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Exports, University-Industry Linkages, and Innovation Challenges in Bangalore, India

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Abstract

The success of the Indian software industry is now internationally recognized. Consequently, scholars, policymakers, and industry officials everywhere generally anticipate the increasing competitiveness of India in high technology activities. Using a structural framework I argue that Bangalore's (and India's) IT industry is predicated on an Indian business model which does not encourage thick institutional linkages such as those encapsulated by the triple helix model. Under this institutional arrangement there is cross-fertilization of new ideas and new modes of institutional interaction between industry, academia, and government. Though there are several hundred IT businesses in a milieu of numerous engineering and science colleges and high-end public sector research institutes, the supposed thick institutional architecture is in reality quite thin. This is due to a particular type of an export-oriented model, which is based on off-shore development of software services, targeted mainly to the US. Neither domestic market nor non-US markets such as East Asia are pursued aggressively by Indian firms, which offer alternative forms of learning. Consequently, Bangalore's dynamism in the IT industry stems from linear and extensive growth rather than non-linear and intensive growth. This paper argues that Bangalore has serious innovation challenges with weak university-industry linkages, lack of inter-firm collaboration, and absence of cross-fertilization between the knowledge-intensive defense/public sector and the commercial IT industry. To strengthen Bangalore's and India's innovation system the Indian business model must be reformed by diversifying geographical and product markets, stemming international and internal brain drain, and contributing to urban infrastructure.

I. Introduction

Bangalore is a mid-sized Indian city in the southern state of Karnataka once known for its quaint houses with gingerbread trim, many parks, defense personnel, and pensioners. Today it is India's Silicon Valley. Multinational information technology (IT) businesses are flocking in to outsource IT services from their subsidiaries and from Indian subcontractors. Some are also establishing R&D centers. Bangalore is also host to numerous universities, management and public policy institutes, engineering colleges, and several government research institutes in aero space research, electronics, and communications. It draws the cream of the country's technical talent as well. This clustering of high-tech economic and knowledge-based educational activities intuitively suggests a thick institutional architecture.

Several factors explain the rise of the Indian IT industry: the country's long-standing emphasis on technical education, fortuitous global demand in the 1980s, the successes of local and expatriate Indian techno-entrepreneurs, dense social networks among professionals, Indian economic policy reforms, multinational investments, and state support for software exports (Arora et al. 2001, D'Costa 2004a, D'Costa 2003a, Kattuman and Iyer 2001, Patibandla and Petersen 2002, Heeks 1996). Among these factors the role of human capital – and thus universities – is given a prominent place. It is clear that universities are directly responding to the growing demand for software professionals by increasing enrolment capacity. By extension, this implies that strong university-industry linkages (UILs) must be in the making in Bangalore if rising productivity (revenues per employee) can be shown (Okada 2004: 291; Athreye 2005). After all, value addition based on deepening skills suggest innovativeness and cutting-edge technologies. And given that there is scattered evidence of foreign investments in research and development (R&D) , other than R&D and increased collaboration between universities and industry, what else could lead to such knowledge-intensive output (see Tsai 2005, Audirac 2003, Doloreux 2002)?

Contrary to expectations, I argue that Bangalore's development is predicated on a business model which does not encourage UILs. Though there is collective efficiency due to the spatial concentration of several hundred IT businesses in a milieu of numerous engineering and science

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colleges and high-end public sector research institutes, most firms do not collaborate with other competing businesses or partner with academia or government institutions. The supposed thick institutional architecture in reality is thin. As one study characterizes India, the "gulf...between the academic world and industry" is significant (Dahlman and Utz 2005: 91). Bangalore's dynamism stems from linear and extensive growth rather than non-linear and intensive growth (D'Costa 2002a). This is a result of an export-oriented model based on off-shore development of software services, targeted mainly to the US. Indian firms are well-positioned to take on large and small high-volume, low-value projects for foreign markets due to the availability of a relatively homogenized IT work force (Kambhampati 2002: 27, Parthsarathi and Joseph 2004: 100-104). Firms face low entry barriers and the IT industry is structurally locked into a model of mostly small, undifferentiated firms. The ensuing "excessive" competition, though healthy for dynamic change, in the absence of deeper local institutional and intersectoral linkages discourages inter-firm cooperation, encourages high labor turnover, and contributes to a local wage-cost spiral. Hence, the sustainability of the extensive model could be at stake if competitiveness shifts toward East and Central Europe and East and South East Asia or if Indian firms continue to serve foreign markets in an enclave fashion (D'Costa 2006, 2002b).

There are strategic options. To break out of the extensive growth trajectory, non-routine knowledge-intensive endeavors are necessary (Looy, Debackere, and Andries 2003: 225; OECD 2001: 7) by way of cross-fertilization of new ideas and new modes of institutional interaction between industry, academia, and government, known as the triple-helix model (Etzkowitz and Klofsten 2005; Baber 2001; Etzkowitz and Leydesdorff 2000; Leydesdorff 2000, Hayashi 2003). With rising costs, Indian firms could be compelled to move up the value chain by innovating, nurturing highly skilled talent, and establishing strategic UILs. Universities will then have to become "entrepreneurial," meaning, in addition to supporting firms and governments, they are expected to be "source of firm formation and regional development" (Etzkowitz and Klofsten 2005: 245). But that would call for an institutional make-over, akin to the triple-helix model. Currently this is a tall order for Bangalore as there is neither a working triple-helix model nor are there signs of one forming in the near term. The other option would be to continue with the extensive model, that

is, growth would be based on a few highly innovative firms with the remaining large and small firms engaged in relatively routine IT services. This option is dependent on the growing supply of IT workers and demand for such services. A third option lies somewhere in between, forging some strategic partnerships with universities (see Basant), diversifying product and geographic markets, and overhauling the university curriculum to take advantage of both imminent labor shortages and new technological opportunities in the global economy (D'Costa 2004c).

The next section briefly presents the sources of Bangalore's growth by reviewing the supply of technical talent and the characteristics of external market demand. Section three presents some of the shortcomings of the extensive model in operation by examining the structure of the industry, the impact of excessive competition, and learning constraints. I conclude that the incentives to set up major UILs do not exist at this time. However, as section four outlines some intermediate steps to go beyond intensive growth, it shows that such measures may incrementally call for the establishment of UILs. These steps include a greater focus on the domestic market, the diversification of export markets toward East Asia, anticipating new technological trajectories, and retaining and attracting expatriate talent.

II. Some Sources of Bangalore's Extensive Growth

2.1 Human Capital and the Supply Side

Extensive growth of Bangalore has created an expanding cluster of IT firms, engineering and science colleges such as the Indian Institute of Science, IT training centers, government high technology entities such as the Indian Air Force headquarters, Indian Space Research organizations, and Hindustan Aeronautics Ltd, and state-sponsored critical infrastructure such as satellite links in centrally organized software parks (see Heitzman 2004: 222-229, Taebe n.d.). However, the mere concentration of public-sector academic and research institutions is not a sign of UILs since the earlier model of top-down state-dominated academic and industrial agenda in a semi-closed, security-conscious economy has not been completely shed (Sridharan 2004, 1995). What has changed recently is the rise of active state promotion of the Indian IT industry.[1] For example, the Software Technology Parks of India (STPI) under the Department of Electronics of the Ministry of IT and Communications has provided critical infrastructure support for exports. In 2003-04, Bangalore exported $3.8 billion, 36% of all STPI exports.[2] The state government of Karnataka established an Electronics City in 1985, a few kilometers away from Bangalore's city core. Electronics City houses numerous software firms, including one of India's largest and most successful firms, Infosys. Later, an international, export-oriented high-technology park (ITPL) has been established by a consortium of Singapore companies led by Ascendas Land (International) Pte. Ltd., Tata Industries Ltd. (the investment arm of the Tata Group), and the government of Karnataka. ITPL is host to 107 foreign and domestic firms. Many clients of ITPL are global organizations in need of state-of-the-art information, communication, and physical infrastructural facilities.[3]

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[1]In the 1970s the state set up the National Informatics Center, the Computer Maintenance Corporation (CMC), the National Center for Software Development and Computing Technology, and regional computer centers. There are other research organizations in astrophysics, defense, space, artificial intelligence, basic sciences, microwaves, power, biological sciences, and mathematical modeling and computer simulation.

[2]The New Okhla Industrial Development Authority (NOIDA), an industrial agglomeration near Delhi, came a distant second.

[3]www.intltechpark.com Accessed 04/18/2005 11:55 AM

Extensive growth of Bangalore has been sustained by the supply of IT workers. Though the state of Karnataka has only 5% of India's population it has nearly 15% of its higher education enrolments.[4] Its engineering colleges exceeded one hundred and nearly 12,000 students took IT-related courses (Table 1). Karnataka had 83 engineering colleges under Vishweshvaraiah Technology University offering the Bachelors of Engineering degrees.[5] Of these, 25 colleges were located in Bangalore; 59 are in the Bangalore region. Most of these colleges graduate students proficient in basic engineering skills, mathematics, and programming. There are eight other non-engineering universities, two of which are in Bangalore. Bangalore University itself has over 50 colleges located within Bangalore.[6] Though not a source of engineers, these colleges contribute to English-speaking science and IT-proficient graduates. Karnataka has two of the nine national institutes of technical education including the recently created the Indian Institute of Information Technology (IIIT) and the established Indian Institute of Science (IISc), two of the 43 regional engineering colleges, 12% of the country's degree colleges under universities granting technical degrees, and 15% of diploma-granting polytechnics (Okada 2004: 298).

Recently, the government of India, the Indian software industry association (NASSCOM), the state government of Karnataka, and some transnational corporations established the Indian Institute of Information Technology in Bangalore. It aims to link academic technical training with hands-on business experience. A similar institute has been established in Hyderabad. Bangalore's IIIT is located in Electronics City to encourage close academic-business interaction with IT firms in the campus, including firm-specific training.

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[4]www.bangaloreit.com/html/ Accessed on 04/15/2005 10:34 AM

[5]Other sources put the number at 103. www.educationinfoindia.com/engg/karnatakaeng.htm Accessed on 04/18/2005 11:06 AM

[6]www.educationinfoindia.com/streamwisecolleges/others/ Accessed on 04/18/2005 12:24 pm

However, barring a few world class technical institutions, Indian tertiary education is plagued by shortages of high quality staff, underinvestment in research facilities, and poor training (see Dahlman and Utz 2005: 63-72). As observed by an expatriate Indian manager, "India needs to build a richer academic ecosystem" (in Cookson 2005). The industry association NASSCOM laments the low quality of faculty at universities in teaching and research and high student-faculty ratios when compared to Cambridge and Harvard Universities (NASSCOM 2002a:73-74). For IT training there is the added problem of the flight of instructors for the more lucrative software industry. NASSCOM fears the problem is going to get worse as faculty are pressured to raise non-public sources of revenues through consulting and teaching in non-degree programs. The raw talent needed by most Indian IT firms is substitutable and under the extensive growth model in-house training is adequate to serve the global customized services market at this time. Hence, the incentive to create UILs appear limited.

At the same time, for all the human resources available in India there are shortages of highly skilled professionals due in part to poor quality staff and low enrolment ratios in tertiary education. For example, between 1990-2001 India's tertiary enrolment barely increased to about 11% of gross enrollment, while China, starting from a much lower ratio, reached 13% (Dahlman and Utz 2005: 57-58). Similarly, despite the technical education progress made by India, the number of doctorates in engineering is low. In 1979 the figure was 506, which increased to 546 in 1995 (Dahlman and Utz 2005: 61).[7] The low number of engineering doctorates suggests poor quality in education and the R&D environment. The overall research environment in terms of spending and share of tertiary students in science and engineering is low by international standards. What this implies is the build up of "IIT's graduate student population, and [improve] links between universities and public research labs and industry" (Cookson 2005).

Consistent with extensive growth of the Indian IT industry has been an outflow of technical talent through temporary and permanent emigration of Indian science and engineering students and

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[7]Arora and Athrey (2002: 263) report that the numbers fell from 675 in 1987 to 375 in 1995.

IT professionals to foreign markets (D'Costa 2005). For example, roughly 44% of the US's H1-B visas have gone to Indians, allowing Indian professionals to work in US firms. Despite signs of some reverse flow, most Indian professionals do not return home (see Hira 2004).[8] While this has given the Indian IT industry a foothold in export markets, generated a brand name, and established professional networks, it has also induced the local university system to be content with replenishing the outflows of students without much regard to enhancing post-graduate training in core engineering fields.

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[8]This dynamic is expected to lead to labor shortages in India itself (see NASSCOM 2002a:67).

Weak R&D is also reflected in the small number of patents filed in the US (Dahlman and Utz 2005: 81). Between 1991 and 2003 China was granted 2,038 patents compared to India's 1,555 (U.S. Patent and Trademark Office 2005: A2-1). In the same period Hong Kong and Taiwan were granted 4,191 and 45,127 patents respectively. There is no Indian IT company that has a patent, though the top ten patent holders in the world are IT companies (siliconindia.com 2006). This does not mean that research in India is not being done, but it is mostly undertaken by government institutions and a few universities (see Mani 2004). India's research strengths lie in the pharmaceutical and chemical industries, a reflection of India's larger output of science doctorates (almost six times engineering doctorates) suggests a better R&D record in non-IT sectors such as pharmaceuticals, automobiles, and electronics (Dahlman and Utz 2005: 84). India is also strong in high-science activities such as space research and high energy physics but India's role in industrial innovations is negligible due to the enclave nature of government institutions (Sridharan 2004).[9] Research by Indian faculty is weak as reflected in the low number of citations and lack of original research. India declined in scientific publications from eighth position in 1973 to 15th in the world (Jayaraman 2002a: 100). Between 1980 and 2000, India's science-related publications fell from 14,983 to 12,127, while China's rose from 924 to 22,061. NASSCOM also identified several areas concern including more student exposure to project, skill sets identification, curriculum standardization, and so on (NASSCOM 2005). Without such efforts it will be an uphill task for the Indian education system to obtain necessary international certifications and accreditations (NASSCOM 2005).[10]

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[9]Incidentally, Taiwanese firms are not known for new products, rather they innovate products developed elsewhere and in which markets are well-established (Breznitz 2005: 157), that is, they "leverage" existing knowledge (Mathews and Cho 2000). Taiwan has an excellent hardware sector, which is effectively driving the weaker software sector. It does little research but a lot of design (Lu and Liu 2004: 460). Between 1991 and 2002, the number of IC design companies increased from 57 to 225 (Breznitz 2005: 161). But even Taiwan seems to lack meaningful university-industry linkages.

[10]www.nasscom.org/ Acessed 04/18/2005 10:10 AM.

2.2 Exports and the Demand Side

Bangalore's extensive growth is also reinforced by the particular business model adopted by the Indian IT industry. Its principal characteristic is outward orientation based on off-shore development for exports with a focus on software services and heavy dependence on the US market (nearly 65%). There are nearly 100 multinational firms in Karnataka state, most of which are in Bangalore (http://www.bangaloreit.com 2005). Roughly 24% of India's top software firms are located in Bangalore, of which over 63% were multinationals (Okada 2004: 286). In 2002, of 102 Bangalore-based NASSCOM members, close to 40% of firms had 100% exports, while 67% of the firms had export ratios over 80% (NASSCOM 2002b). Over 80% of the firms had export ratios exceeding 60%.

According to one estimate (Table 2), India's strength is in customized software, with about 25% of the global market. However, this segment itself is estimated to be less than 4% of the global IT market. In other segments, where India's prospects are considered to be high do not require advanced skills except for network infrastructure management and packaged software. In fact, processing services and information services outsourcing are consistent with India's relatively abundant supply of English-speaking graduates, which is reflected in the growth in IT Enabled Services (ITES), commonly referred to as call centers and Business Process Operations (BPOs).

The growth of the ITES sector is a welcome development for a labor-abundant Indian economy. But this is not a sector that can boast of being at the cutting edge of technology. The role of universities is limited for this sector as IT training institutes are likely to impart basic technical training to English-speaking graduates. Firms will remain responsible for job-specific training. Thus far the low cost of labor relative to OECD norms makes ITES outsourcing to India attractive (Hoffman 2003), especially when competition under recessionary conditions in OECD countries compels cost cutting. The wage arbitrage in this sector is high enough to reinforce extensive growth of the Indian IT industry.

III. *The Pitfalls of Sustained Extensive Growth*

One of the central sources for industrial development and innovative capability is the embeddedness of firms in the local production system (Parthasarathy 2004, Hsu 2004). According to UNCTAD (2004: 151), "high-skill services," among other things, "require advanced skills at high levels of specialization, often with strong educational institutions. They involve agglomeration economies, <u>with different skills, enterprises and institutions interacting with each other to share work, stimulate knowledge flows, and allow specialized skills to be fully utilized</u>" (author's emphasis). Bangalore appears to enjoy many of these characteristics. However, as it will be shown below, the particular business model adopted by the IT industry sustains extensive growth and thus discourages the kind of interactions necessary to be at the technological frontier. Related to this model is the significant influence of export markets. When foreign economies and firms are the principal clients and innovators, they influence what gets produced, how, and for which markets. This is not intrinsically an unfavorable situation since diversified external market growth could translate into local technological learning opportunities. This is certainly evident in India. But institutionally, the tension between exogenous drivers such as export demand and technical talent and the endogenous "local production system" could undermine an "interlocking ... collective order" (Scott 1998 in Lombardi 2003: 1444). As a result, under an export-driven system favoring extensive growth, forming thick <u>local</u> institutional linkages such as UILs for innovation are either unnecessary or structurally difficult (see D'Costa 2004b).

Extensive growth presumes continued demand for customized software services and an elastic supply of Indian IT professionals. Such growth results from maximizing revenue strategies by adding more employees. The consequences of this are a fragmented industry, institutional disconnectedness, and high labor mobility. Except for institutional incoherence, neither of the other two outcomes by definition are detrimental to intensive growth. If fragmentation means lots of small firms one could assume competition is rife and thus a basis for innovation. Furthermore, such an industrial structure is consistent with global patterns of export domination by large IT firms. Similarly, labor mobility suggests competition among firms, skill upgrading, knowledge transfer, rising wages and thus innovation-led intensive growth. However, as it will be shown below

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transitioning to intensive growth in IT without an explicit innovation policy incorporating UILs is daunting.

3.1 Fragmented Industry Structure

Unlike hardware manufacturing, the entry barriers in software services are low and competition among small firms in India is intense. While this does not necessarily lead to market inefficiencies arising from monopolistic practices (Khanna and Palepu 2004), the proliferation of firms reinforces extensive growth based on low value-addition by an elastic supply of IT workers.[11] Going by the National Association of Software and Services Companies' (NASSCOM) membership, which represents 95% of the industry's revenues, the number of member firms rose from 38 in 1988-89 to 402 in 1996-97 and 892 in 2004, with 24% of all members located in Bangalore.[12] The growth in India's software output is largely attributed to growth in the export market. This, at first glance, is a healthy sign of rising Indian entrepreneurship as global market opportunities are capitalized on by Indian and foreign firms (D'Costa 2003b). A crude ratio of revenues per firm shows that the average Indian firm has increased its export revenues from $7 million in 1995 to $21 million in 2003. This is a three-fold nominal increase, though in real terms it is likely to be less.

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[11]Curiously, Khanna and Palepu (2004) do not consider that Indian IT companies may be facing monopsonistic situations compounded by the fact that the going international price is far above of what the local market can bear. Hence, there is no "rent-seeking and entry-deterring behavior" since India is still considered to be low-cost producer relative to the US. All of these are consistent with an externally-driven IT industry.

[12]www.nasscom.org/artdisplay.asp?cat_id=109 Accessed on 04/18/2005 12:56 PM.

On closer inspection the average revenue is misleading since most Indian software companies are small in terms of revenues and number of employees, indicating the "easy phase" of exports (Figure 1).[13] Most new firms end up clustering around low-end activities (see BusinessWeek online 2003).[14] The top 20 Indian software exporters still account for about 60% of total exports, leaving more than 800 firms with the remaining 40% of the software market (Data Quest, various issues). The top 10 firms based in Bangalore contribute more than 50% of Bangalore's exports (Okada 2004: 286). In theory, size per se is not important since most software projects tend to be small and thus well suited for entrepreneurial initiatives. In practice, however, large firms are able to carry out multiple projects simultaneously and thus not only spread risks across projects and markets but also carry out large, complex projects by quickly mobilizing large numbers of professionals. Large enterprises, local or foreign, can exercise monopsonist clout relative to smaller firms, though they too could be subject to periodic shortages of specific skill sets. Even the Economist, favorably disposed toward India, reports a shortage of over 1 million "suitably qualified people" by 2010 (Economist 2005: 58). As we will see below extensive growth itself is reproduced in a systemic way.

The fragmentation of the industry suggests that irrespective of size most Indian companies pursue whatever projects they can secure and which maximize the absolute difference between costs and revenues. This generalist and undifferentiated nature of Indian firms suggests competition based on price (Arora et al. 2001). Thus most improvements in productivity are typically passed on to the foreign (read US) clients (Arora and Athreye 2002: 255). The implication of this is that innovative capability is likely to be confined to a few large firms and a handful of medium-sized highly entrepreneurial firms, resulting from founder's or team's particular technical strengths, professional networks, and first comer advantages. It also implies that the incentives to form creative UILs are not high at this stage of extensive growth.

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[13]In comparison software revenues per employee in 1995 were for Israel $100,000, Ireland $142,000, India $9,000, and the US $126,000 (Arora and Athreye 2002: 259).

[14]The correlation coefficient between number of software employees and revenues per employee at the firm level for 2002 for Bangalore's 102 firms is not significant at 0.297.

Figure 1: Bangalore's Fragmented Software Cluster

Figure 3: Bangalore's Fragmented Software Industry(Revenues/Employee (USD) by Size of Firm
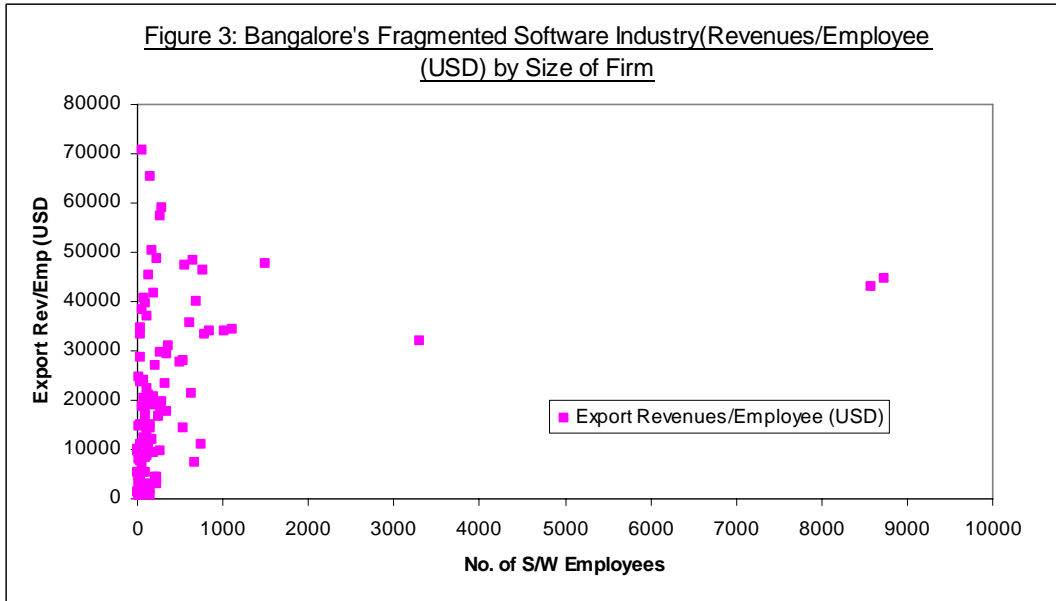
3.2 Competition in Undifferentiated Software and Software-Enabled Services

One important consequence of a fragmented industry is cut-throat competition. There are costs and benefits to such competition. An excessively competitive environment distorts compensation rates, induces a high labor turnover, a real estate bubble, and stress in the urban industrial and physical infrastructure. These would not be much of an issue over the medium term if supply responses by the public and private sectors were speedy and flexible. However, the political economy of Indian development suggests that a variety of political and institutional factors slow responses.[15] Such competition also undermines inter-firm collaboration, which, by most cluster experience contributes to industrial dynamism.[16] This can be also inferred from the number of alliances between Indian and US firms, which exceed the number of alliances among Indian

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[15]For example, talks for replacing a small, ageing airport with a new international airport in Bangalore has been going on for several years, with the most recent discussion breaking down as recently as in 2005.

[16]This was verified by most of the 75 firms surveyed during 1998, 1999, and 2005 in India. Of the 30 firms surveyed in 2005, 17 of which were in Bangalore, this author found no evidence of inter-firm collaboration (Survey carried out in February and March 2005).

companies (Basant 2003). Intense competition is evident from the secrecy maintained by firms when discussing projects and clients (see Prabhu 1999: 504). This has been true for small electronic and engineering firms in Bangalore as well, where mutual suspicion among entrepreneurs has overshadowed cooperative ventures (Holmström 1998: 225). Social trust is still weak in India and hence cooperation among IT firms remains limited.[17] A recent study observes that:

"[C]ooperative relations do not – to any significant degree – extend beyond limited complexity including information networks. We have not been able to identify e.g. research consortia among local firms, the use of common components in the (sic) software production, nor are there high complexity cooperation through joint R&D or joint product development. Hence, cooperative relations between firms can hardly be characterised as enduring and intense...The cluster is not characterised by cooperation alongside competition, but rather by competition alone...[A] central feature of the software cluster in Bangalore is that firms are not – to any significant degree – linked by input-output relations (Lema and Hesbjerg 2003: 142).

Lack of trust is reinforced by the business model that facilitates the compartmentalization of off-shore development of software projects. This division of projects structurally inhibits inter-firm cooperation, constrains project capabilities, and restricts joint-coordination of activities (Lema and Hesbjerg 2003: 137-143). For example, a foreign client may outsource two components of the same project from two Indian firms but the Indian firms operate completely independent of each other. They do not know what the component is for, how it might integrate with other software components, and do not have the technological understanding of the larger project to which they are contributing. Of course this could be a strategy by the client to protect key technologies. However, the result is that the systems integrator, typically the client or a consultant, has the knowledge of diverse domains rather than the individual Indian component suppliers. This can act as a systemic barrier to moving up the value chain. So even if Indian firms have mastered the production of

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[17]For example, some large, successful Indian firms in the Japanese market went even to the extent of refusing to sell a successful product made by another Indian company in the Japanese market (Lema and Hesbjerg 2003: 140).

components of complex software projects, they find moving to project architecture daunting. The lack of trust translates into a strategy of capturing whatever projects come by and a growth strategy based on employment growth and talent poaching (see Kumar and Joseph 2005: 100).

The undifferentiated nature of most Indian software firms induces severe competition.[18] As a result there is high labor turnover with more than 20% labor turnover (Athreye 2005: 20-23) and a wage-cost spiral based on high IT compensation growth averaging 30% per annum throughout the 1990s, poaching of talent by large firms, and curiously, labor shortages in certain areas.[19] However, tight labor markets also compel productivity growth for the industry. Rising salaries lead to greater enrolments in technical education, subsequent investment in educational infrastructure, and further growth of the industry.

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[18]This was confirmed through interviews of over 70 firms, carried out in several Indian cities in 1998, 1999, and 2005.

[19]Large Indian firms are also responding to rising costs by investing in lower-cost countries such as China.

A recent survey shows that IT salary hikes exceeded 18% over the 2004-05 period and the top three paymasters were all multinationals (Cadence Design, Sun Microsystems, and Philips), while the top 20 had five multinationals (Arora 2005). On the surface, this is a good development as higher revenues are shared among greater number of employers and employees. With international opportunities for students and software professionals, there is an outflow of technical talent and pressure on local wages.[20] There is also internal brain drain as engineers and other professionals exit non-IT sectors to join the more lucrative IT sector (Arora and Athreye 2002: 266). But as costs rise in Bangalore, other lower-cost locations in eastern India such as Kolkata (formerly Calcutta) and Bhuvaneswar (capital of Orissa state) become attractive. This is a welcome development if deconcentration of urban centers and the diffusion of economic activities are intended. However, this is very much in line with extensive growth, meaning a repetition and a geographical dispersion of more or less similar activities. Such dispersion can also prematurely end the agglomeration economies, which Bangalore selectively enjoys.

Such wage pressures have been felt even in the IT-enabled services (ITES) segment, which consists mainly of call centers and back office processing. A recent report warns that India's advantage in ITES could be eroded by wage inflation, which is higher than in the US (Siliconindia.com 2005a). Wages have gone up from $114-136 a month to $159-204 a month, an increase of 40-50% in four years (Siliconindia.com 2005b). Rising costs could no doubt compel firms to pass some of the costs on to the client or force them to move up the value chain. The very rationale for foreign clients to reduce costs through outsourcing is undermined. Moving into technologically challenging markets, among other things, requires a fundamental realignment of the business model and an array of institutional linkages, including UILs. The warning that India's cost advantage in ITES could be challenged by other lower-cost countries such as Vietnam, Eastern European nations, and the Philippines illustrates the predicaments of low-end service provision (Siliconindia.com 2005c). The growth of the ITES sector in effect works against the anticipated

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[20]The issues surrounding brain drain and return migration are discussed in D'Costa (2005).

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inter-institutional architecture for high technology growth associated with an evolving triple helix system.

3.3 Other Challenges to Innovation

High turnover suggests inter-firm mobility of labor in an industrial cluster, leading to technology transfers and learning spillovers. But the compartmentalization of IT projects, with subcontractors responsible for a component or two of the entire project, and high labor attrition does not make knowledge transfer easy. An alternative interpretation suggests that high labor turnover could be detrimental to skill development and project completion, if there is a scarcity of particular skill sets. For example, highly talented engineers conversant in Japanese are still limited in India and a professional with such skills leaving an organization can create uncertainty. There is anecdotal evidence of firms having to scramble for certain skills because of sudden employee resignations (Field Research, Japan, May-June 2005). As long as there is a steady supply of raw talent, extensive growth can continue and hence high labor turnover can be accommodated by the industry. This is the likely scenario in the absence of major UILs. The problem arises when either the quality of engineers suffers due to unregulated growth in educational institutions or when external demand slows due to erosion of competitiveness. There are signs of both. Training institutes and private colleges have mushroomed in India, churning out ill-prepared students (see Basant, this issue).

Extensive growth deepens domain expertise in a limited way as user feedback is constrained (D'Costa 2004b, Parthasarathy 2004). The modular type of production undertaken by Indian producers limits the understanding of "kernel" technologies associated with high technologies and subsequently to an inability (real or perceived) to carry out systems integration.[21] Nor does the model provide the incentive to serve the domestic market, which in effect is priced out by foreign clients. Export revenues also discourage development of software products locally, which could be

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tested locally and further refined for subsequent export at higher returns. The current incentives not only encourage service exports but also discourage software product and hardware development (D'Costa 2004a). This decoupling can be argued to constrain technological learning of the Indian IT industry. The result is a form of disembeddedness in which local institutions operate as enclaves. Even multinational subsidiaries undertaking high-tech R&D in Bangalore operate as enclaves (Arogyaswamy n.d.). They have no local ties other than the professionals they hire, often poaching talent from financially less-endowed Indian firms. Confidentiality requirements discourage subcontracting to local firms. They report to directly to their parent R&D unit, and continue to remain captive markets for R&D output (D'Costa 2002a, Parthasarathy 2004). The insular security-conscious defense-related R&D public sector also operates as an enclave with respect to the commercial market.

IV. *Transitioning to Intensive Growth*

Given the structural constraints of the business model adopted by the Indian IT industry, the question is how to break out of the extensive growth trajectory. The significance of UILs in innovation and the knowledge-driven economy suggests a more robust alliance between universities and industry. There are already some UILs in India such as NIIT's cognitive research center located at the Indian Institute of Technology in Delhi. Up to this point most UILs have been confined to pharmaceutical and chemical industries (see Mani 2004: 858). The Indian Institute of Science has 22 projects with eight universities, seven colleges, and seven national research institutions in aerospace, IT, defense, and space research (Vijayakumar 2005). Similarly, the Society for Innovation and Development located at IISc has university-industry programs in numerous R&D areas (www.sid.iisc.ernet.in 2005). Other explicit UILs have been created between IISc and foreign and domestic companies such as Nortel, Motorola, BPL, and Satyam. The Indian Institute of

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[21]This has been the strategy of Taiwanese IT firms outsourcing R&D services from China (Lu and Liu 2004: 460-462). This is no different from the asymmetrical relationship between Silicon Valley and India, which entails "value chain modularity" (see Sturgeon 2003: 204).

Technology in Chennai successfully implemented UILs, with faculty members forming a new IC design company and teaming up with Analog Devices of the US to manufacture chips (Basant 2003). Former IIT faculty and its engineering doctorates are also working in a handful of firms such as Sasken and Softjin, which develop complex embedded systems for the Japanese telecom market (Field Research, Bangalore, February 2005). However, the number of projects is low, often ad hoc, and confined to a handful of research universities and technical institutes and their collaborations tend to be mostly with foreign firms. Again, intrinsically this is not detrimental to building knowledge capabilities if there are sufficient spill-overs from such activities rather than enclave type research activities (see Parthasarathy 2000; D'Costa 2002a). Weak UILs are in part due to India's weak, albeit improving manufacturing capability for complex IT products such as semiconductors and a wide variety of third generation telecom products. New lines of IT hardware and embedded software comprise the future of the IT industry. Most Indian IT firms for both market and technical reasons are not seriously engaged with this segment.

Rather than strictly argue in favor of fostering UILs, given the incentive structure of the current model of off-shore based software service exports to the US market, I suggest an intermediate set of approaches to support a potentially intensive form of growth. This involves reorienting the export business model by addressing the interrelated areas of domestic market needs, export market diversification, and expatriate talent. However, to adequately to meet these challenges the role of universities cannot be ignored since technical education, improving the research environment, and anticipating new technologies are integral to innovative capabilities.

4.1 Developing the Domestic Market

India is weak in product development. Low level IT diffusion constrains the development of local software products (Kambhampati 2002). While costs for international marketing are prohibitive, software products for the home market can be used a stepping stone to sell abroad. Several India-made products are available in banking, finance, and software tools. There is good potential for software products in vernacular languages as evidenced by HCL Infosytems' unicode-compatible PCs to support seven Indian languages. Another area of software use is explicitly for

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development purposes for providing critical government services. Here again, India has a better record than most developing countries but India needs to bolster software use even more for wider impact (Kaushik 2006, Thomas 2006). Also, the recent efforts by Indian firms such as Encore Software and the Indian Institute of Science have led to the development of an indigenous, low cost computer called "Simputer." Relying on the open source Linux operating system, the Simputer promises to be a good alternative to relatively expensive foreign products (Jayaraman 2002b:359, Personal Interview, Encore, Bangalore, February 2005). Already the affordable Simputer is being marketed to other developing countries in Asia and Africa. Due to export controls, Indian research institutions have developed alternatives to supercomputers made by US firms. These are good examples of software and hardware application for low-income countries, complementing and diversifying export markets.

4.2 Diversifying Export Markets

The Indian IT industry depends heavily on the US. Consequently, some of the technologically more challenging markets are not served by Indian firms. Japan is a case in point. NASSCOM estimates that of the nearly $10 billion software service exports by India in 2002-03 only 2% went to Japan, whereas nearly two-thirds went to the US (D'Costa 2004c: 17). Poorer regions of the world imported more software services from India than Japan.[22] Among all the regions Japan had the lowest dependency ratio, which suggests India's penetration of the Japanese market is extremely low. While there are institutional and business reasons for India's limited participation, the opportunities are immense in the Japanese market.[23] Japan is the second largest IT market and is known for design and embedded software, areas which the Indian industry is only

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[22]The relative dependency ratio, computed by taking the share of Indian exports to Japan (2%) and divided by the region's share in world IT services spending ($34.9 billion/$349.1 billion), was 0.2.

[23]The highly competitive Japanese hardware producers have always bundled their software, hence the development of an independent software industry in Japan has been discouraged (Anchordoguy 2000). However, this development also suggests that the Japanese are strong in hardware-intensive software development, which for technical reasons has its own entry barriers.

beginning to develop. The high-growth East Asian economies, including China, with their vast high-technology manufacturing base, offer new markets for the Indian IT industry.

There are many intermediate products such as bluetooth software applications and telecom-related hardware that could be sold as intellectual property by Indian firms to foreign manufacturers. Such domain expertise requires advanced university technical training, project-specific learning, and market exposure. The first calls for revamping the engineering curriculum, especially in microelectronics; the second demands domain expertise (Basant 2003). A few Indian firms such as Mindtree Consulting, Sasken Communications, and Interra Systems are engaged in such activities for Japanese clients, where the market for embedded systems and technology-related software IP is large. These are lucrative projects even if the projects tend to be small (Field Research, February-March, India; May-June, Japan 2005). The global market for such services is growing rapidly, particularly in East Asia. Hence, it is in India's interest to tap the under-served products market by creating high caliber engineering talent capable of design, development, and implementation of complex projects. Japan, Taiwan, and China are behind in software development and hence offer new opportunities for the Indian industry. But to serve these markets leading firms will have to make UILs a central strategy.

4.3 Anticipating New Technologies and Markets

In the related area of market diversification, the direction of the Japanese IT market is instructive. In 2001, the Japanese Ministry of Economy, Trade, and Industry (METI) launched the Industrial Cluster Project, with 30 local governments proposing Knowledge Cluster Plans (Interview, Kitakyushu Science Research Park, June 2005). Later, ten clusters were finalized in eighteen areas (Ministry of Education, Culture, Sports, Science and Technology (MEXT) 2004). These represent increasing specialization of knowledge, science intensity, and aggressive R&D efforts (MEXT 2004: 43-44).[24]   Hence, it is not surprising to see six educational institutions,

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[24]These included embedded systems, intelligent electronics (high precision controls, wireless networks), bioelectronics (multifunctional chip devices, nanotech materials), smart devices (nano carbon composites, organic nano

including Kyushu Institute of Technology, Waseda and Cranfield Universities siting their engineering training programs in Kitakyushu Park along with semiconductor design and manufacturing firms.[25] The lesson for the Indian industry is to explore these technological options, given anticipated labor shortages in Japan and the increasing technological demands of future industries.

4.4 Attracting Expatriate Talent

To tap Indian talent from abroad, even on a temporary basis, both professional opportunities and high quality urban amenities are necessary. India has to compete with rich countries to attract its own talent. Recently the UK government announced plans to retain Indians in the UK (Siliconconindia.com 2005d). While matching US salaries in India would be difficult, a high investment environment consistent with high macroeconomic growth would be the necessary first step. Taiwanese engineers returned on a large scale only after two decades of significant growth and structural change (Saxenian 2004: 171). Taiwan had the luxury of gradual evolution and considerable diversification of the semiconductor and electronics manufacturing industries entailing large investments, dense intersectoral linkages, and thickening of local institutions. Bangalore is banking its growth and development on the far less capital and R&D intensive, service-driven IT export model based on thin institutional arrangements. The select return of Indian expatriate talent is good for local production, especially if they encourage the inflows of venture capital (Dossani and Kenney 2002). However, often enough they, too, subscribe to the off-shore development model, reinforcing extensive growth.

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materials), super visual imaging (medical, solid state), system LSI design (design methods, architectures, EDA technology), SoC technology (IP and design technology, sensor networks).

[25]I am grateful to Shoichi Yamashita of International Centre for South East Asian Development for introducing me to Takao Kageyama, Project Director of Kitakyushu Park.

Some progress beyond extensive growth has been made with increased R&D by multinationals, the promotion of Bangalore as a biotechnology hub, and a shift toward development of embedded systems (UNCTAD 2005, UNCTAD 2001, NASSCOM 2002a, Reddy 1997). Bangalore now hosts about 70 firms engaged in embedded software (Personal Interview, STPI, Bangalore February 2005). There are also reports about university initiatives in setting up joint projects, fellowship programs, and establishing endowed chairs. This evolution is consistent with India's better patent record in chemicals and pharmaceuticals and the availability of more doctorates than in IT. Thus the challenge for Bangalore is to go beyond writing algorithms and more toward science and technology based knowledge developed.

It is too early to tell if recent manufacturing plans in India by Nokia, Samsung, and other major telecom and electronics manufacturers is the beginning of a major knowledge-intensive innovative thrust. Thus far the Indian IT industry is decoupled from the hardware industry (D'Costa 2004a, Kumar and Joseph 2005). The Indian firm TCS intends to move from design to fabrication of semiconductor chips, which is novel since it has been usually the other way around, with software following hardware development (Kash, Augur, and Li 2004: 789, 795). It is a welcome development, given India's lack of chip fabrication plants. But it is imperative to forge appropriate institutional links with universities and public research institutions since semiconductor production is complex and capital-intensive as the Japanese efforts indicate. Such manufacturing activities could be a harbinger of high-end research, which could retain and attract expatriate talent as well.[26]

The Taiwanese experience offers some lessons. Like their Indian counterparts, Taiwanese students went to the US to study engineering and sciences. Most stayed, but the rate of return increased from 11% in the 1970s to over 25% by the mid-1990s (Chang 1999: 82-83). The government offered returning Taiwanese talent travel subsidies, job placement, opportunities for

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[26]There is some anecdotal evidence of engineering students trained in complex subjects being lured away by commercially-driven firms working on less challenging assignments (Personal Interview, Indian Space Research Organization, Bangalore, July 1998).

year-long research jobs before permanent employment, appointments for expatriate professionals in research and academic institutions at attractive salaries, and housing and schooling facilities (Chang 1999: 70-75, Mathews and Cho 2000: 191-192). Those who did not return nevertheless became integral to networks that linked Taiwan to Silicon Valley through the circular movement of Taiwanese techno-entrepreneurs (Saxenian 2004: 270, Dicken 2003: 414, Breznitz 2005: 167). Return migration has been facilitated by the systematic support of the state for private-sector initiatives in the electronics and semiconductor industries. The state's establishment of the Industrial Technology Research Institute (ITRI) in the 1970s for semiconductor research and the Hsinchu Science-based Industry Park in the 1980s encouraged expatriate talent (Castells 2003: 269). Today the government subsidizes private investments through equity participation in high technology companies in the science park and more public-private partnerships for basic research on fundamental technologies, nanotechnology, and digital signal processing (Dicken 2003: 186, Mathews and Cho 2000: 194).

V. Conclusion

Bangalore's evolution as a high-technology cluster is a mixed story. The success of Bangalore is readily recognized in terms of the growth of the software industry and the responsiveness of the state and educational institutions. However, several challenges remain to transition from extensive to intensive growth. The industry as a whole needs to reorient the business model and establish thick institutional linkages. The current incentive structure does not encourage creating UILs at this time. Nevertheless the intermediate steps that leverage an elastic supply of IT workers suggest diversifying India's IT markets by focusing on both the domestic and East Asian markets. Attracting expatriate talent is integral to this strategy, as they are likely to have an

advanced technical degree from abroad and richer market and R&D exposure.[27] If successful, these measures are likely to incrementally induce intensive growth and possibly more robust UILs.

Bangalore is a good illustration of a developing country's success story pushed by its history and local and national institutions. It is also a warning of the structural challenges faced in overcoming technological and market barriers in the world economy. Developing countries can learn a number of lessons from Bangalore's experience. First, in a knowledge-driven economy technical education in emerging industries is critical. Both public and private parties can be involved and collaboration between the industry and public educational institutions is important. Second, Bangalore's high growth illustrates a cumulative outcome of history, changing business strategies, and global (mainly US) demand. Third, rapid growth could lead to increased enrolments and lower quality of applied technical education and push some firms to upgrade their activities. Fourth, the retention and return of expatriate talent can assist in intensive growth. Small countries are likely to find this daunting unless offset by sustained high macroeconomic growth. India stands a good chance of creating the incentives for investments and the return of expatriates. The final lesson is that Bangalore offers a cautionary tale about rapid growth of a narrow sector that requires high skills, which might detract from more fundamental needs of development such as basic education, health, and infrastructure. The economic and social polarization resulting from Bangalore's growth may not be politically sustainable. A strategy of domestic inclusive development, combined with a long-term national innovation policy for sectoral upgrading and export market diversification, will go a long way toward ensuring Bangalore develops a dynamic competitive edge and does not become merely an appendage to Silicon Valley's appetite for low-cost services.

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[27]Of course the physical quality of life in Bangalore must be improved drastically if it is to attract and retain talent. It took the author more than an hour travelling from the city center to Electronics City, which was 12 km away (Bangalore, February 2005). Urban congestion, unreliable electric supply, pollution, ageing airport, and skyrocketing real estate prices are the norm (Fannin 2004).

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Table 1: The Growing Supply of IT Professionals in Karnataka State

		Engineering Colleges B-Tech			Diploma Colleges	
	Engineering Colleges	Intake in IT-related Courses	% of Total Intake	Diploma Colleges	Intake in IT-related Courses	% of Total Intake
1980 -81	41	-	-	44	-	-
1981 -82	42	25	0.3	46	-	-
1986 -87	50	1,240	8.4	150	n/a	n/a
1991 -92	51	2,020	2.1	165	2,364	10.3
1996 -97	53	2,758	14.1	178	4,379	15.2
1997 -98	70	4,028	16.9	196	5,682	17.8
1998 -99	71	4,190	17.0	184	5,585	17.1
1999 -2000	106	5,802	22.0	186	6,120	18.0
2000 -01	109	11,565	34.5	201	n/a	n/a

Source: Government of Karnataka in Okada (2004: 299).

n/a = not available

Table 2: Forecast of Global IT Services and India's Opportunities

	Global Market (2001)		Global Market (2005)		India's Exports (2001, US $ b)	India's Global Share (2001, %)	Potential for Exports
	US $ b	% Share	US $ b	% Share			
Professional Services	142.9	32.5	238.7	34.1	5.3	3.7	
IT Consulting	21.3	4.8	31.5	4.5	0.1	0.3	Low-Medium
Systems Integration	81.1	18.4	142.1	20.3	0.1	0.1	Low-Medium
Custom Applications	19.3	4.4	25.3	3.6	4.5	23.1	High
Network Consulting & Integration	21.2	4.8	39.8	5.7	0.7	3.3	Low
Product Services	117.9	26.8	176.9	25.3	0.4	0.3	
IT Training & Education	25.5	5.8	40.9	5.8	-		High
H/W Support & Installation	44.4	10.1	49.4	7.1	-		Low
Packaged Software Support Services	48.0	10.9	86.6	12.4	0.4	0.7	Medium-High
Outsourcing Services	179.2	40.7	284.8	40.7	0.1	0.0	
Processing Services	78.4	17.8	103.8	14.8	-		High
IS Outsourcing	64.0	14.5	100.2	14.3	-		High
Application Outsourcing	13.4	3.0	39.0	5.6	-		Low-Medium
Network Infrastructure Management	23.4	5.3	41.8	6.0	0.1	0.3	Medium-High
Total	440.0	100.0	700.4	100.0	5.7	1.3	

Source: Calculated from NASSCOM 2002: 24, 46 in D'Costa 2004a.

Notes: IT=information technology; IS=information services; H/W=hardware

- not available or not applicable