The Globalization of the Software Industry: Perspectives and Opportunities for Developed and Developing Countries

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1. Introduction

One rather unexpected phenomenon of the 1990s has been the spectacular growth of the software industry in some non-G7 economies. The first element of surprise is that these are not countries where one would expect to see the growth of a human-capital intensive industry. In fact, in some of these economies the software industry is not properly high-tech like in the leading areas of the advanced world. Yet, it is definitely human-capital intensive. The second element is that what the 1990s have shown is not just growth of the industry, but a remarkable growth. In India, for example, software production was virtually non-existent in the early 1980s. Today software employs more than 450,000 employees, sustaining annual growth rates of 30-40% in revenues and employment over more than 10 years. Although less remarkable than India, similar two-digit growth has characterized other non-G7 countries like Ireland or Israel, as well as China and Brazil more recently.

This paper addresses two sets of inter-related issues. First, we explore the determinants of these successful stories. We then touch upon the broader question of what lessons, if any, can be drawn from for economic development more generally. Second, the Indian, Irish and Israeli software industries export a substantial fraction of their output (and services) to advanced economies – particularly the U.S. There is a major debate in the U.S. regarding the desirability of outsourcing, which along the familiar "free trade versus jobs" lines. Rather than join this debate, we prefer to focus on a related one, which arguably is of greater long term significance. Specifically we ask whether the growth of the software industry in emerging economies is beneficial for the U.S., and what it means for the technological leadership of the U.S. in the longer term.

In the next Section we discuss the growth of the software industry in five newcomer regions – India, Ireland, Israel, Brazil and China. This is based on the results of a two-year international project that led to a forthcoming volume that we are editing on this topic (Arora and Gambardella, 2005). The five comparisons provide an interesting basis for our discussion because while the growth of India, Ireland and Israel has been fuelled by exports, China and Brazil have grown largely thanks to their domestic market. From the evidence collected for these countries we discuss some of the reasons why they have been successful in software. Among the others, we highlight the growing supply of human capital that faced lower opportunity costs than in the more advanced countries. This has encouraged entrepreneurship as opposed to seeking jobs in established industries and firms. At the same time, the three export-driven countries have been able to take advantage of the growth of demand for software in the advanced world, and especially in the U.S. India, in particular, has specialized in software activities that complement those of U.S. software firms instead of competing with them, and hence could take advantage, rather than competing, with the growth of information technology (IT) in Europe and the U.S.

In Section 3 we discuss some of the implications of this growing international division of labor for the U.S. economy, and in particular, we examine whether this implies growth in software productivity levels in countries like India. Section 4 takes the Indian point of view. We ask whether and how this process is beneficial to India. Apart from the obvious benefits of having a more productive domestic industry, there is one effect in particular that has to be assessed more carefully, and this is the large outflow of human capital from India. We discuss the pros and cons of these flows for both India and the U.S.

Section 5 discusses whether the patterns of growth of software in our five countries can provide lessons for other emerging economies, in software or in the IT industries more generally. In particular, we note that there these countries were especially well suited for taking up these opportunities. Yet, there are also some exportable lessons, which we highlight. The concluding section then speculates on whether this is a new model for economic development.

2 The Software Industry in Some Newcomer Countries: India, Ireland, Israel, Brazil, and China[1]

2.1 Size and Growth of the Industry

During the 1990s India, Ireland and Israel have emerged as significant software exporters. In the same period, Brazil and China also have developed an extensive software sector relying largely on the domestic market, and are now attempting to move to exports.[2] As Table 1 shows, the software industries of our five countries are comparable in size. In 2002 the Irish industry reached $13.9 billion in total sales, of which $12.3 billion was due to multinational companies and $1.6 billion to indigenous companies. The 2002 sales of the Indian and Chinese industries were respectively $12.5 and $13.3 billions, while the 2001 sales of Brazil and Israel were $7.7 and $4.1 billions.

TABLE 1 ABOUT HERE

These figures mask the diverse nature of these sales. For example, the Irish multinational sales are inflated by accounting devices guided by the substantial tax concessions offered by Ireland. While multinationals in Ireland have employment levels comparable to that of the

[1] The data shown in this section are from Arora and Gambardella (2005), and specifically many of them come from the chapters of the book that we edited. Below we will cite the specific chapters whenever relevant.
[2] There are other non G-7 countries with large and vibrant software industries. However, none have captured the public imagination in the way that the three Is have. The inclusion of China and Brazil is mostly because these are two large economies whose software strategy is apparently to "walk on two legs" instead of purely the export leg.

indigenous firms (15,300 and 12,600 respectively in 2002), their sales are over 8 times as much. Since multinationals mostly localize their products in Ireland not design them, this gap must mostly arise from accounting, not superior value added. A more plausible estimate of the true size of the Irish software industry would therefore put it closer to the other four.

There are wide differences in the employment base across these countries as well. Employment in the Indian software industry is estimated to be around 250,000 in March 2003.[3] The 2000 figures for China and Brazil are respectively about 160,000 and 190,000. As noted, the 2002 employment in the Irish software industry was about 28,000, while the 2001 employment of the Israeli industry was about 15,000.[4]

Of course, this produces notable differences in the sales per employee. The revenues per employee of the Israeli software industry has increased significantly over the 1990s, reaching over $270,000 in 2001, though the number has fallen since then. Revenue per employee for the Irish multinationals is far higher (about $800,000), although this largely reflects the accounting artifact that we mentioned above. A more comparable figure is the one of the Irish domestic firms. The revenue per employee of the domestic software firms in Ireland have also increased in the 1990s, from slightly over $45,000 to over $120,000 in 2002. The revenue per employee of the Indian industry in 2000 was about $35,000. The ratio between the 2000 sales figures for Brazil and China (7.2 and 7.0 billions) and the employment figures for 2000 reported above, produces sales per employee equal to $45,500 and $37,600 respectively, or about the same level

[3] This excludes what NASSCOM calls IT enabled services, such as call centers and help desk operations, which employ 160,000. Another 260,000 software professionals are estimated to work in what NASSCOM calls user organizations.

[4] To put these figures in perspective, employment in the U.S. software industry was slightly above 1 million, with sales of around $200 billion, while the comparable figures for Japan were 534,000 and $85 billion. Germany, the third largest software producer had employment of around 300,000 and sales of around $40 billion. It is likely that in these countries, the true size of software production is higher since a large number of firms not in the software business, such telecommunications, banking and finance, and large retail and banking firms produce significant amounts of software for their internal use.

as India. The picture that emerges from these figures is fairly clear. The Israeli software industry is largely product- and R&D-oriented. The domestic software industry in Ireland, Brazil and China is in between, while the Indian industry tends to be very heavily service oriented.

In all our countries but China total software sales over GDP is generally higher than 1.5% (Arora and Gambardella, 2005). This is close to the U.S., Germany, and Japan; it is higher than the U.K., and it is comparable to the figure for the G7 group of countries as a whole. The ratio of total Chinese software sales to GDP is around 0.6%. However, software is likely to emerge as a leading industry in China in the near future because of its central role in the 10th Five Year Plan (Tschang and Xue, 2005). Moreover, in all five countries, including China, software ranks high when compared to their overall level of development. Botelho *et al* (2005) compute the ratio between the ratio of software sales to GDP and the GDP per capita of the country, taken as a measure of its development. In our five countries these ratios are far higher than the U.S., Germany, Japan, and the U.K.

But the most impressive figures about the software industry in these emerging economies are their growth rates. The Indian software industry grew from a tiny level to slightly more than $0.5 billion in 1993 to $12.5 billions in 2002. This corresponds to an average growth rate of over 40% a year. In turn, this has made software one of the leading employers in all of the Indian industry in just a decade. Israel, Ireland and Brazil also grew at around 20% a year during the 1990s, while double digit growth is only a recent phenomenon in China. Sales growth has been accompanied by a growth in the number of firms, although in each of the 3*I*s, the leading firms have grown in size as well. For example, in India, the membership of NASSCOM increased from around 100 in 1990 to 797 in 2000 (Athreye, 2004). Similarly, Sands (2005)

reports that in Ireland the number of new software firms increased from less than 300 in 1991 to 760 in 2000. Botelho *et al* (2005) report the history of firm creation for a sample of 685 Brazilian software firms that were in existence in 2001 and find that 210 (a little less than a third) were founded between 1996 and 2000, and a slightly larger fraction, 221, were founded between 1991 and 1995.[5]

2.2 Exports

Our five countries exhibit notable differences in their shares of exports over total sales. There is a first order distinction between the 3Is on the one hand, and Brazil and China on the other. The former group of countries has high export shares: 70% for Israel in 2001, almost 80% for India in 2002, and 85% for the domestic Irish industry in the same year.[6] By contrast, exports account for about only 1.2% of total Brazilian software sales in 2001, and about 5% of the total Chinese sales.

Even among the 3Is there are differences. Figure 1 portrays the trends in the export share of the Indian, Israeli, and Irish-domestic software industry since the early 1990s. It clearly shows that although the export shares for the three are converging in the late 90s, the starting points differ greatly. In the Indian software industry exports were a large share of sales from the early 1990s. In 1993, the first year for which Athreye (2005) reports export and total sales data, the share was 59%, whilst in 1991 it was 41% for the domestic Irish industry and 20% for the Israeli industry. As Breznitz (2005) notes, the Israeli industry was catalyzed by domestic demand and became an international player only later on. Although the leading Irish firms have

[5] There are no specific figures for the creation of new software firms in China or Israel. However, the existing scattered accounts support the idea of high rates of entry into the software industry in both countries.
[6] As shown in Sands (2005), the software multinationals in Ireland exported 95% of their sales in 2002, and this percentage has been largely above 90% since 1991.

been export oriented from the beginning, the growth of the Irish industries owes a great deal to the activities of MNCs who located a variety of software operations in Ireland.

FIGURE 1 ABOUT HERE

Not only have exports been the main driver of the Indian software industry, but they also have provided the initial push. This impetus initially took the form of the on-site model, in which the Indian firms (and many U.S. based firms as well) literally rented out software programmers to work at the client's site and under the client's management. India based firms enjoyed a clear cost advantage over their U.S. based rivals in the lower end of software services, and did not compete directly with market leaders such as EDS, Computer Science Corporation, Anderson Consulting (now Accenture) and IBM. With booming demand, Indian firms had the opportunity to learn how to manage relatively large projects. Euro conversion projects and Y2K projects were well suited for the kind of competences and skills that the Indian software industry had by then developed.

The domestic Irish industry shows a less pronounced initial dependence on exports. Sands (2005) argues that multinationals were an early source of demand for the domestic software firms. As also discussed in Arora, Gambardella, and Torrisi (2004), many successful Irish software firms started as programming houses for the subsidiaries of the multinationals in the information technology (IT) sector, or as software application developers for other non-IT firms, whether Irish or foreign-owned. Interviews with several Irish software firms indicated that they saw the multinationals both as a source of revenue and as providers of access to foreign markets.

Of the 3Is*,* Israel relied the least on the export market at the outset of its software industry. Breznitz (2005) argues that "the rapid expansion of defense R&D and the fast

accumulation of IT skills by both university graduates and graduates of the military technological units created both local demand for IT usage, the knowledge base to supply it, and a positive attitude toward this nascent industry." In addition, the Israeli software industry sits on the shoulders of a giant. It is linked to the sizable Israeli IT hardware industry (55,000 employees in 2002), a source of both demand and learning.

2.3 Domestic market

Banking and telecommunications, along with customer electronics and retail automation, are the principal sources of domestic demand in China. Of course, the government is another big player, with national and regional governments often favoring domestic vendors for a variety of PC based software, from the operating system to application software.[7]

Brazil has an uncommonly high share of IT expenditures on GDP. World Bank data cited by Botelho *et al* (2005) indicate that in 2000 Brazil spent 8.3% of its GDP on IT. This compares to 7.9% in the U.S., 7.4% for Israel, 5.7% for China, and only 3.9% for India. The Brazil figure stands out when compared to its neighbors Mexico (3.2%) and Argentina (4.0%). Lead users such as banks have been central to the growth of the Brazilian software industry. Similarly, the telecom industry pushed the demand for communication software (e.g. the growth in the demand for cell phones). Public sector demand, exemplified by the installation of an electronic voting system, also helped. Botelho *et al* (2005) note that in the Brazilian case large government procurement contracts were acquired by domestic companies. They see this as evidence of the increased competitiveness of the national firms, though a sceptical observer might wonder about the possible biases towards domestic firms.

[7] For example, Saxenian (2003) reports that the Beijing municipal government and the Guangdong provincial government recently required that all their departments used a Chinese language office software package, WPS2000, rather Microsoft Office2000, in spite of its lower technical quality.

The focus on the domestic market has many characteristics that are common to the software industries of Brazil and China. The first is the relatively small size of even the leading firms. Another striking aspect is the broad range of activities and firm types. In the 3Is, software firms are easy to characterize. In India, they are software services firms; in Ireland, they are product firms and in Israel, they are technology firms. China has them all, from systems integrators to custom software developers to firms developing operating systems for hand-held computers. Similarly, though the leading Brazilian firms have naturally focused on banking and telecommunications, Brazilian firms develop ERP systems and a number of them provide software services and systems integration services. A related characteristic is that the leading firms in Brazil and China are often heavily diversified. Once again, this is only to be expected because firms attempt to maximize the return from what they perceive to be their major asset, namely preferential access to domestic buyers.

2.4 Human Capital and the Supply of Skills

One regularity among the 3Is is that they exhibited an "excess" supply of human capital in the 1980s and early 1990s, and specifically, an excess supply of engineering and technology graduates. The 3Is are not the countries with the largest proportion or even number of science and engineering graduates. Rather, the excess supply was relative to the demand from manufacturing and related services. Simply put, the 3Is have produced more engineers than their hitherto lackluster industrial sector could absorb.[8] This is particularly relevant from about the mid 1970s up until the mid to late 1980s. During this time, these countries grew only modestly,

[8] In the Israeli case, the economic crisis in early 1980s and with the growing military alliance with the U.S. after the 1973 war led to a significant downsizing in the defense industry, the most notable instance of it being decision to stop the development of the latest fighter-jet ("The Lavi"). The result was that thousands of highly trained and experienced engineers became available. Breznitz (2005) also notes that generous redundancy packages became seed capital for many of these would be entrepreneurs.

while continuing to invest in science and engineering. Indeed, the average growth rate of GDP per capita for India between 1970 and 1990 was barely 2% per annum, while both Israel and Ireland managed to grow at 2.4% and 2.9% respectively. In all three cases, however, this performance is lower than the performance of peer countries. Moreover, it masks the large decadal variation. In India, the 1970s were a period of very low growth, while the 1980s could be called the lost decade for both Israel and Ireland, a feature is which also reflected in the migration patterns to the United States, as discussed in section 4 below as well.[9]

In the more advanced countries and the rapidly growing Asian countries such as South Korea, Taiwan and Singapore, the science and engineering graduates faced a high opportunity cost of working in the software sector. Plentiful job opportunities in industry, in well established firms with good opportunities, mean that there would be fewer entrepreneurs setting up software firms, and nascent software firms would find it difficult to attract talented engineers.

Why the 3Is were abundant in technically skilled workers is not well understood, but there is no doubt that having such abundance was crucial for software success. There are two issues here. The first one has to do with the level of supply of the relevant human capital. The other issue is about the elasticity of the supply of graduates in the countries that we are studying. The education institutions in all five countries have responded with sizable increases in the number of graduates as the demand for their services rose over the 1990s.

Accredited engineering capacity in India increased from around 60,000 in 1987-88 to around 340,000 in 2003, and IT capacity as increased from around 25,000 to nearly 250,000. It is likely, however, that actual number of IT admissions increased more slowly and the number of

[9] A regression of the stock of scientists and engineers on per capital GDP and other factors (not reported here) showed that the 3 I countries all had actual stocks that were higher than the predicted stocks of scientists and engineers.

IT graduates increased even more slowly. NASSCOM figures indicate that in India the number of number of IT graduates increased from 42,800 in 1997 to 71,000 in 2001. By comparison, the number of IT graduates in the U.S. increased from 37,000 in 1998 to 52,900 in 2000. During this period the IT workforce (which does not directly correspond to IT degree holders) in the U.S. was probably five or six fold larger than the IT workforce in India. Thus, though the increases are comparable, in proportionate terms, they are much more significant in India.

Other countries report a similar pattern. Tschang and Xue (2005) report that in China the number of IT graduates increased from 29,000 to 41,000 in 1999-2001. Botelho *et al* (2005) note that the 18,000 graduates in IT in Brazil in 2000 implies a greater per capita number than China and India. OECD figures show that in 2001 the share of Irish population between 25-64 with academic degrees was 14%, up from 11% in 1999 (OECD, 2002 and 2001). For people between 25-34 this percentage was 20% in 2001 *vs* 16% in 1999.[10] More recent data indicate that Ireland, with 34,000 graduates per year, now has the third highest share of adult population with tertiary degrees (30% of which are in science and technology), after Canada and the U.S.

Such increases were accomplished through a mix of private and public efforts, with the mix varying across countries. In Israel and China, the bulk of the efforts were probably in the public sector. Table 2 shows that Ireland differs markedly from comparable European countries such as Greece and Portugal in investing a much larger share of EU funds in human rather than phyisical capital. In Ireland, though education is largely in the public sector, the latter appears to have been very responsive to the economic environment. Sands (2005) describes how the Irish system for channeling the high school students to academia helped direct them towards the new

[10] This compares to more modest increases in the share of population between 25-64 with academic degrees in the four leading European countries. The U.K. moved from 17% in 1999 to 18% in 2001, Germany remained stable at 13%, Italy moved from 9 to 11%, and France from 11 to 12%. For the population between 25-34, the U.K. moved from 19 to 21%, Germany from 13 to 14%, France from 15 to 18%, and Italy from 10 to 12%.

disciplines for which there was rising demand, and how polytechnics modified their curricula to serve the needs of major local industries.

TABLE 2 ABOUT HERE

In India, a substantial fraction of additional engineering capacity created during the 1990s was created in the private sector. Data from the All India Council on Technical Education show that the accredited intake capacity for engineering students at the undergraduate level in 2003 was about 340,000, of which nearly 80% was in privately financed colleges, those that did not receive grants from the government. (See Figures 2 and 3.) Moreover, nearly half of this capacity appears to be in in colleges founded after 1994. In other words, it is likely that Indian engineering production has more than doubled in less than half a decade. The role of privatley financed colleges, the vast majority of which were created in the 1990s itself, is even more marked if one looks only at IT related engineering programs. Such a rapid expansion of engineering training capacity has raised valid concerns about the quality of the education and a variety of other social costs. Nonetheless, this supply response does speak to the flexibility that is rare in more advanced countries, and also speaks to the perceived returns on human capital.

FIGURES 2 AND 3 ABOUT HERE

2.5 The "Diaspora"

The final element of the picture is the role of human capital flows. In addition to the human capital "embedded" in exports, the 3Is, but China and Brazil as well, have also directly supplied human capital, particularly to the U.S. As a result, all the countries have a substantial Diaspora in the U.S. Unlike the embedded variety, the direct exports have different fiscal and economic welfare implications.

The Diaspora both reflects the excess supply and also affects this supply of skills, albeit in different ways for different countries. A recent set of estimates provided by Carrington and Detragiache (1998) indicate that the stock of high skilled (more than 13 years of schooling) immigrants in the U.S. from China, India and Brazil were about 400,000, 300,000 and 60,000 respectively. Moreover, the fraction of such immigrants coming to the U.S. as compared to other OECD destinations was slightly higher for China at 51% compared to about 44% for the other two countries. Both China and India have experienced a net outflow of skilled workers, with only a small fraction returning.[11] Brazilian emigration of skilled workers tends to be low in absolute volume. However, as a percentage of the stock of skilled population, the figures are comparable with India and China.[12]

In recent years, both countries have seen significant outflow to the U.S. of engineers and scientists leaving directly for employment. Kapur and McHale (2005) show that China is the second country after India ranked by the number of approved H-1B visa petitions by the U.S. Immigration and Naturalization Service (INS). Indians alone account for more than 42% of all the H-1B visas approved in this period, over half of which went for computer related occupations. Independent estimates of the U.S. IT workforce indicates that more than 15% of this workforce is from Asia, of which slightly less than 1/3rd are from India (IT Workforce Update, 2003), implying that Indian born account for about 5% of the IT (mostly software) workforce of about 3.2 million.

Saxenian's (2002) also highlights the role of the Indian and Chinese Immigrant Professionals in Silicon Valley. Of Saxenian's sample of Indian professionals 38% worked in

[11] There are suggestions that return rates have increased substantially after 2001, particularly for H1-B visa holders.
[12] Unfortunately, the small absolute size of the stock of Brazilian immigrants in the U.S. has meant that little is known about their role in the growth of the Brazilian software industry.

the software industry, while 20% worked in computer and communications occupations, and an additional 9% in internet content services. The corresponding percentages for the Chinese professionals are respectively 26%, 26%, and 7%. Though Saxenian's account suggests that a significant fraction of Indian and Chinese immigrants are likely to return, Kapur and McHale are more guarded in their assessment. They point out that NSF data on U.S. PhD students from China and India indicate much lower rates of return, around 5%-10%.

Only in Ireland the return of skilled emigrants has clearly increased the domestic supply of skilled people. As Kapur and McHale note in their chapter, for many years Ireland has been a net supplier of immigrants to the rest of the world, and to the U.S. in particular. In the 1990s however it experienced a net return of people. Moreover, the returnees were better educated and more productive than their non mobile peers. Barrett and O'Connell (2001) estimate an earning equation for the cohort of 1992 Irish graduates, using earning data from 1998, and find an overall premium of 5% for the returnees vis-à-vis those who never left. Most interestingly, all else equal, the returnees working in computers and software earn 16% more than the others, though it is not clear whether the returnees are more productive because they have been abroad, or because they are better to start with, or both.

There are other benefits as well. Sands (2005) survey of 58 Irish software entrepreneurs indicate that 66% of the founders of the Irish software firms in her sample have worked abroad, 55% have worked for multinational companies, and 74% of her companies had one founder who worked abroad, largely consistent with earlier findings that roughly a third of all entrepreneurs had worked for an MNC directly before starting their company (O'Gorman *et al*, 1997).

The Israeli case is similar to India. There is little evidence of systematic returns of immigrants to the U.S. At the same time, there is no evidence of major skill shortage in Israel.

As Kapur and McHale note, some Israeli students do take their PhDs abroad, and particularly in the U.S. However, the number of U.S. PhDs awarded to Israeli nationals has remained stable since the early 1990s. At the same time, the number of PhD students who plan to stay in the U.S. have increased slightly from 51% to 57%, albeit well below the corresponding figure for Indian and Chinese PhD recipients in the U.S.

The Diaspora can provide links, act as "reputational intermediaries", and upon returning, can bring back valuable skills and expertise. On the other hand, the outflow of skilled engineers, scientists and doctors represents a net loss of talent and of the considerable investment in training the emigrants. The broad question about the net effects of the international mobility of skilled people on the home country is a complex one and well beyond the scope of this article. However, Kapur and McHale conclude that the benefits from the Diaspora outweigh the costs for the three Is for the development of the software industry. In other words, setting aside the question whether the brain drain represented by the Diaspora was a good thing or not, the software industries of India, Ireland and Israel certainly benefited from having a Diaspora. Given the domestic market orientation of software industry China and Brazil, the tradeoff has likely been less favorable.

3. Has the Growth of the New Software Producers Been Good for the U.S.?

It is natural to ask at this point whether the prominent growth of the software industry in the newcomer countries produces a net benefit for the world leader in software production, the U.S. To understand the impact of the rise of emerging economy software sectors, one must understand the nature of software engineering. Specifically, software engineering work can be decomposed into separate elements, and, at least at a technical level, there is no necessary requirement that theses elements are performed by engineers with the same firm or even in a

given location. This basic insight about the nature of this technology results in two important observations. First, while there has been rapid growth in export-oriented software in these countries, the bulk of export-oriented activities have involved software activities that are (a) complementary to value-added activities done in the U.S. and (b) at a "lower level" of the value chain (e.g. maintenance rather than initial product development). Second, though early attempts to establish an international division of labor in software have focused on software products and services that are likely easily decomposable, the next generation of contracts is much more likely to involve a higher level of integration between firms and locations. As a result, it should not be surprising if Indian software firms start to establish facilities in the U.S., and that leading U.S. firms begin to locate at least some high-level engineering work in emerging economy establishments. The remainder of this section develops our basic insight about product modularity more carefully, and then draws out the implication for the impact of these factors on economic development in the U.S. and emerging economies. Since outsourcing to India is the most significant in terms of employment, we focus on the Indian case to exemplify our argument.

We shall not address the debate on whether the current job losses due to growth in software production overseas will be quickly made up by the creation of new opportunities at home. In our view, this debate echoes earlier debates that appear to pit free trade against job losses in existing industries. The conclusion of most mainstream economists, with which we broadly agree, is that although free trade creates winners and losers, the gains are greater than the losses, and thus, if the winners were able to compensate the losers, free trade ought to be supported. In this instance, we think that policies, such as retraining, which ameliorate the

impact of such job losses, are a good idea.[13] It is also worth pointing out that the total Indian software workforce engaged in exports (estimated to be less than 400,000) is still a small fraction of the more than 3.2 million software professionals in the U.S. Indeed, it is conceivable that the business cycle and technical progress in software technologies, which are making possible the automation of a variety of tasks, such as some aspects of network and database administration, and testing and code reuse, are more potent in this context than the growth of the Indian software sector.

Thus our focus is on a related question. Suppose that the free trade is superior in that the U.S. is relinquishing activities which are becoming commoditized, in which the U.S. no longer enjoys a comparative advantage. Some observers have speculated that this process will lead to Indian software industry become more sophisticated and productive, so that the current set of activities in which the U.S. currently dominates, namely those intensive in design and innovation, will also be lost. A more extreme version of this view is that R&D follows manufacturing, so that the offshoring of manufacturing will quickly lead to R&D activities also moving offshore. Might therefore the offshoring of software coding and maintenance cause it to be soon followed by the more design intensive activities as well? The answer is simple. Such a succession is neither quick nor is it inevitable. Indeed, there are strong reasons to believe that the U.S. will remain the center of software innovation for the foreseeable future.

Though it is not easy to find the analogue of "production" in software, one can roughly divide software related activities into design, coding and maintenance. Subject to the usual caveats when one draws such sharp contrasts, one can think of coding and maintenance as analogous to "production". Much (though not all) of the software related activity being carried

[13] On the debate about the outcomes for the U.S. of the outsourcing game in software and IT more generally, see for instance Mann (2003) and the McKinsey Global Industry Report (MGI, 2003).

out in the emerging economies is of the sort that complements the activities carried out by software firms, substituting for the most part activities carried out by the user sectors. Software is a general purpose technology, with the result that user sectors account for a very substantial portion of software production. For instance, the latest available data from the Bureau of Economic Analysis shows that of the 3.2 million IT workers (including programmers, network administrators and IS managers), only about 1 million worked in the software industry itself. Thus, nearly 2/3rds work in the rest of the economy, especially insurance, banking and finance. Indeed, this is also reflected in the very even geographical distribution of IT workers.

In this sense, much of what is being offshored to India is the production of software, rather than its design. We have already noted the low revenue per employee in the Indian software industry, approximately 20% of that in the U.S. industry. Other evidence points in the same direction as well. Arora *et al* (2001) cite evidence from interviews with Indian software firms between 1997 and 1999 and find that porting existing applications from mainframe to client server, maintenance and enhancement of existing applications are examples of typical activities. Interviews with U.S. firms outsourcing to India indicated that the typical projects were small and technically undemanding (and responses to a survey of Indian software firms indicated that the "most important project" in 1998 had a median size of 150 man months). Since then, the activities have become more sophisticated and larger in scale (Athreye, 2005). However, requirements analysis and design, not to mention creation of new products and "solutions" is still mostly the province of the U.S.

There is evidence that in many industries the locus of production and the locus of invention are physically separated. This is particularly true when the body of knowledge underlying the invention process has a strong scientific basis. For example, Mariani (2001)

studied the location of R&D and production facilities by the Japanese multinationals in Europe. She finds that the percentage of facilities with an R&D lab close to a production facility is higher for low and medium R&D-intensive industries, while R&D labs are more likely to stand alone from production in more R&D-intensive industries. Similarly, building on earlier work by Lamoreaux and Sokoloff (1996, 1997), Sutthiphisal (2003) studied the location of production and invention in three different industries during the Second Industrial Revolution, viz. textile, shoe, and the electric industry. He finds that in general the locus of invention did not shift with the locus of production as the latter moved to other locations, and that what determines the location of invention need not be the same factors that explain the location of production. Moreover, he finds that the link between location of production and invention is weaker in the more "science-based" electric industry, confirming our earlier point on this matter.

If India is taking up mostly production and maintenance jobs, while leaving the more innovative segments of the industry to the U.S., we then have to understand the implications of the physical separation of these two activities. A physical separation between the design intensive and production activities comes with its costs, including transaction and contracting costs, and communication and management costs. Physical separation may reduce the potential from learning from production (e.g., Arrow, 1962, Enos, 1962) or from feedbacks and linkages emphasized by Kline and Rosenberg (1986). Nonetheless, the lower cost of labor and the ability to work around the clock are important offsetting features. Perhaps the least appreciated benefit is the greater project management and delivery ability of Indian software firms, which they have acquired over the last decade. Competition among Indian firms has meant that the benefits have accrued largely to the customers of Indian software firms, that is to say, to American firms. This point is obvious when stated insofar as it is a benefit of free trade. Less obvious is the

implication that firms from countries such as Japan, Germany and France benefit far less. Since the principal competition for U.S. firms is still from these countries, there are important strategic benefits as well. Simply put, by outsourcing, U.S. firms are gaining important advantages over European and Japanese competitors in terms of lower costs, greater flexibility, and shorter product development cycles.

With globalization of production, it is perhaps inevitable that competing regions and countries will be able to learn and improve their productivity and challenge the leader. The leader cannot stay ahead by standing still. Instead, the leader must make sustained investments in innovation. Evidence about these patterns is offered by the long-run history of the U.S. chemical industry. The U.S. chemical industry grew through technology borrowed mainly from Germany and the U.K. The Second World War and the shift from coal to oil based feedstocks marked the rise of the U.S. as the technology leader, albeit some time after it had emerged as the leading chemical producing nation. Over time, chemical production has grown elsewhere, particularly in the economies such as Taiwan and Korea, and since the 1980s, China and India and the Middle East. Moreover, as discussed in Arora and Gambardella (1998), the U.S. chemical industry has developed since the 1950s an independent sector of specialized engineering firms (SEFs) that supplied new process technologies via licenses and chemical process engineering services to the rest of the world. In so doing, they were nurturing the international competitors of the U.S. chemical firms as much as they were nurturing the U.S. chemical companies.[14]

Similarly, Indian software capabilities will improve and Indian firms will be forced to

[14] Moreover, even if the U.S. chemical suppliers may have been hurt by the international diffusion of technology, U.S. engineering firms and contractors have benefited. Indeed, the U.S. is still the world leader in the provision of chemical process technology and engineering services.

"move up the value ladder" by competition. Some of this is already happening. Thus, although software producers such as Cadence have set up development operations in India, for the most part, it is users that are outsourcing software development to India. For instance, NASSCOM figures indicate that the three largest industry "verticals" in terms of the share of export revenues for the Indian software industry are Banking, Finance and Insurance (35%), Manufacturing (12%) and Telecom (12%) (http://www.nasscom.org/artdisplay.asp?cat_id=314). This is consistent with the earlier observation that user sectors account for a substantial share of software activities, with Banking, Finance and Insurance, and Telecommunications being among the leading user sectors.

Can the U.S. specialize and keep its comparative advantage in the higher end? The starting point for this discussion is to note that there are two key resources required to remain the center of innovation in software: access to talented designers, software engineers and programmers; and proximity to a number of large and technically sophisticated users. The U.S. dominates on both counts.

As noted in the earlier section, emerging software producing regions are leveraging their abundance of relatively underused human capital, especially of engineers and IT professionals. The U.S. also produces abundant human capital. But that is not all. The very same processes of globalization that have led to the growth of software overseas have also worked to attract the best and brightest to the U.S. We have shown how many IT engineers from the newcomer countries themselves, and particularly from India, are moving to the U.S. In the next section, we shall discuss whether this is beneficial to India or not, and the more general implications of the Diaspora for both countries. Here, it suffices to say that thanks to the size and the openness of its culture and economy, the U.S. has had no difficulty in attracting talent, providing it with a strong

advantage over potential competitors such as Japan or Western Europe.

Even more prominent is the relationship with the users. New software applications depend largely on knowledge about demand, and about the use of the applications. This is apparent for example in telecommunications and semiconductors, where the software that is needed to design the chip is part of the product itself. More generally, a substantial fraction of software is used for running businesses and business processes. Hence, proximity to business activities is crucial for innovation in this industry. Indeed, the development of new commercial applications or "solutions" is a very special comparative advantage of the U.S., and of areas that specialize in IT production like the Silicon Valley.

The most prominent example of such users is in the financial sector, and manufacturing and retail. Thus, a strong economic base of software users, which are able to push the industry with a sophisticated demand for software products, is crucial for innovation in this realm. The U.S. has such a strong economic basis. India's economy is growing, and we expect that sophisticated domestic demand for software will eventually rise in India. At present, however, the U.S. lead is overwhelming.

Moreover, as was true of human capital, globalization may even reinforce this lead. We find that innovative companies from Israel, Ireland and even India are likely to move their operations to the U.S., in order to be close to their users. In some cases, venture capitalists are likely to push for such as move as well. Indeed, although firms do not have to be based in the U.S. to tap its equity markets, a strong presence in the U.S. does help a great deal. Similarly, other intermediating institutions such as legal services and thick and well functioning labor markets are other important sources of advantage that the U.S. enjoys, which are not likely to be eroded soon.

There are, of course, counter tendencies as well. Insofar as Indians, (and Chinese, Israelis or the Irish) have a preference for staying in their home country, the cost of scientists and engineers will be lower in India, so that the cost of R&D activities that are human capital intensive (and relatively less sensitive to physical infrastructure) will be lower. There is evidence that India is being viewed as an attractive location for certain types of R&D activities, although anecdotal evidence suggests that U.S. firms are not locating mission critical activities in India, nor are they moving activities at the technological frontier.

To conclude this section it is useful to cast the discussion developed so far in a broader framework. In this respect, we believe that the story of the pros and cons of software trade between the U.S. and India can be understood by employing the framework about international trade, and the potential advantages or conflicts thereof, proposed by Gomory and Baumol (2000). Gomory and Baumol note that the present situation about international trade is inherently different from the one proposed by Ricardo in which the sources of comparative advantages were immobile. Because the sources of comparative advantages can be acquired, and they can change over time, countries can in principle specialize in many different industrial activities, and this can give rise to many equilibria where one country specializes and trade in any one product and another country specializes and trade in any other product. For example, one country can specialize in one industry because it started earlier with it, and hence enjoys learning advantages, or because of any other reason that makes it more productive in a certain sector. Interesting enough, Gomory and Baumol show that the set of equilibria in this model also correspond to the set of equilibria in a model without economies of scale but one where countries can increase their productivity in particular industries.

Gomory and Baumol study among other things the implications for a given country if its trade partners becomes more productive in a certain sector. Although productivity growth is pareto improving (in the sense of expanding the total pie), it may, under some conditions lower the welfare in the trading partner that does not experience such a productivity increase. Thus, building on earlier work by Hicks (1953), Dorfman, Fischer and Samuelson (), and others, Gomory and Baumol (2000) show that there could be conflicts between two trade partners if they are more similar in terms of income and international trade shares. In sum, when one trading partner become more productive in a certain field, trade conflicts are more likely to arise when the two partners are at similar income levels. However, a rich country will typically gain from productivity growth in a much poorer trading partner.

The India-U.S. software trade falls into the latter case. In the 1980s the U.S. dominated the entire value chain of software. This included lower end activities were it had no comparative advantage. It was forced to do so because there was no trade partner that could take up these activities efficiently. But in the 1990s India and other countries arose and become productive in these tasks. The U.S. could outsource to them these lower end activities and reap the benefits of specialization. As Gomory and Baumol suggest, the advantages of the U.S. rest critically on their ability to redirect the resources that are liberated by the outsourcing onto higher end activities. There will still be internal distribution problems in the U.S. Specifically, the new jobs that will be created will not be available to the very same people who lost their jobs in the lower end of the software business. Yet, to the extent that the overall value of production for the U.S. increases, it is not difficult to envision policies that use part of this higher surplus to mitigate the transition for those who will be displaced by the outsourcing, such as unemployment insurance and training.

4. Is the Globalization of Software Good for India?

The other natural twist of the question that we asked in the previous section is whether the growth of software, and particularly, its globalization, has had net benefits for India.[15] In addition to the standard benefits from specialization according to comparative advantage, the Gomory and Buamol framework also suggests benefits from increasing returns to scale and from possible productivity increases as Indian firms learn and gain experience.

In this respect, it was a crucial strategy for India to specialize in activities wherein it was complementary with the international industry. If India had instead moved up quickly onto higher value added products, as many had suggested, perhaps because of the common belief that moving up the value chain is only way to sustain an industry, it would have most likely conflicted with the U.S. Ireland and Israel did face this problem, especially during the downturn of the international IT demand after 2000. Because software *product* development was more important in these countries than India, it was natural that the reduced international demand for IT had a bigger impact on them. Indeed, as shown in Arora and Gambardella (2005) the performance of the Irish and Israeli software industries faltered in 2001-2002, with reduced profitability and employment for the first time since the early 1990s. By contrast, the growth of the Indian software industry slowed but only to about 20% per year in this period.

To summarize, the opportunities created by the international demand, India has had obvious benefits from its rising software skills. First and foremost, the growth of software has contributed in a non trivial way to the growth of the country as whole. Moreover, the growth of the software industry has provided the basis for the growth of a new entrepreneurial model,

[15] Once again, for reasons of space we focus on India.

which has in turn had spillovers for related activities, such as business services and even some type so R&D tasks.

There is one realm however in which one has to dig more deeply in order to understand whether there are inherent benefits to both India and the U.S., and this is the observed patterns of international migration of human capital. As Table 4 shows, the number of Indian born resident in the U.S. increased nearly three fold between 1990 and 2000, with over 80% of the Indian born residents having tertiary level education. Figures for Brazillian and Chinese born show similar trends, albeit lower levels of tertiary education than for Indians, but still above 50%. To put these figures in perspective, around 50% of the native born adult population in the United States has tertiary education, second only to Canada.

TABLE 3 ABOUT HERE

Such large scale migration of human capital has conflicting welfare implications. The standard argument is that migration entails a higher supply of skilled workers, which stems from higher wages in the U.S. vis-à-vis India. To the extent that the increase in the U.S. labor supply curbs the U.S. wages, native born workers have lower welfare than would obtain without international labor mobility. By contrast, the Indian workers gain because the salary of the emigrants increases and the salary of the workers who stay in India also increases, or at least it is not reduced as much by the increase in the supply of native computer engineers. The standard argument however also implies that because the migration follows more productive opportunities in the U.S., the re-allocation of Indian workers to the U.S. implies a higher combined output of the two countries than if migration did not take place. Hence, proper redistribution policies, or the extent to which Indian workers ships some of their rents back to India (e.g. links to Indian

software companies, returnees, consumption of other Indian commodities), may in the end enhance the overall value for India as well.

Yet, if there are externalities, due to spillovers or scale economies, associated with the agglomeration of human capital, in software production, the picture could be very different. Such externalities are plausible in activities like software. With externalities it is possible that as more Indian IT engineers flow to Silicon Valley or other U.S. locations specialized in IT, the productivity of these workers may even increase, at least until congestion effects overwhelm them. The increase in productivity would then encourage more migration from India. In addition, if the Indian industry suffers from reduces spillovers or lower scale economies, due to the outflow of skilled workers, Indian software salaries may not rise fast enough to match U.S. salaries. This may imply persistence differences in salary that feed a continuous outward flow of software professionals from India to the U.S.

Is this a problem for India? It could be if this implied a growing deficit of skilled workers domestically. The problem would be even more severe if there is some sort of selection, that is, if those who move are the more productive workers who can take greater advantage of the opportunities that open up in more advanced nations. In turn, the lack of externalities in India could undermine the productivity of its own skilled workers, which may in the end bring to a close the spectacular growth of the software industry that we have observed so far. Indeed, this is the problem faced by Europe today, whose brain drain to the U.S. does imply a worrisome deficit of highly skilled people. Yet, there is one major difference between Europe and India, and this is that India keeps producing new human capital at a substantial rate. Moreover, especially if compared to the ageing population in Europe, the demographics in India are

favourable, as the inflow of population into the university system can be sustained for a longer time.

The available evidence suggests that in fact Indian software salaries have increased faster than those in the U.S. Athreye (2005) presents data which suggest that whereas U.S. salaries for a variety of software occupations such as programmer, project leader, quality assurance specialist and systems designer increased by about 21% between 1995 and 1999, Indian salaries increased by nearly 45%.

In sum, while the migration of Indian talents to the U.S. can be a problem for India if there are externalities involved in these activities, it is India's ability to sustain a continuous flow of human capital that may turn this into a major opportunity. As people move, but they are replaced by new workers, while, the flow of workers to the U.S. feeds its software industry with talented programmers and motivated entrepreneurs. Indeed, it may well be that the main Indian (or Chinese) resource, could be its academic system, supplying human capital to the world. Even in this domain there could be some sort of vertical specialization with the U.S. system, or that of Europe and Japan. The advanced countries could take additional advantages by moving up to higher end educational and training activities. This could be graduate and postgraduate academic training or training inside firms or institutions that perform higher level research or that carry out more advanced activities or that have more sophisticated organizational structures.

5. Software: A Model for Other Emerging Economies?

The spectacular growth of software in India, Ireland and Israel raises the natural question whether other developing countries can take up a similar opportunity. However, potential emulators will likely find it difficult to replicate two central features of the successful growth of the software industry in the 3Is: The excess supply of skills and the international connections.

Most developing economy are short of skills, with an excess supply of unskilled labor. There are a number of developing countries with substantial number of underemployed college graduates. However, few are English speaking countries with a Diaspora or other means of linking to their potential export markets. Therefore, it is unlikely that others can replicate a success of similar proportions, even more so because they would be playing catch-up.

Nonetheless, there are a few regions in the world where software has thrived, even though not at the rates that we have observed for our 3Is. As discussed in Arora and Gambardella (2005) some other successful examples in software include Finland and South Korea. To a lesser extent, Hungary and the Czech Republic are also showing some signs of vitality in this area. Broadly speaking all these cases fit our model. They all have a relatively higher share of educated population compared to their level of development. At the same time, they do not have a wide and diversified industrial basis, which implies that the opportunity cost of these people to work in the software industry is not significant. At the same time, there are domestic sources for the formation of software competencies, like the electronics industry in Korea, the telecom leader Nokia in Finland, or some investments in ICT and electronics foreign firms in Hungary and the Czech Republic.

More generally, one can list the exportable lessons for other emerging economies. First and foremost, our cases have underscored the importance of openness. Export markets can facilitate scales of operation and opportunities for learning that would otherwise not be possible. However, as we have emphasized, this is more than simply a prescription for “Free Trade”. Openness includes openness to multinationals. In Ireland, for instance, multinationals have been important as sources of demand and competencies, and in India, they appear to have helped in legitimizing India as a source of software. Doubtless, relying upon export markets also makes

one more vulnerable to the vagaries of the business cycle and policies in those markets, policies over which one can have little control. Openness has other costs as well, as domestic firms may be squeezed out of learning opportunities and experienced managers and engineers may lured away to jobs in the developed countries, as in India or Israel. Such mobility of people, which is an important componet of openness, can however be turned into an advantage because ethnic links often underpin important trade links (e.g., Rauch, 2001), and in a human capital intensive industry such as software, such links are vital. If conditions are right, some of the emigrants may also return, as was the case in Ireland, bringing with them valuable skills and experience, both technical and managerial.

A second exportable lesson is that the “upgrading” to overcome the inevitable erosion of initial competitive advantage can take many forms. In particular, it does not have to take the form of rapidly moving up the value chain. For instance, many observers of the Indian software industry have noted that with the growth of the industry the advantage of low wages would decline. Many even characterized the growth of the Indian software industry as unsustainable unless firms began to invest in R&D to undertake sophisticated product development. The prescription that emerged was that Indian firms would have to move rapidly from merely performing programming to “higher value” activities such as design and product development (e.g., Heeks, 1996; DaCosta , 1998).[16] Such recommendations are often part of a broader

[16] Frequently, this recommendation was accompanied by a complementary recommendation for firms to focus on the domestic market, which would provide the initial demand for more sophisticated products and services. Arora *et al.* (2001) conclude that the competencies developed in the domestic Indian market were not helpful for exports. Athreye’s study of CITIL (now i-Flex), a Citibank subsidiary, indicates that the Indian market could provide a fruitful learning base for products (in this case, a backend banking product) that could be successfully exported. The study also makes clear, however, that this strategy depends on a number of concomitants for its success. In this case, Citibank’s own internal use of the product (albeit in India and other developing country markets) provided important legitimization. Further, CITIL’s strategy was to initially focus on other developing country markets, particularly in the British Commonwealth, avoiding head to head competition with incumbent producers in developed countries, most of which were not large established firms. Only after succeeding in othe export markets did CITIL enter the developed country markets.

mindset wherein progress in technology intensive industries must necessarily take the form of moving up the technology ladder, to parallel (if not imitate) the activities undertaken in the rich countries. Indeed, policy makers in developing countries often point with pride to the technological accomplishments achieved in their countries, treating them as indicators of success. Considerable pride is staked on the formation of national champions and the ability to undertake high-tech projects and produce technically sophisticated products, regardless of their commercial feasibility.

The lessons from the Indian experience are the opposite. To be sure, in recent years the leading Indian firms have managed to take on a larger range of activities. But, for the most part, developing new products or undertaking high level design has not been the principal means of offsetting the wage advantage. Rather, Indian firms upgraded their ability to take on and manage larger projects. Instead of moving aggressively into product design, they focused on taking on lower end functions such as maintenance and support. As also discussed earlier, this strategy also fits theoretical models of the advantages from international trade as the one by Gomory and Baumol (2000). In this respect, although not as lucrative, the lower end activities undertaken by Indian firms involve a steady and predictable stream of revenues since maintenance contracts are typically three to five years in duration. Moreover, this focus leveraged the capabilities Indian firms had developed, which was to manage projects with large teams of skilled people. These capabilities are further evidenced by their more recent move into business process outsourcing, such as customer support, which are even less technology intensive and require lower skilled workers.

Conversely, most of the early forays of Indian software firms into product development did not pay off. We do observe other Indian software firms, mostly later entrants that do not

have the same possibilities in software services, investing in developing products for targeted niche markets as a means of differentiating themselves. Some of these are likely to succeed. However, even if they fail, it is unlikely to shake the foundations upon which the Indian software industry has grown.

This also speaks to the validity of the development-led export model of Brazil and China. Growth based on domestic demand can give rise to development processes that help firms move down their learning curve, even though the drawback of any strategy that relies too strongly on the domestic market is that there can be too narrow a focus on the idiosyncratic needs of local users, as the Brazilian case suggested. The Chinese strategy, which is essentially one of import substitution, is even less promising in terms of the export markets in the West. It may, however, prove of some value in terms of the East Asian export markets of Japan and Korea.

Finally, our case studies highlight the importance of entrepreneurship: In each of the countries, firms have sprung up to exploit the opportunities opened up by the growth of demand for software. However, these firms have not arisen in a vacuum. Frequently, related industries such as IT, telecom and hardware have supplied the entrepreneurs and managers. In some cases, particularly in Ireland and India, nationals working and trained overseas have played an important role as well. For countries wishing to develop their own software industry, a key question to whether they have the related industries to act as the nurseries for future software entrepreneurs and managers.

But our studies also provide a message of hope in this regard. For India and Ireland, and to a lesser extent for Israel, the entrepreneurship in high tech industries had hitherto been the exception, not the norm. These countries had mostly lacked a culture of risk taking that one takes for granted in the U.S. Financial institutions and capital markets were not set up to

promote entrepreneurship, and there were few role models to follow. In India, commercial success had hitherto required preferential access to government permits and capital markets to exploit the protected India market. In Ireland, few believed that Irish scientists and engineers could develop and commercialize world scale technology until the Ionas and the Baltimores proved them wrong. Quite simply, the elasticity of entrepreneurship has proven to be high. For policy makers in developing countries, this should be welcome news. What is required are not special programs to encourage entrepreneurship, but a clear opportunity, and an economic environment that minimizes legal barriers to entry and exit. For software, this welcome news must be tempered. Not only is the sustained boom of the 1990s unlikely to repeat itself in the near future, even if such a boom arose, they would have to contend with established incumbents.

6. Implications for Policy

The previous three Sections hold specific implications for effective policy in both the U.S. and emerging economies. The implications for U.S. policy are two fold. On balance, the rise of software services in emerging economies is a boon for the U.S. economy. Calls for restricting outsourcing are likely to harm the competitiveness of U.S. firms and reduce efficiency. However, since equity often sacrificed at the altar of efficiency in economic analysis, it is to stress important that policies for mitigating the impact on software professionals receive more than mere lip service. Upgrading the technical skills of the U.S. workforce is important also for sustaining the U.S. technological leadership.

The U.S. leadership in technology has been based in some measure on access to skilled and talented people from the world over. In the short term, concerns over terrorism and anaemic job growth now threaten one of the most potent sources of U.S. advantage: Its open economy and

culture. Though such threats are perhaps not severe and although the U.S. is likely to remain the primary destination for emigrants with training and drive (often educated at public expense in their home countries), policy must take account of the growing attraction of other economies.

In terms of the emerging economies, policy to encourage economic growth on the basis of the development of these types of industries must be organized around an investment in human capital, openness to international trade, investment, and competition, and domestic economic liberalization.

The implications for technology policy are more diffuse. Israel and Ireland are instances where enlightened government policy did help the software industry. Even here, the evidence for the efficacy of targeted sector specific policies is limited at best. Israel's software industry benefited from general support for R&D and human capital development, and from the earlier growth of the computer hardware and electronics industries. The benefits of government venture capital funding and incubators are difficult to assess, and in particular, whether the benefits outweigh the costs. Ireland's welcome for foreign direct investment was aimed at boosting employment rather than promoting software. Software did benefit directly because these multinationals were initial sources of demand and as sources of competencies. We speculate that the indirect effects, including the training of managers and of legitimizing Ireland as a place to develop software, will prove to be more important.

The Indian case shows that a weak and inefficient bureaucratic structure works best when it attempts not to do too much. It also shows the virtues of decentralization. There is no doubt that competition among Indian states to develop software has kept political excesses in check and has focused government policy on addressing issues such as physical infrastructure instead of attempting to channel the industry into "high-tech" and "high value added" directions, or

attempting to regulate entry and entrepreneurship. This is an instance also of the political economy of success – the success of the software industry has provided celebrity status for Indian software entrepreneurs and political clout to the industry, which the industry has used to push for sensible tax and capital market policies (e.g., Arora, Gambardella and Torrisi, 2003).

7. Conclusions

In the traditional neoclassical model, capital and labor are symmetric. Countries relatively abundant with labor can just as easily specialize in labor intensive sectors and adopt labor intensive technologies as countries with abundant capital can specialize in capital intensive sectors. However, as we all know, labor and capital have been anything but symmetrical. Poor countries have had to follow in the footsteps of richer countries, moving from agriculture to manufacturing, moving from labor intensive to capital intensive sectors. Might software, with its dependence on human capital but relatively low intensity in physical capital, offer a new way for labor abundant countries? Can developing countries leverage their abundant labor endowments to target human capital intensive service sectors for exports and growth, without having to invest the large amounts of capital that manufacturing requires?

It is true that software, particularly software services, do allow a country to participate in the high-tech sector with only a limited physical infrastructure. However, even a successful software industry is likely to account for a small share of GDP and employment. The software industries in the countries we have studied account for less than 2% of the respective GDP, and an even smaller fraction of the total labor force, so that the direct impact on economic growth is likely to be small. Hence we turn to examine the indirect effects.

One possible set of indirect effects works through the links to other sectors. Some authors have argued that software is to the knowledge based economy what capital goods were to manufacturing – an input source whose importance for productivity and innovation was far greater than was reflected in revenues or share of GDP. Software does supply basic inputs to virtually every industrial sector. Better software would therefore increase productivity across the board.

Though attractive, this argument has a problem. Software is internationally traded and it is not clear why a country could not rely uopn software developed in other countries. There may be some advantages to have a domestic software sector which could tailor software to local requirements at lower costs. However, this must be weighed against the possible lower efficiency in developing software domestically. The net effect of all these factors is that having a domestic software industry provides at best a modest contribution to the overall growth of the economy even when considering the potential effects on the large set of domestic user firms and industries.

Moreover, software is labor intensive but it does require skilled and trained labor. Indeed, in software, there is very little use of workers with modest education and training, in marked contrast to large scale manufacturing operations. Most developing regions have abundant labor, but rarely abundant skilled labor. The rise of software could therefore mostly benefit the small segment of the population of the highly skilled and educated, and leave virtually untouched the rest. Indeed, the growth of the software industry draws away skilled engineers from other sectors. This may not only increase inequality, but may also reduce rather than increase total output (e.g. Gambardella and Ulph, 2003). However, as long as the software sector contributes to overall growth, the rising incomes of the middle class would increase demand for a variety of consumer goods and services. Insofar as these are not entirely from

imports, there is a positive multiplier effect for the domestic economy. But other than this conventional effect, there is another one as well.

The software industry can act as an exemplar to the rest of the economy, particularly for other sectors that rely upon skilled workers, of a new business model that features flatter organizations, individual incentives, competition, and export orientation. Most of the successful software firms in the 3Is, in modeling themselves after their Silicon Valley counterparts, have also stressed shareholder value, and responsible and transparent corporate governance and accounting. Though American corporate governance is under attack, and with good justification, it is likely superior to the practices of the traditional firms in many developing economies, which frequently resemble family fiefdoms more than the shareholder owned corporations. It is likely the software will be an immediate role model only for services such as accounting, but over time may apply more broadly as well.

Success at an export oriented industry also has spillovers for other industries in terms of enhanced reputation. China's initial success in producing and exporting light manufactures of all kinds has earned it the reputation of being a desirable location for all manufacturing. Conversely, years ago, Japanese automakers had to fight the reputation for shoddy quality that its early exports of light manufactures had earned it. Today, India enjoys a reputation for service quality, largely due to the software industry. It is no accident that it is the favoured destination for other service exports, ranging from call centers, customer care and medical transcription to high end R&D services.

But perhaps most important of all, the success of an export oriented software industry can show to potential entrepreneurs what is possible with talent, luck and hard work. If they can convince enough people that success is not reserved for those with good connections or *guanxi*

or for those born to wealth, this would succeed in unlocking the drive and creativity that is the mainspring of economic growth under capitalism. In Ireland, the success of the software industry provided others with the confidence that Irish high tech firms can compete with any in the world. In India, software was virtually the first instance where wealth was created honestly and legally, and more important, visibly so. Before this, wealth came either from breaking laws or at least bending them to one's convenience, using existing political and economic power. Partly as a result, commercial success had invited envy, cynicism and even outright hostility, and only rarely, admiration. While envy and hostility are not gone by any means, there is much more of admiration, and more importantly, a desire for imitation. Of course, entrepreneurs can only succeed if other conditions, which we have discussed, also obtain. Some of these, such as international links and supply of skills, are not easy to create. However, the task for any underdog region is probably easier today than at any other time in the past.

Policymakers in the U.S. should not view the growth of underdog regions. Instead, the U.S. economy will broadly benefit from their growth. However, over time, the growth of software and other high technology industries in these economies may raise other challenges. U.S. technological leadership rests in part upon the continued position of the U.S. as the primary destination for highly trained and skilled scientits and engineers from the world over. Though this is likely to persist for some time the increasing attractiveness of foreign emerging economy destinations is a long-term concern for continued U.S. technological leadership.

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Table 1: Estimated size and characteristics of the software industry in selected countries in 2001-02 ($ Billions)

Countries	Sales	Exp (%)	Empl (000)	Sales/Worker ($ '000)	Firms (00's)	Growth 91-99 (%)
Brazil	7.2	2	158	45	100	490
China	7.4	5	186	37	100	n.a.
India	8.9	66	350	30	8	1000
Ireland	8.6	85	30	270	8	330
Israel	3.7	70	35	120	4	490

Source: (Adapted from Arora and Gambardella, 2005)
Notes: These estimates are compiled from a variety of sources and may not be directly comparable. Figures for Ireland likely overstate the true size of the industry due to MNC accounting practices. (See text for more details).

Table 2: Distributions of EU Structural Funds 1989-1993 and 1994-1999 (%)

Country	**Human Resources**		**Infrastructure**	
	1989-1993	**1994-1999**	**1989-1993**	**1994-1999**
Greece	25.6	24.6	40.9	45.9
Spain	24.2	28.4	54.0	40.4
Ireland	38.0	43.9	27.7	19.7
Portugal	26.1	29.4	29.2	29.7
Italy	21.6	21.4	38.7	29.8
Average EU11	29.6	29.8	35.2	29.5

Source: First Report on Economic & Social Cohesion 1996 DG XVI EC Brussels, taken from Sands (2005)

Table 3:

1) Selected Foreign Born Populations in the United States Aged 25 and Over

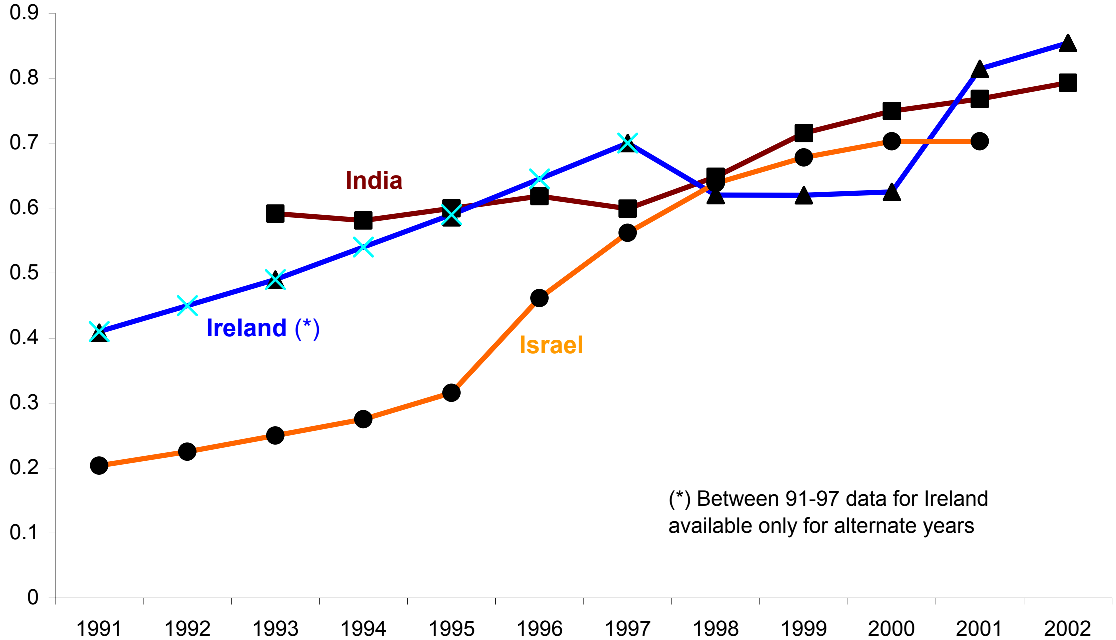
	1990	2000	% Chng	% of 2000 population entering post 1990	Educational Attainment (2000)		
					Primary %	Second. %	Tertiary %
India	304	837	175	55	5	15	80
Brazil	54	154	186	49	9	36	55
China	405	847	109	66	20	26	54

2) Selected Foreign-Born Populations in the United States by Year of Entry

	Indian-Born	Irish-Born	Israeli-Born
Before-1960	1%	32%	4%
1960-1969	3%	19%	1%
1970-1979	14%	8%	28%
1980-1989	24%	23%	35%
1990-1995	23%	13%	18%
1996-2001	36%	5%	14%

Notes: We have taken this table from Kapur and McHale, 2005. The original data are from the March 2001 Current Population Survey of the United States.

Figure 1
India, Ireland, Israel: SW Export Shares 1991-2002



Source: Arora and Gambardella (2004)

Figure 2
Sanctioned Engineering Capacity (BS) in India, By Field and Year, in '000s

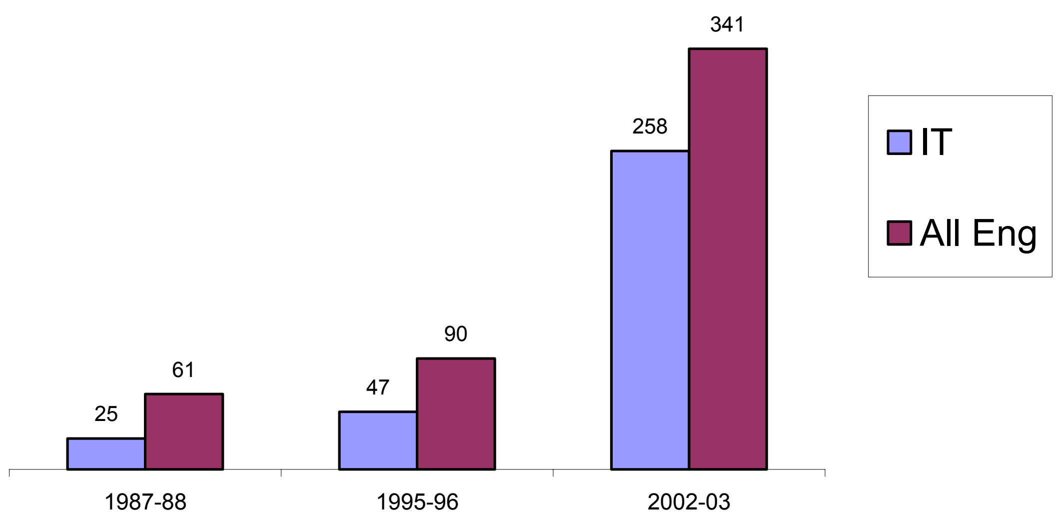
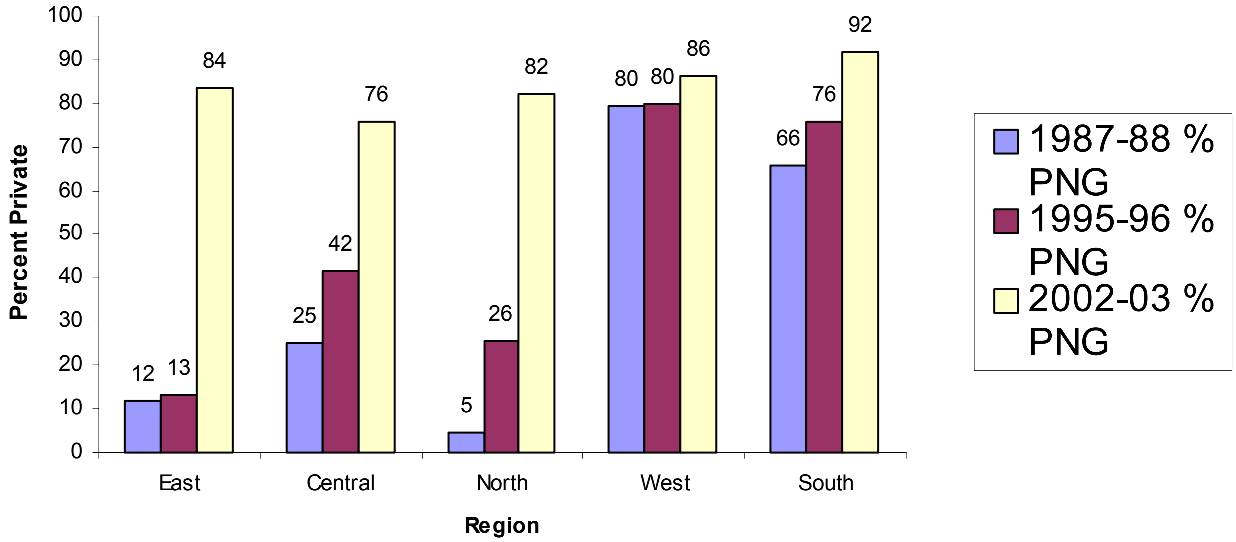


Figure 3
Share of Privately Financed Colleges in Indian IT Capacity, by Region and Year



Notes: PNG refers to “Private Not Granted”, which are privately financed colleges.
Sources: Figures 2 & 3 are derived from data from the All India Council on Technical Education (AICTE). More details are available on request.