (universities and institutions) and applied technologies. The return on innovations (patents) on spending entails reasonably supported and useful conclusions. Furthermore, the analysis of the diffusion of biotechnologies and the potential for adoption in the two countries reflects future path setting in high technology industries. For instance, the development and application of stem cell in real life medical problems refers to therapeutics, and the genetically modified food and crops refers to agro-biotech. Hence, to broaden the understanding on the institutional systems, both therapeutic and agro-biotech are the part of the description.

To formally estimate the growth rate of each system, the hard data were used. The hard data refers to patent counts on four technologies and their respective growth in citations (quality). A log of the exponential function was used to estimate the annual growth rate in 12 years. Then the growth rate of China and India was compared referring to patents and citations for quantity and quality respectively.

4.0 RESULTS

Corresponding to the four sections in the theoretical framework, and based on their respective analyses, the results consist of four relevant sections. The first section data consists of the tables 1 and 2. The secondary data in these tables constitute the supporting evidences towards the institutional paths of the systems. These institutional trajectories are the result of both micro-level elements at the firm level and macro-elements at the national system level. Thus, columns 1 through 5 in the tables show the secondary sources of data, concepts, and their indicators for China and India respectively. The multiple dimensions of these data reflect the subsequent parts of the NIS in the framework.

Table 1

Business Journals

Data Sources	Concepts	Indicators	China (World Factory)	India (World Back office)
Financial Times (2006)	Capital Markets	Stock markets lowered down	Shanghai has	India as soared
Financial Times (2006)	Growth Patterns	Micro-macro co-evolution	Low-micro; high-macro	High-micro; low-macro
Financial Times (2006)	Institutions	Financial	Less Developed	Fully developed
Financial Times (2006)	Physical Infrastructure	Physical & Social technologies	Fully Developed	Less Developed
Financial Times (2006)	institutions	Which came earlier and effective	Liberalization in China	Liberalization in India
Business Week forecasts (2006)	By 21st century		China over takes US	India overtakes Germany
Business Week forecasts (2006)	Reforms	Reforms process	China in 1978 and grows 9.7%	India in 1991 grows 5.8
Business Week forecasts (2006)	Resources	Services/products	57% FDI, 90% more than India	10% of China FDI level
Business Week forecasts (2006)	FDI	In Dollar terms	$80 millions	$50 billion
Business Week forecasts (2006)	Sources of FDI	Diaspora/expatriates	Own Diaspora	Home grown entrepreneurs
Business Week forecasts	Bilateral trade (2006)	Raw /final goods	China exports final	India exports Raw to china goods
Business Week forecasts (2006)	Professionals	Engineers	Both produce 500,000 a year	C+I = 500,000
Int’l Herald Tribune (2006)	A battle of Ideas	Predictable/no predictable predictable	Top down control; not	Democratic; predictable
The Wall Street Journal (2006)	Bilateral Behaviour	Relational Strategies	China forthcoming	India is reluctant
The Wall Street Journal (2006)	Global space Status	FDI R&D	750 firms, UNTD R&D Preferred	Ranks lower
The Wall Street Journal (2006)	Institutions	Property rights	Low patent protection	Medium patent protection
The Wall Street Journal (2006)	Potentials	Growth Direction	Factory to Laboratory (Govt)	Office to factory
The Wall Street Journal (2006)	Human Capital	High Education	5 Mn. graduates 1/5 science+ Engg	R&D 0.77% of GDP in 2005.
The Wall Street Journal (2006)	High Technology Focus	Biotechnological Innovations	World’s first Rice Genome base	Nothing specific
The Wall Street Journal	Innovative?	R&D and Output	1.5 %, plans up 2%	India ½ of China

(2006)			GDP by 2010	½(1.5)%
Far Eastern Eco. Review (2006)	Liberalization	External	China first,	India second
Far Eastern Eco. Review (2006)	Industry	Firms activities	Small scale rural industry-export	No small scale rural industry
Far Eastern Eco. Review (2006)	Economic Conditions	Infrastructure	Export led better infrastructure	Hobbling low-tech industries
Far Eastern Eco. Review (2006)	Dirigisme paths	Institutional dependence	Struggling to shun it off	Struggling to shun it off
Far Eastern Eco. Review (2006)	Rule and Language	Formal Institutions	Less developed	Highly Developed
India's Business Standard (2005)	Investment rate	% of GDP	China is about 40	India ½ of it
India's Business Standard (2005)	Growth	Capital versus labour	Labour intensive	Less labour intensive
India's Business Standard (2005)	Economic Systems	Liberal versus non-liberal	Chinese embraced capitalism	Not yet embraced capitalism
India's Business Standard (2005)	Knowledge Flow	Inside-or outside-in	Foreign trained Chinese	Indians do not recognize yet
India's Business Standard (2005)	Alliances	Joint-ventures	China with MNC and FDI	Low such JVs
India's Business Standard (2005)	Market Directions	Domestic markets	High for local and foreign	Low for local and foreign
The Straits Times (2003)	Path-dependencies –	Institutional Roles/Capabilities	Manufacturing giant Vs unequal wealth distribution	World IT hub Vs. low regional cooperation

Table 2

Institutional Publication

Data Sources	**Concepts**	**Indicators**	**China (World Factory)**	**India (World Back office)**
Morgan Stanley estimates (2005)	40% population	Human Capital, Market, Tech.	China overtakes US in a decade	India overtakes Japan in a decade
Morgan Stanley estimates (2005)	India Vs. China?	FX $ billions, FDI, literacy, Year of reforms	1.3 bn, 53%, 32 %, 47% Invest/GDP, FX $870, FDI 50 Bn, lit. 95%, Internet 6.3%, lib. 1978	1.1 bn, 22%,, 56%, 24, 145 billions, 4 billions, 68%, internet users 1.7%. Lib. 1991
Deutsche Bank (2006)	Economies by 2020	Regional as well as global	China Second largest and	India third largest
McKinsey Global Institute (2006)	Young Scientists	Life Sciences	35% growth by 2008	C+I = 30% growth
McKinsey Global Institute (2006)	US growth of Scientists	Life Sciences will drop by 11%	Life scientists/ Engineers	IT Engineers
UNTD Report (2005)	Innovation Culture	Money (Extrinsic) or non-intrinsic	Intrinsic	Extrinsic

President China Agricultural Universit (2003)	Agro-biotech Innovations	Commercializing Anti-GM	First GM crop. Animal varieties in pipeline. GM adopting farmers benefit	Initial stages of biotechnology, understanding questions/answers
Hall & Soskice (2001)	Market Structure	Integrated Level	National Coordinated	Less Coordinated
Hall & Soskice (2001)	Standardization Trend	Divergence	Nationally Bounded	Nationally Bounded
Desai (2003)	Political Comparison	Economic or Political leaders	China a viable Great Power	India a Great Democracy
Yasheng, and Khanna. (2003).	Innovation Systems	Private entrepreneurship	High Tangible	Struggling
Yasheng, and Khanna. (2003).	Liquid Assets	Surplus-Deficit	No fiscal deficits	Fiscal deficits
Yasheng, and Khanna. (2003).	Overseas returnees	Expertise/Tacit Knowledge base	Diaspora, world's factory	Diaspora may be world tech lab
Yasheng, and Khanna. (2003).	Know-how	Value Chain Expertise	Consists of professionals	Consists Entrepreneurs
Yasheng, and Khanna. (2003).	Potential	In high tech (Biotech)	China ahead of India in biotech	India ahead of in Software
Yasheng, and Khanna. (2003).	Social Institutions	Casts/equality	Equality/no castes	How-low castes
Friedmand and Gilley (2005).	Social Norms	Freedom versus constraints	No political voice to public	Political voice to public
Friedmand and Gilley (2005).	Banking	Governance	Bankrupt state-owned firms	Non-bankrupts enterprises
Friedmand and Gilley (2005).	Financial institutions	Functions in Business	Low Financial Institutional	High Financial Institutions
Friedmand and Gilley (2005).	Regulatory Positions	Trends	No deregulations	Deregulations
Friedmand and Gilley (2005).	Market Structure	Liberal vs. Non-liberal	Low Internal/ high external Lib.	High Internal/ Low external Lib.
Friedmand and Gilley (2005).	Reponses	Receptive/conditions	Receptive to the Diaspora	Non receptive, until recently
Friedmand and Gilley (2005).	Language/Culture	Language, govt. and freedom	Low English, non democracy	English good, democracy

The second element of the NIS refers to the interactive structure of two countries. The theoretical literature outlined in the theoretical development partially corresponds to these structural formations. Partially, the data on technological activities in figures 2 through 8 provide support for the structure. And partially yet, the discussion section highlights the attributes and features of the structures of two systems. The third element in the data refers to the governance structures in which technological focus is on biotechnology and market structure is on the levels of the intensities of interaction. Figures 2 through 8 represent an indirect support for the governance structures. For instance, in China, most of the patents are owned by the research institutions such as universities, laboratories and hospitals. In turn, the research projects are financed by the public agencies. In contrast, the Indian patents are mostly owned by either the research academies or privately owned firms. Neither is publicly support as compared to China.

The figures show data related to patents on biotechnology, sub-biotechnology classes, and citations of those sub-classes. The first group consist of two figures, containing patents on four sub-technologies of biotechnologies. Figure 2 contains Chinese patents associated with four chosen technologies. Figure 3 captures the data on India on the same four technologies. The horizontal-axis shows years and the vertical-axis shows number of patents on a certain technology. These four technologies in figures 2 and 3 for China and India respectively show the core technologies such as DNA, proteins and tissues/cells. These are aggregated for each in figures 4 and 5 for China and India respectively. So the figure 2 constitutes the aggregated data in figure 4; while figure 3 constitutes data in figure 5.

Figure 2

Chinese Core Biotechnology Patents

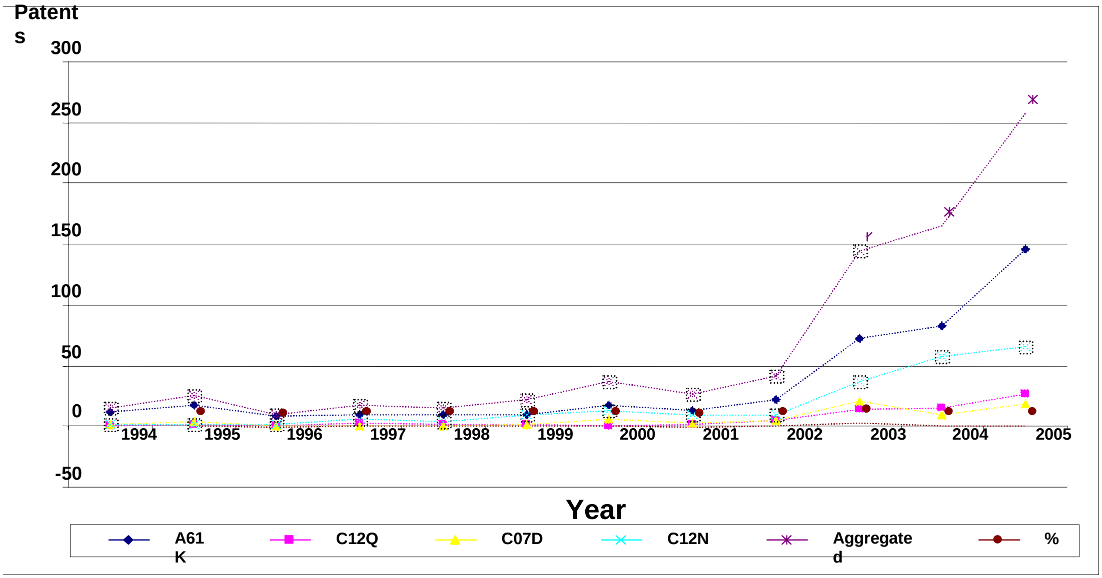


Figure 3

Indian Core Biotechnology Patents

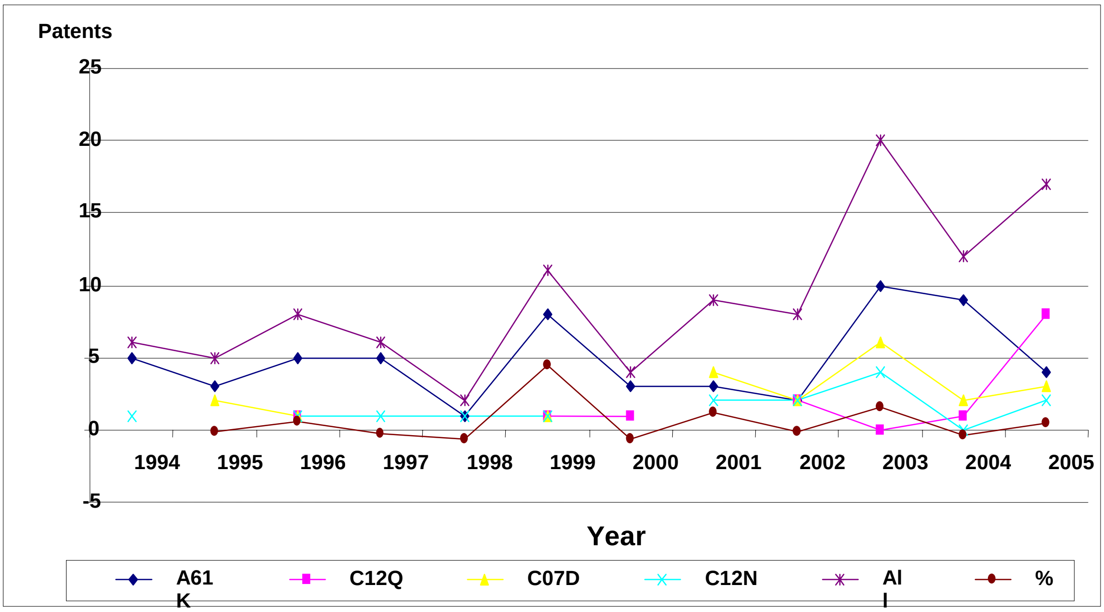


Figure 4

Chinese Total Biotechnology Patents

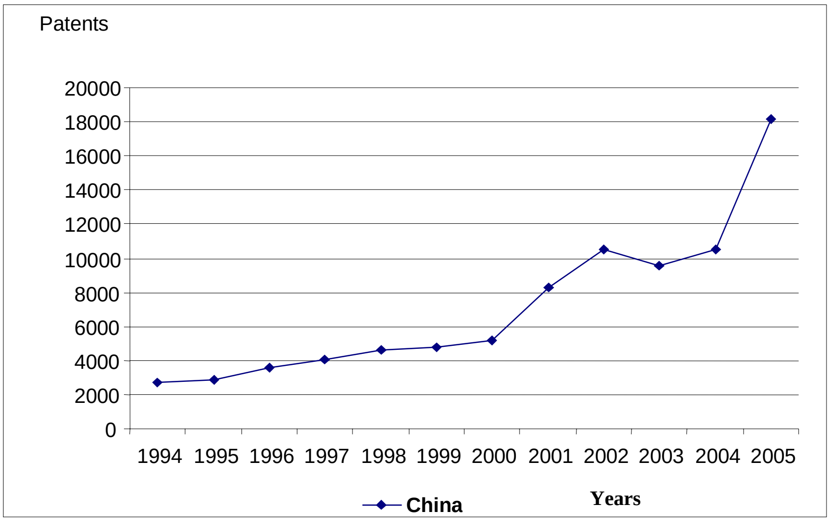


Figure 5

Indian Total Biotechnology Patents

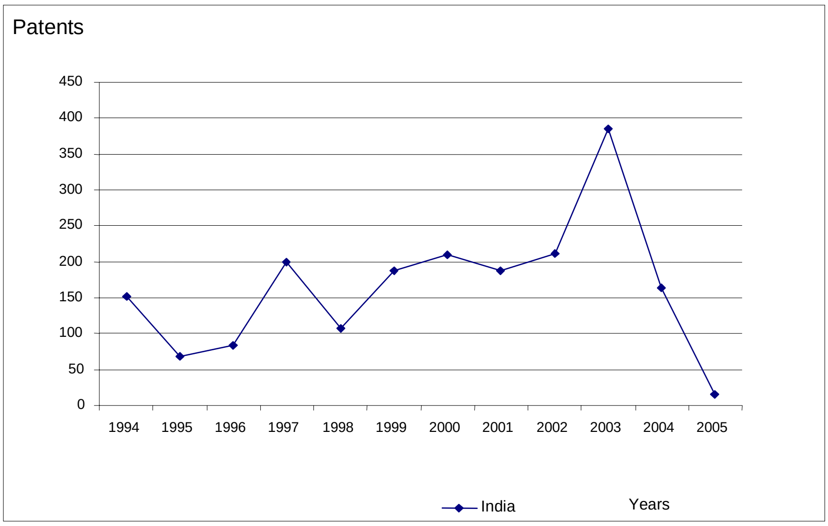


Figure 6 shows the comparison between the two economies on a single graph. The upper trend-line shows Chinese while the lower trend-line shows Indian patents. These data are the estimated quantities of the activities. There are qualitative dimensions of these activities. Figure 7 compares the citation of Chinese versus Indian patents. The upper trend-line shows Chinese citations, while the lower trend-line shows Indian citations. Although the focus of this study is on comparing and contrasting China and India, the gap between the two is widening. So an alternative comparison is made with the US as a reference point in the global space.

Figure 8 compares China with the US. The upper trend-line in figure represents the US total biotechnology patens on the above selected four technologies. The lower trend-line in the figure shows Chinese total patents on those technologies.

Figure 6

China vs. India Total Patent

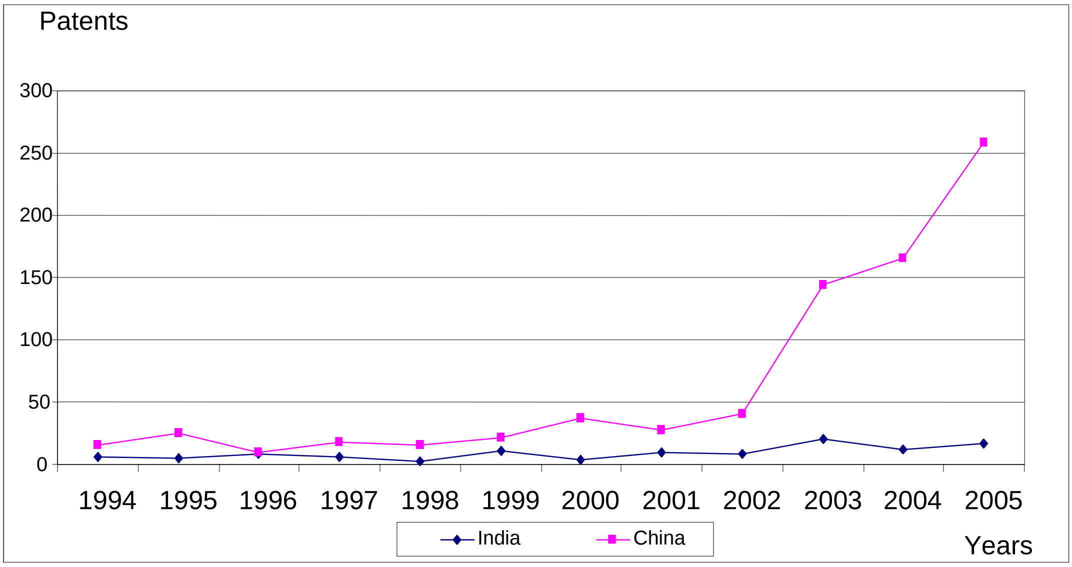


Figure 7

China vs. India 4-Biotechnology Patent Citations

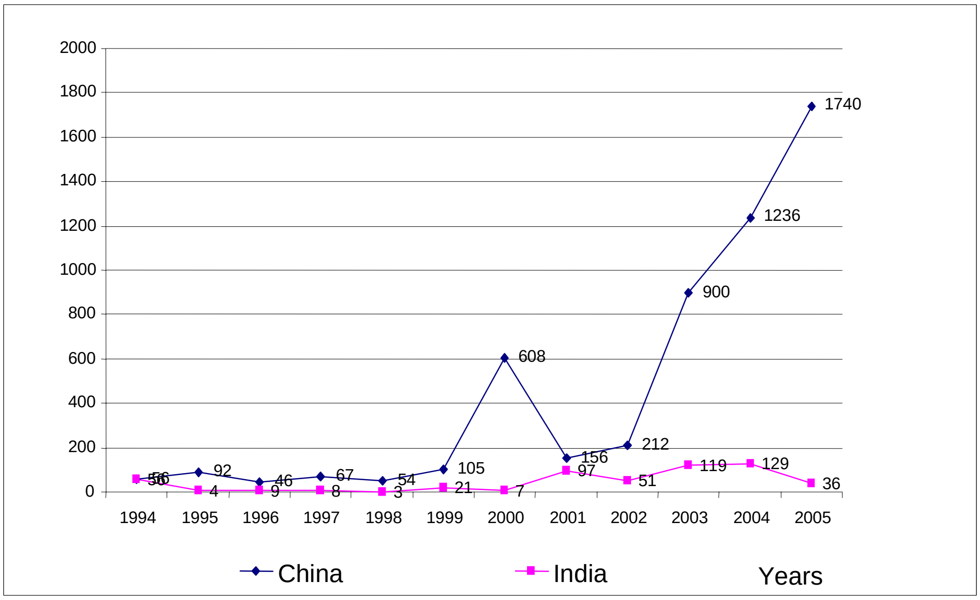
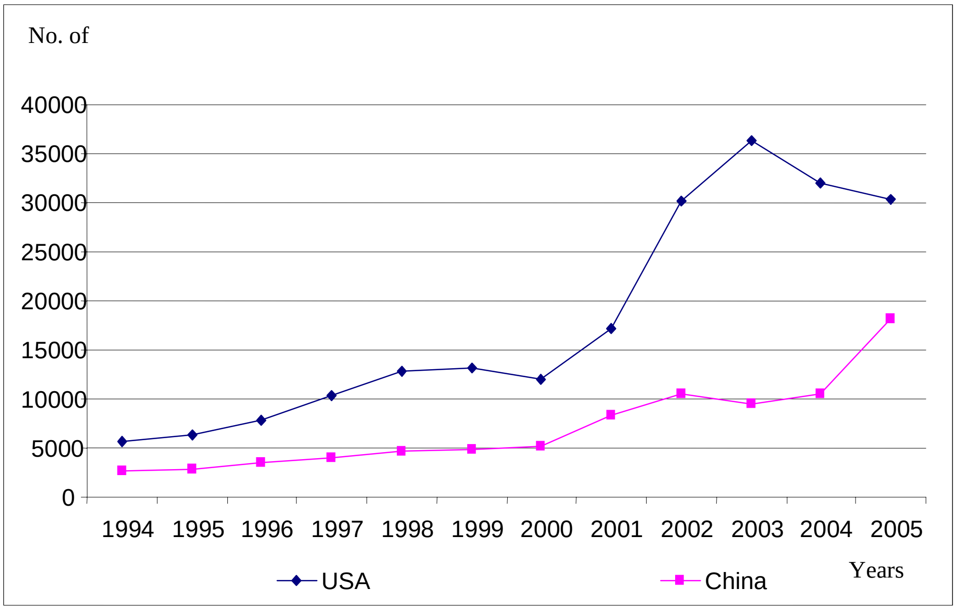


Figure 8

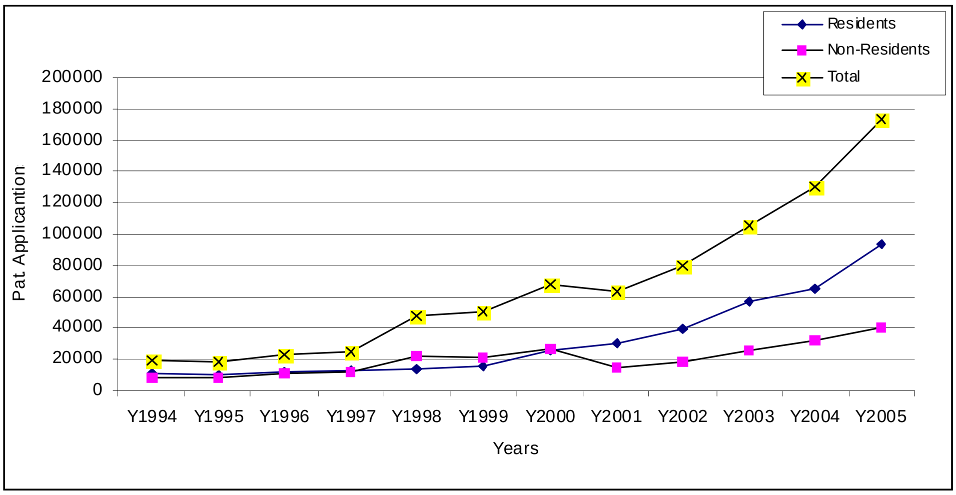
Chinese versus the US Biotechnology Patents



These patterns have shown a narrower perspective on the core biotechnologies to a broader perspective in terms of cross-countries comparison—including the US. To further supplement these data on yet a broadest perspective, a figures 9 and 10 show general capabilities of the two national innovation systems. These data represent the patterns of patent applications to WIPO over the years.

Figure 9

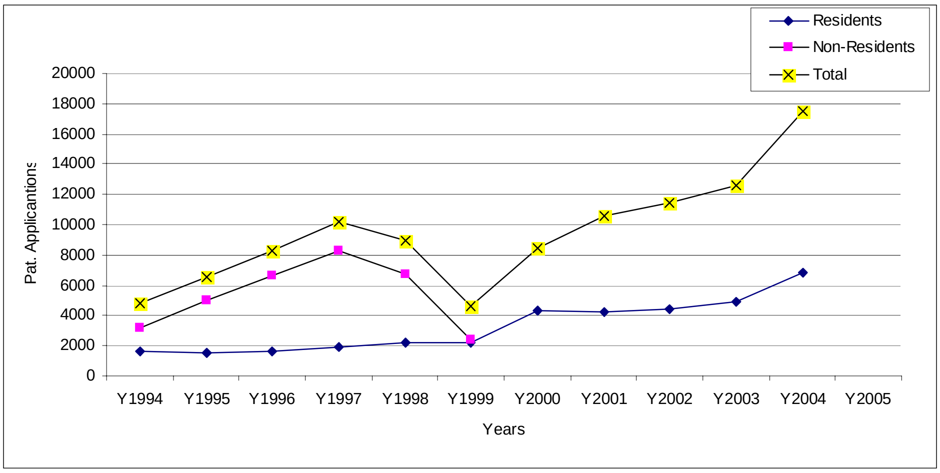
China: National Level Patents Applied



Sources: WIPO

Figure 10

India: National Level Patents Applied



Sources: WIPO

The above evidences are the descriptive statistics and raw figures. In a formal estimation, the annual growth of patents and citations are given for Chinese and Indian respectively. The Chinese annual patent growth is 18% while citation growth is 28%. These are estimated the following exponential functions[24] :

$$China - Patents$$

$$G_{t1} = G_{t0} \cdot e^{rt}; G_{t2005} = G_{t1994} \cdot e^{rt}; G_{t1994} = 30;; G_{t2005} = 260;$$

$$30 G_{t2005} \cdot e^{rt} = 260; 260 = 30 * e^{rt}; t = 12\, year;$$

$$= \frac{260}{30} = e^{r12}; e^{r12} = 8.67; \ln 8.67 = 12r$$

$$r = \frac{8.67}{12} = 0.18 = 18\%$$

Growth of Chinese citations over the twelve-years is as follows is about 28%.

$$China - Citations$$

$$G_{t1} = G_{t0} * e^{rt}; G_{t2005} = G_{t1994} * e^{rt}; G_{t1994} = 58;$$

$$G_{t2005} = 1740; 58 G_{t2005} * e^{rt} = 1740;$$

$$1740 = 58 * e^{rt}; t = 12\, years; = \frac{1740}{58} = e^{r12};$$

$$e^{r12} = 30; \ln 30 = 12r; 12r = 3.4; = \frac{3.4}{12} = 0.28 = 28\%$$

In contrast, India patents growth rates are estimated as follows:

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[24] *G = growth, r = rate, t0=1994, t1=2005, ln = natural log*

$$India - Patents$$

$$G_{t1} = G_{t0} * e^{rt}; G_{t2005} = G_{t1994} * e^{rt}; G_{t1994} = 25;; G_{t2005} = 30;$$

$$25 G_{t2005} * e^{rt} = 30; 30 = 25 * e^{rt}; t = 12\, years; = \frac{30}{25} = e^{r12};$$

$$e^{r12} = 1.2; \ln 1.2 = 12r$$

$$r = \frac{ln1.2}{12} = \frac{0.18}{12} = 0.02 = 1.5\%$$

The annual citation growth in India is about 1.5% over the 12 years.

$$India - Citations$$

$$G_{t1} = G_{t0} * e^{rt}; G_{t2005} = G_{t1994} * e^{rt}; G_{t1994} = 58;$$

$$G_{t2005} = 36; 58 G_{t2005} * e^{rt} = 36;$$

$$36 = 58 * e^{rt}; t = 12\, years = \frac{36}{58} = e^{r12}; e^{r12} = 0.62$$

$$\ln 0.62 = 12r; 12r = -0.48; r = \frac{-0.48}{12} = -0.04; r = -4\%$$

The annual growth of citations in the case of India patents is – 4% (negative). These simple statistics and the contextual data patterns in the two innovation systems are the bases for the discussion in the next section. The contextualization of these evidences can provide broader perspectives and contextual frames for explanation of the phenomena (Wolcott, 1994; Yin, 1981).

5.0 DISCUSSION

The evidences reflect that Chinese innovation system outperforms the India on the biotechnology capabilities. The contextualization of this gap in the framework may illicit better understanding, and it alludes to some important cues. The analytical framework follows path routines to future patterns; and so follows the current discussion in this sequence. First, the discussion draws a comparison on the path-dependence, then it devises current disposition in the context of market institutions. At the next stage, it moves to the governance mechanisms, and then it draws on the comparative advantage of the potential paths and technological trajectories. Finally, the discussion leads to the conclusive argument as a response to the questions on the comparative advantage of the two systems, based on their technological capabilities in biopharmaceutical industries.

5.1 Institutional-Paths

The Chinese past reflects hardware manufacturing, and the Indian past lies in software engineering. The Chinese knowledge is in factories, and the Indian is in offices. The former has competence in tacit knowledge in physical technologies such as hardware manufacturing; the latter has expertise in basic technologies such as software engineering. Hence, for both, linking upstream or downstream are complementary resources. This is consistent with the generic view that organization systems carry forward their path imprints (Stinchcombe, 1965). Accordingly, they are likely to search and select in their technological proximities for innovation (March, 1991). Generally, the proximities to Chinese systems may be viewed as the applied technologies and their complementary software resources. The proximities to Indians software may be referred to their complementary hardware.

5.2 Formation of NIS Structures

Notwithstanding, biotechnology is a deviation from the paths in both systems. Despite different economic paths and social imprints, their responsive strategies to the external environmental dynamics are different. Since biotechnology is a potentially viable innovation for the future economic development, the competitive advantage can be predicted with the existing resource endowments (Teece *et al.*, 1997). Biotechnology is new to China and its response is incremental, consistent, systematic, and sustainable (Huang *et al.*, 2004). That is both in terms of externalization of internal knowledge through patents, and internationalization of external knowledge through collaboration and citations.

Zhou and Leydesdorf (2006) note that China has achieved fifth rank in scientific publications after the US, Japan, the UK and Germany. Hence, China has not only surpassed India, but it has joined the rank of high technology actors in the global space.

Likewise, biotechnology is new to India, and its response is consistent with the existing market patterns for basic sciences. For instance, India is considered strong in upstream professionalism and basic science because of its advantage in English, and financial institutions (Huang & Khanna, 2003). Nevertheless, in the context biotechnology, its responses are less stable and less consistent to the environmental pressures. Hence, where Chinese are consistent in policy formulation and deployment, there Indian institutions are less so. This way, it is less plausible to assume that Chinese institutional model is not as conducive to future technological capabilities and competitiveness in high technology innovation as is India. However, it is also plausible that Chinese systems are different and incomparable with the other frameworks of the market economies. Chinese policies seem to be a fit between the enterprising and the centralized intervention driven economic reforms. These in turn generate a different type of venture capital and entrepreneurship in China (Liu & White, 2001; White *et al.*, 2005).

Chinese venture capital has its advantages and disadvantages in contrast with India. Chinese government policies are changing towards open market practices, which encourage evolution. Some observers note that a hybrid of four types of Chinese companies is emerging: (a) National champions, (b) dedicated exporters, (c) competitive networks, and (d) technology upstarts. The last type is relevant to this discussion. The technology upstarts are using innovations developed by China's government-owned research institutes to enter emerging sectors such as biotechnology. The evidences presented in the finding section are consistent with the literature that implies that China has a lead over India. It seems that a shift from factory to laboratory has more effective impact in terms of innovation performance in biotechnology than has in India from laboratory to factory. China liberalized its economies a decade earlier than India did, which may mean that China was able to recognize the external dynamics and potential opportunities ahead of India; whereas, India recognized these opportunities far later.

The economic opportunities recognition and capitalization on the technological capabilities reflect the dynamics of institutions, and these institutions seem to be transcending the barriers such as the English language and weaker banking sector in China. These inferences contradict the literature that implies Indian lead because of its developed banking system (Huang & Khanna, 2003; Lal, 2004). Banking system is essential and fundamental factor in economic development, however, some strong capital market and banking institutions could not sustained the recent virtual and internet busted phenomenon in late 1990s. Strong banking systems are not necessarily a safeguard against failure of a punter capital system (Edquist, 1997). So, what is drawing China in biotechnology ahead of India? It is commonly believed that Chinese system is relatively constrained economic system, a close society and a passive political system (Huang & Khanna, 2003).

However, the progressive patterns suggest that in terms of biotechnology, Chinese economic system is more active than it is perceived. Chinese are more proactive in innovation than defensive to their existing capabilities. Indians are more defensive to their basic technologies and their internal R&D disposition (Katrak, 2002; Ramani, 2002). The Economist (2006) notes that India is defensive towards Chinese investment in India because of the historical rivalries between the two economies. China is willing and it is able to go upstream from its downstream factory. Chinese internal market is driving its economic growth and innovation consumption; Hence, the view that China is purely FDI (foreign direct investment) driven is not sufficient to support that the argument that China is liable to become dependent on the FDI.

The FDI is low in India because the innovative conditions and efficient infrastructures are lacking. The external resources (FDI) are flowing into China because of her innovative patterns, economic capacity, and consumer behaviour. China invested 37.5% of its GDP on investment during 1994 to 2004; while India reached 22.5%. Since investment on technology precipitates technological capabilities in terms of innovations and economic performance, Chinese labour productivity increased 6.7% versus India 4.2% from 1991 to 2003 (Kalish, 2006).

Although the bottom-up perspective defines Indian entrepreneurship, it is limited to conventional industry (except software). Hence moving from factory knowledge to laboratory knowledge is more likely to add to innovation than the other way around. Internal markets derive long-term innovative capabilities and sustainable economic growth. India pharmaceuticals are entirely dependent on generic technology licensing for mass production. Lastly, a healthy banking institutional system and English language proficiencies are essential in this era of globalization but not sufficient conditions for innovative capabilities. The Philippines and Sri Lanka may have higher English literacy per 1000 population, but their innovation are proportionately far below the comparison. Chinese consistency, cooperative competition and incremental change (endogenous) are driving innovations in biotechnologies and likely to continue in nanotechnologies that is proximal to the precision engineering in which Chinese have the upper hand. Thus, given the warranted evidences, China has a clear lead in biotechnologies. If its patterns remain on the increasing path, it will be comparable to the US rather than to India (c.f. figure 9).

Consistency and stability in institutions and change in knowledge seem to be driving China's lead in high technology industry for several aspects. This resonant to institutional stability and divergence from the technological rigidities divides the two giants. For instance, Xie & Wu (2003) find that China economic model has several attributes. First, it has diverse and repetitive opportunities for learning and resource deployment. Second, it has vibrant competition among domestic firms. This is contrary to the assertion that Chinese firms lack competition. Third, unlike any other market, Chinese domestic market is vibrant, dynamic and evolution with the environment. Chinese domestic market is source of growth not only for Chinese, but now the global economies are relying on the Asian consumer markets (China on the lead) (Economist, 2006). Fourth, Chinese central intervention is phased-based rather than radical, and therefore it is sustainable in contrast with inconsistent but radical markets. They are complex but dynamic institutional systems.

In contrast, India is gaining a high technology momentum that is a divergence from the past. For instance, political focused slogans like 'India Shining', whereas majority lives far below the poverty line by any standards, was little divergence from the past. However, now apparently, new policies are driving majority to cross that line. This in turn generates a purchasing power, internal market, endogenous change. Perhaps than India might join the ranks of the developed systems; and perhaps than India might surpass China in terms providing welfare to the entire society.

5.3 Governance Structure & Mechanisms

Unlike the granted assumption that China lacks entrepreneurs (Huang & Khanna, 2003), there are number of risk taking entrepreneurs with capabilities to recognize opportunity and capitalize on informed-decisions. These factors are peculiar, and therefore, may not be replicable to others (Xie & Wu, 2003). These are not replicable in even highly developed contexts. Take the case a biotechnology entrepreneurial firm, called Beike Biotech. It is a joint venture of Shenzhen government, Peking University, and the Hong Kong University of Science and Technology). Launched in 2005, Beike Biotech specializes in stem cell treatments that are unlikely to be replicated soon in other contexts. Beike Biotech takes stem cells from aborted foetuses and implants them into patients with otherwise incurable diseases. This reflects two different socio-technical parameters. One reflects the ability and willing of adaptation of the enterprises, and the other shows the ability and willingness of the adoption in the society in China.

Hence, the results showing that China is likely to be a potential leader in high technologies (biotechnology in particular) systematically supplant the existing explanation that China lags the potential to be a viable economic power of the future. China is spending 1.5% of its GDP on R&D and is planning to increase up to 2% by 2010. China is by far the most frequently cited location for R&D. It has a portfolio of 750 million small firms. Although its patent protection is weak, China is moving from factory to laboratory (government spending), it has 5 million university graduates annually, 1/5th majoring in science or engineering and is the first country to establish a full rice genome database.

In contrast, India is spending ½ of Chinese size. Chinese foreign investment flow, both in laboratory and factory, is 90% higher than India. Above all, Chinese partner selection strategy is based on long-term sustainability and short-term change. This again reflects its resonances to stable institutions and novel physical infrastructures and technologies. Its stability is driven by long-term stable partners, and its dynamism is driven by short term alliance formation (Hitt *et al.*, 2004). Hence, Chinese competitive edge in biotechnology is the result of the co-evolution between the social and physical technologies (Nelson *et al.*, 2004; Nelson & Sampat, 2001).

In short, as Lal (2005) suggests that China is embracing capital system in a systematic way, there are reasonable evidences to warrant this argument. It has foreign trained Chinese scientists (38% growth by 2008 in life sciences), it is struggling to shun off its dirigisme past route, it is focusing on both quality and quantity (White & Liu, 1998), and it has domestic market power for local and foreign products. Furthermore, the return of innovation in dollar spent on R&D (Innovation/R&D expenditures) seems to be higher in China than India. This is one of the established metrics for innovation capabilities (Geroski, 1992). While China is weak on both, the rule of law (commercial terms) and language (English), it is proactively seeking solutions.

On the other hand, although India is high on rule of law and language, it is hobbling on small-scale labour intensive industries driven by archaic laws, laggard in embracing capitalism in which it is presumably a leader (Lal, 2005). It has low joint ventures with foreign firms, and low market for local and foreign products. In this regards, Chinese market is more dynamic and adaptive to the change than the India is.

5.4 System Integration & Technological Capabilities

On the one hand, both are integrated market structures. On the other hand, both are disintegrated or less integrated. In terms of the high integration, for instance, China is integrated in biotechnology in the upstream. It has obvious lead in the knowledge resources acquisition, mobilization and institutionalization through patents. In contrast, India is less integrated in terms of knowledge generation. Indian biotechnological innovative capabilities seem to be far lower than China. Its investment on public research is relatively minimal. Its patent numbers have not increased since 1994. Its links between the university and firms seems to be less integrated. Thus, in terms of explorative activities, China is highly integrated, while India is less integrated or disintegrated. As a result, China as a whole outperforms India. For instance, WIPO (World Intellectual Property Organization) observes: an exceptional growth from North East Asia in international patents filing during recent years:

"…China dislodged Canada, Italy and Australia to take the position of 10th largest PCT user… and for the second year running, the most impressive rates of growth came from North East Asia – namely, Japan, the Republic of Korea and China, which between them accounted for 24.1% of all international applications… the from Japan, Republic of Korea and China continues to be exceptional, reflecting the rapidly expanding *technological strength of those countries* (emphasis added). Since 2000, the number of applications from Japan, Republic of Korea, and China, has risen by 162%, 200% and 212%, respectively". ***Sources**: WIPO Press Release 436; Geneva, February 3, 2006 WIPO Deputy Director General who oversees the work of the PCT.*

On the other hand, in the exploitative dimensions, it is commonly understood that Indian pharmaceutical companies license-in technology from abroad and manufacture generic therapeutics. In this sense, the India firms are more integrated because they have institutional support for the development and commercialization inside the country and outside it. A healthy banking system, an open business environment, and increasing liberalization are such examples on the part of the national level strategies. In contrast, Chinese exploitative capabilities appear to be relatively less integrated. Despite high level of patents achievements in biotechnology, they are weaker on the commercialization and diffusion end. Nevertheless, there are two issues usually missed by the outside observers. First, China has a strong domestic market, and its pharmaceuticals are hardly meeting these needs of the market. Second, Chinese market is fast-adopter of the new technologies. The adoption of the genetically modified products by the commercial and end-users are some of the recent examples. An economic system is at an advantage when the innovation supply side is met by the dynamic adopters (Rosenberg *et al.*, 1992). Chinese users are relatively fast adopters of the new innovations (Huang *et al.*, 2006). Hence, the current endowments plausibly indicate two possible future scenarios.

In the biopharmaceutical sector, China is ascending from explorative to exploitative capabilities. The exploitative capabilities require different types of commercial and political institutions than China has. India, on the other hand, is likely to ascend from mere trading patterns (buy-in, sell-out) of the knowledge to be a creative system. Comparatively, China is endowed with capabilities to descend slightly better than India is endowed with the capabilities to ascend on the biopharmaceutical industries value chain. However, were it information technology, China might ascend from manufacturing to software engineering slower than Indian may be able to descend towards manufacturing in the downstream on the IT industrial value chain. Nevertheless, this assumption on the IT is based on intuitive observations rather than systematic studies. In contrast, the evidences from the biotechnology capabilities suggest that China is a clear and present lead over India.

Putting together, the discussion leads to the conclusive argument that stable institutions, induced with consistent resources, are likely to be the sources of novel technologies for a NIS' competitive advantage in the emerging era of high technologies. This is because of the capabilities of a system to deploy resources more efficiently and effectively. Indian institutions in the downstream are stable. For instance, banking systems, commercial laws, and entrepreneurial conditions are some of the examples of the stability of these institutions. So there seems to be a link between the stable institutions for novel technologies in these competencies.

On the Chinese side, the institutions are stable in the upstream direction. Integrated systems such as links between the government, the industry, and the university are some of the explicit examples of the stable demand-supply of the technologies. These stables links provided reasons to recognize the needs for the potential investment and therefore, for the resources allocations. Accordingly, it is obvious that Chinese stable institutions in the upstream are behind the lead in biotechnology patents. Thus, the more the stable the institutions are, the better the inter-linkage in a system likely to be, and eventually, the better the performance may be reached.

6.0 CONCLUSION

The purpose of the paper was to explore the biotechnological capabilities of the giant economies in the global space and their national innovation systems: China and India. The rationale behind this exploration was to understand the roles of the institutional path-dependence in the development of the technological capabilities, innovation patterns, and relative competitive advantage in the economic space. This understanding of the links between the institutional evolution, knowledge flow, governance mechanisms and performance would enable to diagnose the effective context-specific structures from the ineffective ones.

To explicate the question, how two national innovation systems are contributing to their respective biotechnology industries, the NIS (National Innovation System) framework was used to analyze the evidences. The NIS framework was delimited in four sequential segments: (a) institutional paths, (b) interactive structures complexities for knowledge flow, (c) governance mechanism and market structures, (d) and technological performance in explorative and exploitative achievements.

Data were gathered along these four segments in the framework. First, the data were collected from theoretical and empirical literature to support the sources of the institutional patterns of the two systems. Second, the data were collected from popular literature such as business journals, magazines, and newspapers. This stream supports the second section. Third, the core data consisted of patents. This made the core of the research in terms of integrated market structures. These data were used for the final conclusive argument in the last section.

The findings allude to at least three areas. First, both the biotechnological innovations systems are partially integrated and partially less integrated. Comparatively, China is more integrated that India. Second, China is far ahead in terms of NIS capabilities on knowledge exploration and closer to exploitation. Since patens are the base for this inference, and patent innovations can be transacted, China can be potentially leading in exploitative capabilities. Third, stables institutions in their context-specifics contributed to their performances. Along the value chains, each system has evolving institutions driving knowledge flows and innovative capabilities for economic opportunities recognition. India seems to leading in the generic manufacturing, while China in generic discoveries and development. These findings conclude that stable institutions pattern behaviour as well as enable innovation.

In supplementing the ongoing debate, this paper makes some evidence-grounded contribution in terms of insights, importance, policy perspectives, and theoretical supplementation. Biotechnology is am important field in the near future and this paper illicit some of the recent patterns in the two systems. It is timely because of the debate among scholars and writers in determining the potential economic capabilities of Chinese versus Indian institutions. The contribution of this study is useful in the sense that investors learn where to develop their social and economic resource portfolios, which may enable the policy makers to adjust their acquisition and allocation of knowledge resources in both economies. This is both for now and in the future. Policy makers are able to differentiate between the relative advantage (now) and global advantage (future) by understanding the rhetoric from the reality.

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