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In the Footsteps of Silicon Valley? Indian and Irish Software in the International Division of Labour

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In the footsteps of the Silicon Valley?
Indian and Irish software in the international division of labour

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Abstract

This paper analyses the development of software in India and Ireland. The development patterns of the software industry in Ireland and India clearly show both the advantages and disadvantages of being a follower. The most obvious advantage is the ability to sustain growth without a broad based set of technical capabilities, at least initially. With the leaders creating and defining markets, and possibly even the business models, and the policy and technical infrastructure required, many uncertainties are greatly reduced. Moreover, in many instances, multinationals from the leading countries can catalyse growth and may even, as in Ireland, account for a substantial part of the initial growth. On the other hand, relatively narrow sources of competitive advantage imply that the firms in the follower industries tend to be similar in capabilities, with competition among them transferring the bulk of the benefits to customers overseas. Sophisticated and well established competitors located in the leading clusters stand in the way of followers moving up the value chain, leaving innovative firms to search for new niches, and ways to link to lead users. Moreover, clusters in the followers lack the thick vertical and horizontal links, that are important for knowledge spillovers, innovation and growth. However, our analysis, which s draws on the evidence collected in India and Ireland through two surveys of domestic firms and foreign-owned firms, also suggests that early success, narrowly based though it may be, can lay a foundation for future growth that is based more on innovation.

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1. Introduction

It is commonly believed that Information Technology is different and economies based on IT differ from the 'old' economies. These differences are thought to include differences in cost structures and the role of human creativity, and extend to differences in management styles, business models and the role of entrepreneurial entrants. This paper explores the implications of these differences for economic development models by studying the development of the software industry in two follower countries, India and Ireland.

The dramatic growth of IT in the advanced industrial nations had two features that were of great importance for follower countries: the decoupling of hardware from software, and the pronounced human capital intensity of software. Together with the rapid improvements in data communications (and communications more generally) and the steady increase in globalization, they opened a window of opportunity for countries well below the technology frontier but rich in human capital relative to the opportunities for that human capital. But not all countries that fit the bill have been able to seize the opportunity, and those that have, have done so in ways that differ from each other in a number of important respects.

Although India and Ireland are different on many respects, especially size and development stages, along with Israel, they are the most prominent examples of countries that appear to have benefited from this window of opportunity. [1] Both specialise in software and IT services, and have benefited greatly from the increased demand for software workers. The rapid growth in both countries of software firms in specific regions such as Bangalore in India and Dublin in Ireland have prompted comparisons to Silicon Valley.

SV is a natural comparison for every region that aims to enter the production of new technologies. But our stories show profound differences with the SV model of industrial organisation. The development patterns of the software industry in Ireland and India clearly show both the advantages and disadvantages of being a follower. The most obvious one is the ability to sustain growth without a broad based set of technical capabilities, at least initially. Much of the software related work in Ireland and especially India is non-innovative and involves activities such as offshore development and testing, 'localisation' and on-line technical support. Compared to the early development stages of SV, India and Ireland appear to be 'constrained' by limited initial

[1] Ireland belongs to the group of developed countries, thanks to its level of per-capita GDP and the standard of living, while India is a developing country.

scientific and technological capabilities.[2] The markets to be served are in existence and reasonably well defined (although serving such markets from a different country poses a special set of problems). For Ireland and for India respectively the EU and the US provide the major markets. Further, the policy and technical infrastructure required for this growth is reasonably well understood, in part from the experience of the leaders themselves and especially from new industrialising countries such as the Asian Tigers. Also, when the supporting institutions (such as venture capital) are not available domestically, they can be "imported". Moreover, in many instances, multinationals from the leading countries can catalyze, and, as in Ireland, may even constitute a substantial part of the industry.

The drawbacks of being a follower are evident too. The relatively narrow sources of competitive advantage imply that the firms in the follower industries tend to be similar in capabilities and strategy. The fierce competition among them results in the bulk of the rents being transferred to customers overseas. And sophisticated and well-established competitors located in the leading clusters stand in the way of reaching the market niches where competition is based on quality and technology rather than price.

Moreover, the "thick" vertical and horizontal relationships that sustain innovation and growth in successful IT clusters such as the Silicon Valley are missing, handicapping innovative firms. The growth of the SV shows the importance of horizontal links between firms within industries (such as semiconductors, computers, software, data communication and Internet) and vertical links between these industries. These links were facilitated by geographical proximity and flows of people. As Gordon Moore has noted, 'It was fundamental that this was an area of rapid technological growth at all level of the supply chain' (p. 13). The IT-related activities concentrated in industrial clusters such as Dublin or Bangalore is much less varied than in SV. India and Ireland focus on a limited range of technologies. Perhaps the biggest drawback is the pull exercised by the successful clusters in the leading countries. The innovative and dynamic firms that do emerge in follower countries face powerful pressures to relocate to locations where discerning venture capital, lead users, and sophisticated suppliers are more abundant.[3]

Despite these drawbacks, the software industry in India and Ireland has grown rapidly. Computer software and services represent over 50% of the world Information Technology (IT)

[2] As noted by Gordon Moore, one of the pioneers of SV and a co-founder of Intel, in SV there was an initial 'core' of scientists coming from the East Coast R&D laboratories who learned engineering, managerial and commercial capabilities over time (Moore and Davis, 2000)

production, which in turn represents the main source of productivity growth in the US and in other developed countries (US Dept. of Commerce, 1999; OECD, 2000b). Though India and Ireland are only minor players in the world market for software, their importance is likely to increase substantially in the future, albeit in some segments of the industry. The software industry is one of the most important sectors in terms of both exports and R&D expenditures in Ireland. And it is among the most important one in India as well, especially in terms of exports and contribution to GDP growth.

Moreover, although innovation and the dense horizontal and vertical links of the SV model are missing, the software and industry clusters in India and Ireland mark an important change for the economies of these countries. Software is different from the traditional manufacturing industries in many respects, especially in terms of the relatively greater importance of human capital relative to physical inputs. It is therefore interesting to see whether the typical development patterns observed for manufacturing is taking place (from subcontracting, assembling and imitation to innovation) or if novel development paths are possible in this 'new economy'. Indeed, some are looking to the software industry (and IT more generally) to be the engine of growth for these economies.

Third, the growth of software in both countries is very recent. Over 50% of firms in these countries have been established during the 1990s (NASSCOM and NSD, 1999). In the same period the entry rate have been very high. For instance, in Ireland the number of firms rose from 291 in 1991 to 690 in 1999. This growth is largely led by exports, despite marked differences in trade and industrial policies[4] Although foreign capital is accorded a key role in economic development, and particularly in the development of technology based industries, (e.g., World Bank, 1997; Birkinshaw and Hood, 2000), the software industry in India, in particular, has a very strong indigenous component. In Ireland, multinationals have played a larger role but nowhere near that in semiconductors or computer hardware. Thus, the growth of this industry in India and Ireland also offers a tantalising glimpse of the nature and prospects of high-tech entrepreneurship in two economies not otherwise noted for it.

We begin by providing a brief historical overview of the software industry in the two countries in section 2. Section 3 contrasts the economic and business models in the two while

[3] This problem is more acute for Israel, and less so for Ireland and India.

section 4 analyzes why these countries have been successful and speculates about their prospects in the future. Section 5 summarizes our main findings and concludes.

2. A historical overview

Like many other newly developing countries, India and Ireland have grown very rapidly in the 1990s (between 7% and 11% compared with 2.3- 4.9% in the US). Software revenues amounted over $7.7bn in Ireland and $2.7bn in India in 1997-98.[5] This compares favourable with the size of software industry in other rapidly developing economies - e.g., in Israel total revenues have totalled to $ 1.5bn in 1998. Software activities are quite important for the growth of these economies. Software accounted for over 10% of GDP real growth in India (Kumar, 2000). The contribution to employment is less marked but it is rising over time. For instance, in 1998 software accounted for 1.63% of total employees in Ireland but it also represented the fourth largest source of employment after metals & engineering (including electronics), food, and chemicals & pharmaceuticals. And, more importantly, employment in the software industry has increased at a 19% rate during the 1990s against a 6.3% growth rate of total employment. Therefore it represents one of the largest sources of employment growth in Ireland (FAS, 1998, table 2.1). Given India's much larger size, software accounts for a tiny fraction of total employment. However, the over 250,000 people employed by the Indian software industry represent a sizable fraction of the stock of technically trained workers, and the software industry's growth of nearly 50% per year threatens to swallow up the entire cohort of graduating each year. Much of software growth in these countries is accounted for by exports which represent about 70% of Indian's total revenues and over 85% of Irish revenues.

Tables 1 and 2 indicate that the growth of the software industry in Ireland during the 1990s was largely due to the entry of new firms rather than firm growth. Although the number of software firms in the two countries is similar (822 in Ireland and over 545 in India), the average size of

[4] Ireland has removed tariffs and quotas since the 1960s and pursued an aggressive policy of fiscal incentives to attract foreign investments while India is much less open to free trade and foreign investment inflows. The Indian government has removed most barriers to trade and foreign investments only since 1991.

[5] The revenue figure for Ireland is potentially misleading. For instance, in 1997, Irish software revenues were repoted to be about $ 6.7 billion. Indigenous Irish firms that account for 50% of the employment had around 9,100 employees and around $800 million in revenue. Multinationals claimed revenues of nearly $6 billion and employed around 9,200. Even if the average revenue per employee in the multinationals is set at $100,000 per employee (slightly less than twice that in indigenous firms), it would imply that the total revenues in the Irish software industry of about $1.7 billion. Of course, if one is willing to assume that the average value added per employee in Ireland for multinationals is $200,000, (comparable to that earned by the leading software firms in the US) it would imply total software revenues of $2.6 billion. Further, as discussed below, multinationals in Ireland are engaged primarily in activities such as localisation and

domestic firms is very different (about 16 employees in Ireland and between 99 and 295 employees in India (see Tables 2 and 3)[6].

One reason for the small average size of Irish firms is the specialisation in niche markets where there are low entry barriers. However, that most domestic firms grow very slowly may also reflect barriers to growth which are associated with innovation, management and marketing resources. These data also show that the bulk of Irish exports are accounted for by MNCs. It is possible that a substantial fraction of these exports are the result of accounting procedures adopted by these firms which book export revenues (for EU countries) in Ireland, even though the vast bulk of the product development takes place elsewhere. In this sense, even the software revenue figures tend to exaggerate the importance of Ireland. Instead, in India the bulk of exports is accounted for by international contracts with large customers (on site or offshore development projects). Estimates from a sample of 90 of the largest software firms in India indicate that subsidiaries and divisions of overseas firms account for 15-20% of Indian software exports. As tables 4 and 5 show, the main outlets for Indian and Irish software exports are represented by the US and the EU respectively.

Finally, India and Ireland appear to be less innovative Israel, although Israel may be a special case because its software industry has benefited from spillovers arising from the defence sector (e.g., research programmes in real-time applications, avionics software, communication systems and command/control applications) (IASH, 1999).

In India only recently a few firms have started to invest systematically in R&D, with firms aiming to develop proprietary technologies in areas such as mobile telecommunication software and chip design software. The bulk of the R&D would appear to be focused on the development of tools for software development. In Ireland the number of firms that invest in R&D is probably larger but the average R&D expenditures are quite limited. The software industry overall accounts for a significant share of national R&D activities in Ireland. The share of software in national business enterprises R&D expenditures (BERD) rose from 6% in 1993 to 10% in 1997 and the software industry become the fourth largest source of national investment in R&D (see Table 6). As Table 6 shows, domestic firms represent the bulk of total R&D expenditures of the software industry (about

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adaptation, rather than product development, making it likely that the bulk of their revenues are from products developed elsewhere and sold in the EU markets but booked in Ireland for tax reasons (Stewart, 1989).

[6] The figures for India are obtained by using NASSCOM members, which represent over 95% of industry revenue. It is useful to note the different average labour productivity in the two countries. The domestic sector in Ireland has a productivity of over $85,000 while Indian firms' average productivity ranged between $10,000 to 15,000.

67% in 1997). This is mainly due to the fact that by and large MNCs conduct locally only low value added activities.

If we compare the R&D data reported in table 6 with total revenues reported by NSD (see table 3) we find that the R&D/sales ratio for Irish-owned software firms rose from about 4% in 1993 to over 6.5% in 1997. By contrast, foreign-owned firms spent less than 1% of their revenues in R&D in the same years (from 0.31% to 0.41%). It is worth noting that the typical R&D/sales ratio for the software industry is higher.[7] Moreover, the average R&D expenditures of domestic software firms in Ireland in 1997 was about $88 thousands, which is small compared with that of the leading U.S. and European firms in this sector[8]. Despite the limited R&D by the Irish software firms overall, these data indicate that there is a core of domestic firms that have the potential to become significant sources of new software technologies.[9]

3. Economic and business models

As mentioned in the Introduction, the Silicon Valley is a model for many firms or countries that enter the IT sector. However, entry barriers vary across market segments. Late comers face significant entry barriers in segments such as microprocessors and system software due to high R&D costs and network externalities. The entry in other segments such as 'vertical' or sector-specific business solutions (e.g., for banking or finance) and professional services is easier. These differences in entry conditions are closely related to the nature of competition and the sets of competencies required to compete effectively, as well as with factors such as intellectual property rights arrangements. The differences in market concentration across these market segments are consistent with the differences in entry conditions and the nature of competition (Torrisi, 1998).

There are three main business models of relevance, and Table 7 reports representative examples. Table 8 and 9 report the specialisation of software firms operating in Ireland and India.

- Technology-driven, product-oriented and rapidly growing firms that are closer to the SV model compared with other firms. Their customers are typically large foreign firms in finance, telecommunications and electronics.

[7] In Europe R&D intensity of software firms is about 10-15% (EC, 1997). The largest US software firms too show a higher R&D intensity (e.g., Microsoft 15% and Novell 25%).
[8] For instance, in 1999 Microsoft spent about $2.6bn in R&D and SAP spent over $650m. In the same year, Baltimore of Ireland spent $10.3m in R&D, which represents about 20 per cent of the Irish R&D expenditures (domestic sector).
[9] Since the ST&I Department of Forfas does not publish the number of firms that have participated in the survey, we cannot know the concentration of R&D among Irish software firms.

- Service-oriented firms. These include both small firms oriented to the domestic market and larger, export-oriented firms. Small to medium sized firms specialised in small projects for the domestic market specialise in web site design and maintenance, porting (conversion), 'localisation' and technical consulting. Their customers include local subsidiaries of MNCs and domestic firms. Larger service firms carry out customised software development, reengineering, testing and other services for the domestic and the export market (outsourcing). Some of these firms conduct also more sophisticated service activities and tend to offer complete solutions to their customers.
- Multinational corporations. With few exceptions, these conduct relatively low value added activities such as detailed design, coding, testing, localisation and customer support (call centres etc.) in Ireland. MNCs use India as a low cost development platform for designing products.

Product-oriented firms

Amongst the most technically-oriented and rapidly growing firms there are many university spin-offs that focus on niche products. - e.g., development tools and system software, computer-based training tools, business applications for telecommunications, financial and assurance, and distribution. These are usually service-intensive products that require different types of related services such as installation, training, integration (into the customer's information system), support and maintenance. Therefore, we do not find here the typical software publishers that produce shrink-wrapped, mass-markets products (e.g., Corel or Symantec), which require significant marketing and sales effort, and extensive commercial networks.

This model has been adopted by Irish firms such as Baltimore, Trintech and Iona. For instance, Baltimore Technologies is a leading developer of information security products and services for Electronic Commerce and Internet. It provides total security solutions and a security infrastructure from encryption engines to certificates (including e-signature) and key management architecture. Founded in 1976 as a consulting, custom software development firm by a professor of mathematics at the Trinity College Dublin (TCD), it entered the product market in 1996 and at present draws 60% of its total revenues from products sales (royalty fees) while 40% arise from services. Services are important but they are product-driven. Training and system integration, for instance, are strictly related to the firm products. Neither consulting nor system integration

unrelated to the firm's product are conducted by this firm. About 98% of its revenues come from exports. Baltimore has development and support offices in Dublin and London, Amsterdam, Sidney, and Boston. However, its core cryptographic (security) development activities remain in Dublin while the application itself is developed abroad close to the market. It also has sales offices in most countries, including Japan, Singapore, France, Germany and Italy. The rapid growth has brought Baltimore to over 700 employees and $40m revenues in 1999 (from $5m in 1998).

Massana, founded in 1996 by three researchers at the University College Dublin (UCD), presents another interesting example. One of the founders, who is the current managing director, spent seven years abroad working for AT&T and Philips in the Netherlands, Digital Equipment in Boston and Alcatel in Belgium. He then returned to Ireland to work as a researcher at the UCD. Massana specialises in algorithms for digital communications and signal processing applications. Over 100 percent of its sales come from chip design and construction methodology. The design is delivered to the customers in the form of documentation and customised CAD software programmes. This case illustrates clearly a business model centred on sales of intellectual property rights. Its technology (both the design and the software) is protected by patents and licensed to the customers who pay royalty fees. Massana does not conduct development or manufacturing activities and all its revenues are from exports.

Many Irish and Indian firms that now focus on products have started by developing customised software and supplying services for the domestic market and at a later stage of their life have migrated towards software packages for foreign markets. Often product development has been financed by profits in services. Besides Baltimore, a typical example of this strategy in Ireland is Airtel (software products and services for the aeronautical industry). Similarly, in India, Aditi, a firm founded by an ex-Microsoft employee, has used its services revenue to fund the development of a Customer Relationship Management (CRM) product, which has since been spun off as a separate company, Talisma. Similarly, Ramco and Vishesh Infosystems have started servicing customers in India with business applications that have been transformed into Enterprise Resource Planning (ERP) products for the Indian and other developing country export market. In India this business model centred on products has emerged later than in Ireland, epitomized by firms which are focused on specific domains. Notable among these is Silicon Automation Systems (now Sasken), which develops proprietary software for communication and networks. This `company has focused on a range of speech compression products (Vani) and design tools for semiconductor design. Another example is represented by L&T Infotech (software solutions for the non-life

insurance sector). This firm has recently developed a product that is sold on a three tier price structure (license fees on the core product, a customisation fee and implementation service fees) (Noronha, 2001). As yet, however, India has not produced any firms comparable even to the leading Irish product firms.

Services-oriented firms

Customised development services, turnkey projects and professional services (customer support, system installation, maintenance, training and facility management) represent the most frequent type of activity carried out by domestic firms in India and Ireland. Other common activities especially in Ireland are Internet services, multimedia services (which include outsourced video, voice and printed data services, desktop publishing and computer-based training). Localisation services are also common in Ireland. The main tasks of localisation include translation by language specialists, making changes in strings, resources and dialogs, help-desk testing and designing, implementation of computer-aided translation (CAT) tools (machine translation, translation memory, terminology stems), and quality assurance. The typical outputs of localisation include translation (text, graphics, date and letter format), glossaries, and documentation files[10].

There are many small to medium sized firms that specialise in relatively low value added services for the domestic market in both countries. These firms carry out routine activities for domestic customers. An example of this category of firms in Ireland is Manuson, a firm that employs 26 people and offers localisation services. Its customers are subsidiaries of large software houses working on networking, multimedia and ERP. Therefore Manuson has no direct contact with the foreign market. The contracts it uses vary according to the type of services required. For instance, desk top publishing services are offered on the basis of time and material contracts.

In India the services for domestic customers differ from export projects. For the domestic customers the industry provides a wider range of services than for the export market. Moreover, domestic projects are large and complex (e.g., the Bombay Stock Exchange and Reservation System for Railways) while, until recently, the bulk of Indian service exports concerned low-level design, coding and testing and the contractual model was mostly centred on time and material billing (Arora et al. 2000). Export projects involved maintenance tasks for applications on legacy systems such as IBM mainframe computers, development of small applications and enhancements for existing

[10] Localisation includes also lower value added activities such as packaging software programs on floppy discs or CD-ROM along with users' material (registration cards, labels, security devices and manuals).

systems, migration to client-server systems, and increasingly, e-commerce related services and "solutions". Survey data from Arora et al (2000) shows that application solutions were the most common type of export, followed by reengineering (which is the term used to describe porting applications from one platform to another) and conversion projects, such as Y2K projects. The type of work outsourced was neither technologically very sophisticated nor critical to their business[11]. Requirement analysis and high-level design is typically done either in-house or by US based consultants. Not only is the work outsourced technologically undemanding, the projects are typically small. The mean number of man-months involved in the most important export project in 1998 for firms surveyed by Arora et al (2000) was 510 man-months, whereas the median project was only 150 man-months.

In order to "move up the value chain" the leading Indian software service firms, such as Tata Consultancy Services, Wipro and Insfosys, have started to prove services beyond simple programming services, intensive in industry specific business knowledge (domain expertise) and technical capability. This approach enables the software supplier to provide "solutions" to business problems, rather than simply programming services to implement solutions that the customer or firms such as Anderson Consulting and Oracle provide.[12] As the president of Wipro Systems, India's second largest software firm, put it "we need to offer products, rather than commodities - whole solutions, things we can point to and call our own, not just anonymous lines of code buried in someone else's application. We must move up the value chain … companies have to stop giving away the intellectual property rights to their work" (Miller, 1998). Wipro now offers an e-commerce solution framework called *net.profit*. Another type of moderately high value-added services is represented by software development for device drivers, i.e., software for specific hardware components (like printers, cell phones, and modems), which requires somewhat more sophisticated

[11] Managers at a leading electronics and telecom firm said they outsource work related to sophisticated but mature digital signal processing software to their Indian subsidiary. The telecom firms we interviewed outsourced domain related software maintenance or tool development for the maintenance or enhancement of existing applications. Manager at a value added telecom services firm said that they were outsourcing testing of their existing software and to some extent maintenance of their old UNIX based software. However, we did find one exception to the idea that the outsourced projects are not mission-critical: A leading computer manufacturer out sources critical device-driver software that is shipped directly from the Indian vendor for distribution.

[12] Recently, the largest Indian firms, like Tata Consultancy Services, Wipro and Insfosys have started to diversify their business to supply (partly pre-packaged) business applications. This process requires investment in sales and marketing, to build up a brand name and to recruit American-born (or European-born) professionals that can deal with foreign customers. Not surprisingly, Plexus Technologies, a global provider of enterprise connectivity solutions based in Mumbai founded in 1977, has recently announced the appointment of a new chief executive officer from the US. Like Irish firms, most Indian firms do not specialise in mass-market products but solutions (which are similar to products in that branding is possible - e.g., Anderson Consulting).

programming and technical capabilities. Wipro, BFL software, Silicon Automation Systems and Srujana Technologies have provided device driver related services to clients.

In Ireland as well, the more sophisticated service suppliers adopt a business model which diverges from that of the traditional low tech service suppliers. A notable example is Peregrine Systems Ltd., a firm which supplies products and services for the card payment industry. This firm relies on fixed price agreements, licensing agreements and other IPR arrangement that serve to protect its proprietary technology.

Fixed fee contracts involve greater risk taking by the vendor in contrast to cost plus or time and material contracts. With greater risk also comes greater control over the organisation and management of work. The available evidence on India suggests a steady increase in the fixed price component of work, indicating the growing maturity of the Indian software firms, an impression confirmed by several of the managers we interviewed. Bannerjee and Duflo (1998) present data from a sample of 236 contracts (not including offshore development centre contracts) from 125 software companies. They find that 58% are fixed price contracts, while another 27% are "mixed". Only 15% of the contracts are pure time and material contracts. This tends to exaggerate the differences because the dynamic nature of software development results in changes in requirements and specifications, resulting in frequent time and cost over-runs, which are often shared between the Indian vendor and the overseas client. Over half of the firms surveyed by Arora et al (2000) indicated that their most important export project was a cost plus contract, and fewer (42%) of the firms had a fixed price contract for their most important export project.

Multinational corporations

Multinationals are quantitatively far more significant in Ireland than India. In India the early entry of MNCs dates back to the mid 1980s (e.g., Citicorp and Texas Instruments). The initial objective of MNCs was to sell in the Indian market. Later on, however, the main objective became to use India as an export platform. Today some US MNCs have established software development centres in this country. For example, Oracle, like Texas Instrument, Cadence and Motorola, conducts quite sophisticated developing activities in India (e.g., the operating system of Oracle's Network Computer is said to have been developed in India). Increasingly, MNCs are setting up development centers in India as a way of meeting the high demand for IT trained engineers and software developers.

Similarly, in Ireland Sun Microsystems has opened an Internet software development centre and Motorola a cellular phone software development centre. These operations are centred on telecommunication software - search engines, TV, WAP software and broadband mobile phone-internet connection software. However, the majority of foreign-owned firms in Ireland, such as Microsoft, Claris Manufacturing and Symantec, concentrate their local operations on low value added, low skill activities such as porting of legacy products on new platforms, disk duplication, assembling/packaging and localisation (text translation, changing formats etc.). For instance, Oracle, Corel and Novell outsource most of their work and specialise in project management, and administrative or sales backoffice activities (including multilingual customer support). The bulk of Irish exports in this industry are accounted for by multinational corporations that use Ireland as an export platform, where most of the value is added before the software arrives in Ireland for localisation, kitting and distribution (FAS, 1998:27).

An example of this category of foreign-owned firms is represented by a US software house (software packages).[13] Almost all of the revenues of this subsidiary arise from sales of products (licensing fees) and services in Europe and other close by regions. Over 60% of these revenues are assigned to the Irish subsidiary even though sales operations are conducted by subsidiaries or agents located in other European countries. The Irish subsidiary is responsible for backoffice operations like marketing, order processing, preparation of offer conditions for the sales forces, packaging and product localisation for the European market. The licensing fees on product sales are paid to the Irish offices. The remaining 40% of revenues comes from consulting services in European countries, which only in part are conducted directly from Dublin. A limited amount of development is carried out in Ireland, mainly related to localization on specific issues such as bi-directional software for bi-directional languages spoken in the Middle East. The operations in Dublin are responsible for the management of the localisation process which consists of the following operations - disassembly of the original product into different modules and formats (text, GUIs etc.), testing of modules translated, debugging, product reengineering and repackaging. Most of these activities are conducted in-house. Some operations (such as testing, material supply, software manuals and translation) are subcontracted to suppliers located in Dublin or in other EU countries. Many other American software houses located in Ireland fit a similar profile. This result is in line with previous empirical evidence about the activities of MNCs in developing countries. For

[13] We are not authorised to publish the name of this firm.

instance, Pearce and Singh (1992) show that MNCs tend to locate in developing countries only a limited amount of R&D activities.

To sum up, compared with the SV model, software activities in these countries are largely complementary rather than in direct competition with the market leaders. India and Ireland specialise in relatively low value added phases and in niche business applications or products (such as telecommunication software, security software and enterprise solutions). Only a few firms have reached an international position in larger market segments such as Iona of Ireland in middleware.

4. The sources of competitive advantage and growth

In analysing the factors that explain the patterns of development discussed earlier, we must distinguish between factors that have played a role in the early stages of growth and factors that have emerged at later stages. Our analysis suggests that the early stages of the development process map well on to traditional development models that emphasize factors such as the relative abundance of skilled labour. In subsequent development stages "new" factors such as agglomeration economies may increase in importance.

4.1. Economic development with unlimited supplies of labour?

The rising international *demand* for IT, of which software and services represents about 50%, is a major factor explaining the growth patterns observed in Ireland and India. US spending for IT equipment in current dollars increased from $142bn in 1993 to $233bn in 1998.[14] As a result the contribution of IT spending to change in real capital equipment spending rose from 33% in 1993 to 58% in 1998.[15] The expenditures on software and services also rose during the 1990s and the increasing complexity of business applications spurred many user firms to outsource their IT activities. These trends have obviously greatly increased the demand for IT skills.[16] The Information Technology Association of America (ITAA), an industry group, estimates that there were about 859,000 IT positions vacant in U.S. firms in three core IT occupational clusters (programmers,

[14] The price of IT equipment in the US has declined from -2.4% in 1993 to -7.5% in 1997 (US Dept. of Commerce, 1999, Table 2.2).
[15] The average annual rate of growth at constant prices expenditures on IT equipment during 1990-1996 was 23.8% in the US, 18.6% in Western Germany and 17.6% in the UK. The corresponding growth rate for communication equipment was 5.1%, 3.4% and 2.2% in the UK (OECD, 2000, Table V.3).
[16] The issue of IT skill shortage has been debated since the 1960s. Skill shortage has contributed to the software 'productivity crisis' which during the 1980s and 1990s has spurred the introduction of new software engineering tools in the US and Europe (Torrisi, 1998).

systems analysts, computer scientists and engineers) (ITAA, 2001)[17]. As a consequence, the US government has increased the number of H1-B temporary visas to foreign workers from 65,000 in 1999 to 115,000 in 2000 (and 195,000 in the three following years) (Gomolski, 2000). Similarly, the European Commission has estimated about 500,000 vacancies in 1998 and about 1,200,000 by 2002 (EC, 1998).[18]

In the 1980s and early 1990s both India and Ireland had a large pool of IT skilled people. For instance, by the late 1980s India was graduating approximately 150,000 English-speaking engineers (all disciplines) with only a limited demand for their services from the rest of the economy. The large pool of skills also attracted several foreign-owned firms (such as Siemens Information Systems, IBM, Motorola, Oracle and Sun) that established their development facilities.

In Ireland the accumulation of human capital started well before the international skill shortage became a serious bottleneck. In Ireland the share in GNP of public expenditures for education doubled in the 1960s, from 3% in 1961/61 to 6.3% in 1973/74). Today the share of university educated workers (about 26%) is in line with the average of OECD countries. The number of graduates, certificates and diploma holders in computing between 1991 and 1996 has increased by 44%, 27% and 72% respectively (FAS, 1998, p. 80). To meet the increasing demand for skills Irish colleges have both admitted a greater number of students to their programmes and have also increased the variety of computing courses (including joint degrees where computing is combined with another subject, often a foreign language).[19] Table 10 shows the distribution of computing-related higher education by level in 1996.

The share of graduates in computing and related disciplines is particularly high in Ireland also in comparison with other countries - 10.3% compared to 12% in German, 5.5% in Italy, 4.8% in the US and 10.3% in the UK. The share of applied computing graduates is even higher – 14.6% compared to 4.4% for all OECD[20].

[17] The ITAA survey is based on interviews with 191 IT producers and 494 non-IT producers. The skill gap was about 190,000 before 2000 (US Dept. of Commerce, 1998) and is expected to fall afterwards (about 425,000 unfilled positions are expected for 2001 according to ITAA). These estimates are controversial but the increase in demand for skilled IT professionals is not.

[18] In Canada the gap is estimated between 20,000 and 30,000 people ((US Dept. of Commerce, 1999).

[19] According to FAS's estimates the output of computing-related tertiary education system is expected to increase in the next few years - from 1,840 people in 1996 to 2,970 people in 2000 and 4,314 in 2002 (FAS, 1998, p. 110).

[20] One should remember that scale of this labour supply is limited when compared to large countries like the US, where there are over 1.5 million IT workers (with different levels of IT education). As table 10 shows, in Ireland, the total annual output of certificants, graduates and diplomates in computing totalled 1,840 in 1996 and the number of employees in the software industry were 18,300 in 1997.

Though we lack direct measures of the excess supply of skills in India and Ireland, the imbalance is reflected in the significantly lower labour costs compared with other countries. As table 11 shows, in Ireland the total compensation of a project leader and a computer analyst in 1995 was not significantly different than in the UK or in Canada. The widest wage gap concerns the lower end of the skill spectrum (test engineers).[21] As far as India is concerned, the wage gap with North America and the UK is quite significant for all levels of qualification.

The rising demand for skills in Ireland and India has been so rapid during the 1990s that wages of software professionals have grown very rapidly in recent years. According to FAS estimates, in Ireland average salaries have increased at about 20% in the period 1995/97 while productivity growth has lagged behind (at about 13% per annum between 1993-95) (FAS, 1998). In India too, wages have grown at 20% per year, with wages for experienced project managers and skilled designers and developers growing much faster. Turnover rates in excess of 20% are common and more than half of the over 100 firms surveyed in Arora et al (2000) indicated labour shortages as their biggest problem. The labour market in India is made even tighter by the estimated annual loss of 10,000-20,000 IT professionals to the US and elsewhere. This outflow is increasing due to the increasing H1-B visa limits in the US, and a very substantial fraction of emigrants are experienced developers and project managers.

This story is in line W. Arthur Lewis's development model, where growth takes place as labour is reallocated from low productivity traditional sector to the higher productivity modern sector (Lewis, 1954). In the Lewis model, growth lasts as long as the labour can be reallocated without changing the terms of trade in favour of the traditional sector or without increasing wages. Both countries have "enjoyed" a weak industrial base, with low employment opportunities for engineers and professionals. Thus, the growing software industry could readily claim not only new graduates with the required skills, but could also lure away human capital from other sectors of the economy. By contrast, leading European economies like Germany have good IT capabilities and many established firms in the electric and electronic sectors that can absorb these capabilities (e.g., Siemens, ABB and SAP). A weak industrial base may have more subtle benefits as well. A weak industrial base reduces institutional inertia (resistance to change by established institutions) as pointed out by Saxenian in the case of SV: "Silicon Valley's founders…shared a distrust for established East Coast institutions and attitudes...As newcomers to a region that lacked prior

[21] According to the US Department of Commerce (1999) the average annual earning in software and services industries was about $59,000 in 1997 and have grown at about 6.4 percent per year since 1989.

industrial traditions, Silicon Valley's pioneers had the freedom to experiment with institutions and organisational forms as well as with technology" (Saxenian, 1994, p. 30)[22].

Many other regions have a weak industrial base and an excess supply of human capital with out developing a successful software export sector. Obviously, it is the combination of international demand, skills and low opportunity costs (along with some agglomeration advantage) that explains the difference between Ireland/India and other developing (or newly developed) regions.[23] In the cases of India and Ireland the linkages with the US and UK, due to the language and the network of skilled immigrants, have most probably favoured India and Ireland as locations of outsourced activities for both IT and non IT firms.

4.2. Building on success

India and Ireland seem to have leveraged their initial comparative advantages in services and localization to move up the value chain (India in large systems integration and business consulting, Ireland in specialised software products and high end technical consulting). The initial conditions (e.g., international demand and supply of skills and low opportunity cost of human capital for both software engineers, managers and entrepreneurs) opened a window of opportunity. The point of interest is represented by the factors that enabled these countries to build upon the early, and somewhat fortuitous, successes. The early success provided a model for entrepreneurial entrants, provided the political pressures for favourable government policies, and provided very useful visibility in major markets. Although we cannot document these forces adequately in this paper, it is noteworthy that though young, in both the countries, the industry is well served by industry associations that have enjoyed high visibility, both domestically and overseas. The Indian software industry association, NASSCOM, has been a very vocal and potent force in pushing for a variety of policy measures helpful to the growth of the industry. These measures include relaxation of rules regulating the access of companies to the capital markets, improving the ability of firms to issue

[22] This idea is confirmed by Gordon Moore and Bob Noyce experience with Fairchild. Soon after they founded Fairchild Semiconductor, as an affiliate of Fairchild Camera and Instrument, the two scientists-entrepreneurs realised that the parent company's ways of managing a technology firm was incompatible with the Silicon Valley style. Gordon Moore explained these difficulties by noting "I think this was partly because we were controlled by an East Coast company" (Moore and Davis, 2000, p. 8).

[23] A process similar to Ireland is probably occurring on a smaller scale in Sicily. In the so-called 'Etna Valley' the abundance of skills largely unemployed (about 26% unemployment rate) and the presence of specific job creating incentives exempting the payment of Italian social welfare charges for six years has facilitated the formation of more than 200 small and medium sized firms around a few large electronics firms such as ST Microelectronics, Nokia, Alcatel and Canon (Betts, 2000).

stock options to employees, easing of foreign currency transaction related regulations, and improvements in telecommunication infrastructure. NASSCOM has also done well in building visibility in the US through various activities. The initial success of some Indian firms, along with the prominent role of Indian entrepreneurs in the SV itself, has done much to overcome the "made in India" stigma for software. In turn, this has helped new firms enter the market and find customers, and not merely in the traditional software services. In short, success has bred success.

Agglomeration economies: imitation, labour mobility, vertical/horizontal linkages

Typically, such a story of mutually reinforcing forces, or a "virtuous circle", to use Nagnar Nurkse's phrase, involves a variety of spillovers and externalities across firms and sectors. Typically as well, these externalities are geographically localized, and identified with clustering of industrial activity. Clustering can have a number of advantages, such as the thick labour markets, better physical and commercial infrastructure, the development of ancillary, supporting industries, and information spillovers across co-located producers of similar products (Arthur, 1990; Krugman, 1991; Storper, 1993; Saxenian, 1994; Porter, 1998). In short, industrial clusters can develop in regions which do not have traditional comparative advantages if, for whatever reason ('historical accident'), a critical mass of firms is attracted into these regions. Agglomeration economies and historical accidents then drive the process of geographical concentration (Arthur, 1990). One of the most celebrated forms of such agglomeration economies is represented by knowledge externalities which may take place in the form of largely unintentional information spillovers (e.g., through imitation and mobility of skilled personnel) or in the most explicit form of linkages or collaboration among firms (Storper, 1993; Saxenian, 1994, Porter, 1998).

Our analysis shows that the main source of initial advantage is represented by the availability of skills at the right time (which only in part can be considered as an 'historical accident'). Here we have also some agglomeration economies at work. For instance, we have a case for 'imitation effects'. "Early success" has played a role in catalyzing future development through the action of 'role models', experience, learning, rising self-confidence, easier access to capital, and declining social stigma towards failure. As in SV, the examples of successful firms like Baltimore and Iona in Ireland and TCS, Infosys and Wipro in India have created some 'follow-the-leader' effect'. There are quite a few examples of firms that have spun off from first comers - e.g., Euristix from Baltimore, Airtel ATN from Vertel (US), Allfinanz (now FM Systems) from Siemens, Infosys from PCS. More generally, over 50% of the founders of Irish firms interviewed for this study have

worked for a period in a large firm in the IT sector (see the Appendix for the methodology). In India, we identified over 18 software firms spun off from TCS and HCL, and a number of the top managers in the industry have worked at TCS, HCL, Wipro and CMC.

To explore the effect of different sources of potential spillovers we conducted a survey of 41 software firms in Ireland (see the Appendix for a description of the methodology). Table 12 illustrates different factors that can impact upon the competitiveness of the firm - e.g., knowledge spillovers from co-located competitors or suppliers, physical and commercial infrastructures. Except for the access to skills and infrastructures, we did not find support for vertical or horizontal externalities such as those observed in SV (and may be other high tech clusters).[24] Neither did we find strong evidence of decentralised networks of small Irish software firms similar to those observed in countries like Taiwan (O'Riain, 1999, p. 143).[25]

Agglomeration economies based on knowledge spillovers or firm networks appear to be relatively unimportant in the Indian case as well. Contrary to popular belief, the Indian software industry is not concentrated exclusively in Bangalore, although Bangalore is certainly a very prominent location, along with Bombay, Pune, Madras and Hyderabad are important as well. However, with the exception of the region around Delhi, there are no noticeable clusters in the northern or the eastern regions of India. Although we do not have direct evidence on whether this clustering reflects agglomeration economies, a more direct alternative explanation for this clustering can be found in the supply of engineering graduates. The distribution of engineering colleges, concentrated in the western and southern regions, closely mirrors the distribution of the software industry. As Table 13 shows, engineering colleges are heavily concentrated in these two regions, which also account for the greater part of employment in the Indian software industry. Moreover, much of the difference is due to privately financed (as opposed to Federal or State financed) colleges, most of which preceded the growth of the software industry.

[24] As expected, fiscal incentives are moderately important for MNCs.

[25] Our field analysis also shows that trade associations like the Irish Software Association, the Irish Internet Association and the First Tuesday Club, are not important in the development of formal or informal links with competitors and partners. This is especially the case of firms with a strong international presence such as Baltimore and Iona. But also smaller firms that have started to go abroad more recently pay less attention to local networking. This is the case, for instance, of Premier Computer Group, which entered the UK and South Africa markets by acquisition of local firms, and Q-Set, which has set up an office in Boston and has recently acquired a US firms.

International linkages, and the advantages of late comers

International linkages have played a major role in the development of software activities in India and Ireland. The advantages of openness has arisen in two forms:

- international mobility of skilled people and the network of linkages that many former expatriates maintained with foreign business communities;
- access to the services of foreign institutions such as VC firms.

During the 1980s in Ireland and in India the excess supply of skills induced many skilled people to emigrate to the US and the UK to fill the gap of IT skills in those countries. The many costs of the loss of such human capital notwithstanding, it had some benefits as well.

These expatriates provided valuable links with foreign markets, helped Indian and Irish firms to absorb technical and managerial practices and establish contacts with foreign customers. For instance, some Indians who had emigrated to work in US firms in the 1980s have helped US buyers to find suppliers in India. Field interviews with US customers revealed that in a couple of case, the initial impetus for outsourcing to India came from employees of Indian origin. In another case, the US firm was founded by an Indian immigrant. Most, if not all, US subsidiaries in India are headed and staffed by employees of Indian origin. In some cases successful Indian entrepreneurs have also provided money to Indian firms as 'business angels' and help establishing links with US based venture capital firms.

Moreover, in India and in Ireland, returning emigrants have brought with them an important background of working experience in advanced technological and business environments and personal linkages with the international business community. In our interviews with Irish firms we found several examples of people with working experience abroad. Until recently Ireland, along with the UK, was the single EU largest source of emigration to the US, with a large share of emigrants being directed to California[26]. Over time, however, emigration flows have changed substantially. During the 1990s net immigration has increased significantly (from –400 in 1993 to 22.8 thousands in 1998). Over 53% of immigrants to Ireland in this period were Irish returning emigrants. And over 25% of male emigrants with college education have returned to Ireland during the 1990s. Most of these are in the 25-44 years age group (this is the age group with the highest rates of net migration during the 1990s).[27]

[26] About 25% of EU emigrants went to California in 1997 (Mahroum, 1998).
[27] Over 40 percent of Irish graduates in the age of 40 have worked abroad for at least one year (Travers, 1999) and over 73 percent of students who have completed the secondary school have studied a European language (NSD, 1998).

India has been a net exporter of human capital for several decades. Although we lack systematic data, it is believed that Indians account for a very large fraction, perhaps over half of the H1-B work permit visas issued by the United States. Similarly, recent reports suggest that the overwhelming fraction of students graduating computer science at IIT Madras, an elite engineering institute in India, move overseas upon graduation. Thus, despite the growth of the software industry, India continues to be a next exporter of human capital. However, some of these exports are now tied to the growth of the Indian software industry, with many software developers and programmers working overseas for Indian software firms.

International linkages, rather than local ones, have represented an important source of capital for Irish firms as well. For instance, Sun purchased a minority stake in Iona while another large Irish firm, Kindle Banking Systems, has been acquired by Mysis Group of the UK. Another example is Euristix, a medium-sized Irish firm (150 employees) specialised in telecommunication software, which was acquired by Marconi (UK) in 1999. The state agencies have tried to substitute for the lack of local VC firms by helping domestic firms to find capital. However, compared with US venture capitalists, they have been much less important as institutions that facilitate the formation of business partnership. Before 1997 the state was the major supplier of capital to domestic software firms, especially to small startups. Only recently private capital started to become significant. In the period between 1997 and 1999 total investment by venture capital finance increased from $44m to about $178m. In the same period the share of the public sector decreased from 57% to only 8.2% of total funds while that of foreign investors increased from zero to 21.3 percent. (Matheson Ormsby Prentice, 2000).[28] Software was the largest sector of destination for the number of firms backed while it was the third largest for the amount of capital received (after the non financial and the financial sectors respectively)[29].

The typical business model for Indian software service firms does not call for venture capital. Software services, especially for export, are a very profitable business with good cash flows and limited requirements for up front investment. Therefore, finance is not a major problem for software service firms, unless a firm wishes to expand rapidly or wishes to expand overseas. More

[28] The MOP survey covers financial transactions signed by the 15 Irish venture capital funds belonging to the Irish Venture Capital Association (IVCA) and about 22 international funds associated to IVCA. Among IVCA's members there are publicly-owned firms such as Enterprise 2000 fund Ltd (a joint venture between the Bank of Ireland and Enterprise Ireland).

[29] Software firms account for the largest part of 'Support services' firms. Internet-related firms alone received $22.45m in 1999. In India the inflows of capitals to this industry is larger. The IT sector received from business angels and VCs more that $300m in 2000 (from $20m in 1996).

than half of the firms surveyed in Arora et al (2000) indicated that they relied upon personal funds for start-up finance, and only a few firms indicated difficulty in obtaining finance as a major problem they faced.

Obtaining finance is, however, a major concern for firms developing software products. In contrast to services, a substantial investment is required to develop the product, and even more to market the product. Firms that are trying to develop software products have faced problems in getting finance, in part because the inexperience and conservatism of Indian venture capital funds.[30] The problem, it appears, is as much on the demand side as on the supply of venture capital. Venture capital funds associated with well-known Silicon Valley venture capitalists, such as Draper International, have only been able to use 60% of the allocated funds. In addition to the usual problems involved in setting up businesses in India, venture capitalists are interested primarily in products developed for large markets, and therefore, for products that can succeed in the US. Developing products for the US market from India is widely thought to be very difficult. In recent years, as a number of firms focused on product development, or on internet and e-commerce have emerged, and alongside, there has been a concomitant increase in the supply of venture capital and venture capital firms. In 1998, about $1.3 billion had been committed in venture capital (SEBI, 1998), and following policy changes in 1998, a number of firms, included overseas funds, have entered the market. The number of venture capital funds registered with SEBI increased from 8 in 1996-1998 to 14 in 1999-2000.[31]

The interesting point is that as venture capital has become more valuable, firms have been able to get access to such financing, including that from US based firms. More generally, late comers may have access to more efficient markets for key services (e.g., venture capital, legal consulting and general management consulting) compared with the leaders. Being a follower is not the same thing as being the first mover because the cost of using the services of supporting institutions is smaller. First, some of these institutions can be imitated (hence there is no cost in getting the idea), and there is experience about how these institutions function (this is a kind of knowledge externality). Second, to the extent that there is international openness, and these institutions are mobile, one need not generate a certain institution locally, but could acquire the

[30] A manager for an Indian venture fund run by a public sector investment bank noted that although they had invested in as many as 32 firms in the past, only 5 were product focused, the rest being software service firms focusing on exports. However, this venture capital operation no longer invests in start-ups. Instead, they fund expansion or new product development by existing firms with good track records, or by proven star managers in the industry. Funding investments are in the range of $400,000 to $500,000 per funding round.

services produced by such institutions elsewhere. This is the case of venture capital, which, as mentioned before, tends to become more and more internationalised. As the Irish Minister for Science, Technology and Commerce has recently pointed out, " in the context of increasingly European and indeed global investment the concept of local capital sourcing may become irrelevant to a sector increasingly confident on its own capabilities and potential" (Treacy, 2000).

The existence of Silicon Valley, and more generally, a set of advanced countries, is a mixed blessing. Though it provides a ready set of technologies, inputs and institutions to be imported and imitated, it also acts a powerful draw for innovative companies and creative minds. Mention has already been made of the large number of trained IT professionals moving to the US. The gravitational pull acts on Indian firms focusing on developing products for export markets as well. Venture capitalists prefer that the firm be located close at hand. The equity markets of the US have been the friendliest to technology based firms of any, and if that were not enough, the US (and in particular, the Silicon Valley) is where the lead users for many of these products are to be found.

A good example is represented by Greycell Technologies (now Unimobile). This company, which develops software for mobile telecommunications, has recently received financial support by 'business angels' from California and has moved its headquarters to the Silicon Valley to have better access to worldwide market. Another example that points out the importance of key inputs provided by foreign sources is Aztec Software and Technology Services, a firm founded by a computer engineer who studied and worked in the US for DEC during the 1990. Atzec was founded in 1996 with the aim of focusing on "revenue-producing projects that would build core expertise in product development" . They started by developing a database tool on a turnkey basis for a Silicon Valley subsidiary of BMC Software Inc. (a Houston-based firm) which then became their parent company. Aztec realised that their main market opportunities were in the US and therefore it was important to raise new capital there. Relatedly, Aztec's founders understood that for a product firm targeting the US market sales and marketing costs (in US dollars) would be as large as ten times development costs and that it would have been extremely unlikely to find Indian financial institutions willing to provide the required capital. For this reason Atzec relied on its US parent company to raise capital in the US market (Miller, 1998).

[31] http://www.nasscom.org/template/Venture%20Capital1.htm downloaded on 10 August, 2000

Multinational corporations and large firms

One of the typical strength of SV is represented by the presence of large firms such as Fairchild, IBM, Hewlett-Packard and Xerox that conduct R&D at the technological frontier. These firms have created many technological externalities for start-up firms located in the same region.

Established high tech firms and large firms in general appear to be less important in terms of technological externalities for both Irish and Indian software firms. However, in Ireland (and to much lesser extent in India as well) MNCs represented a source of human capital spillovers. The outflows of skilled people from India and Ireland during the 1980s and in part also the 1990s might have hampered the development of local software activities in these countries. The main reason why this did not happen in Ireland is represented by the employment of skilled people by foreign firms and domestic IT user organisations (e.g., in the food and chemicals/pharmaceutical industries). These firms have absorbed a number of software engineers and contributed to the formation of a large base of experienced talent upon which many of the software start-ups drew in significant measure (O'Gorman et al., 1997).[32].

The intensity of these spillovers has been particularly large for Irish firms specialised in localisation and testing services. DLG, a small Irish firm specialised in localisation software development and testing (62 employees) has greatly benefited from its managing director's previous working experience with Lotus, which helped consolidate links between the two firms. The manager has helped the DLG's staff to absorb organisational and management best practices from Lotus. These practices include project management (clear tasks definition, use of milestones, rigorous assessment criteria) and relational and marketing capabilities (ability to conduct a business negotiate, sales skills and formal presentation skills)[33].

Moreover, MNCs often represent a source of revenues for domestic Irish firms. Many successful Irish software firms have started as programming houses (subcontractors) for the local subsidiaries of IT MNCs or as software application developers for non-IT customers (either Irish or foreign-owned firms). They have exploited the network of early customers and the reputation arising from well established customers to gain access to foreign markets (O'Gorman et al. 1997). This is also illustrated in table 14. An example is represented by Kindle Banking Systems, which

[32] Until recently, the outflows of human capital was not a significant drawback for India, given the small size of these outflows relative to the stock of human capital, and given the limits on the number of Indians moving to the US to work. The expansion of the H1-B visa cap has had many benefits for Indian software firms but it has also added substantially to the difficulty of finding experienced developers and project managers.

started in the 1970s by supplying services based on an ICL platform for a US bank located in Dublin. Kindle continued to work in collaboration with ICL and this link allowed Kindle to gain access to a wide base of customers abroad (O'Riain, 1999). Iona Technologies also leveraged early ICL to enter new alliances with other IT customers (HP, NT, Motorola).

Public policy

Institutional innovations have often been of fundamental importance in paving the way to technological change and economic growth (Rosenberg and Birdzell, 1986), and public policy has a major role in affecting such changes. By and large, however, the Government has not played a crucial role in our story. The government has facilitated the growth by providing a good investment environment (e.g., through fiscal incentives and trade tariffs). It has also supplied other public goods - mostly skills and, to a lesser extent, infrastructure.

In Ireland some of these policies have anticipated the growth (e.g., education, favourable trade policies and fiscal incentives in the 1960s) while new policies followed the development process later on (e.g., R&D and employment grants to domestic startups). In India public institutions and public policies adapted more slowly to change. The software industry grew rapidly in the wake of the economic liberalization that had begun in 1991, which provide some respite from the normally stifling laws regulating imports and exports. Over time, the industry has been successful in winning other concessions as well. These policies relate to capital (e.g., easier listing requirements for companies, better tax treatment of export earnings, better tax treatment for options), infrastructure (e.g., physical and communication infrastructure, allowing private ISPs,), labour and training, and exports.[34]

The Indian case, however, is best characterized as one of benign neglect, where the State did not intervene to strangle the growth of the software industry, as it once might have. The State appears to have played a more positive and helpful role in Ireland. A systematic analysis of public policies (and their many failures) in the development of the software industry is beyond the scope of

[33] 'MNCs, especially from the US, have done for the development of this economy more than we can ever imagine especially in terms of confidence in what you do' (interview with the Managing Director of DLG, 21/4/2000).
[34] India has slowly been liberalizing the economy. Since 1991 the Indian government has introduced specific measures to favour software exports and inward foreign investments (relief from import duties on hardware and software, tax exemption for income arising from export, and tax vacancies for firms operating in technology parks and software export zones). The number of software technology parks in particular has increased very rapidly, from 164 in 1991-92 to about 1,400 in 1999-2000 (source: The Indian Ministry of Commerce and the Indian Ministry of Information Technology, http://commin.nic.in and http//www.mit.gov.in respectively).

this paper. In what follows, we focus on the case of Ireland as an interesting example of successful development policies.

The importance of industrial policies for the development of Ireland in general and for the software industry in particular is a matter of some debate. At one extreme, some scholars claim that software development in Ireland is mostly the result of 'unplanned and unforseen phenomena' such as the evolution of the software industry worldwide, which in the 1990s favoured a greater geographical dispersion of production, and 'a happy' accident represented by a surplus of software professionals at the right time (Sterne, 1999). Krugman (1997) presents a more moderate view wherein Ireland has been favoured by the changing geography of the world economy which has shifted towards more service-intensive products, which are less influenced by traditional comparative advantages or transportation costs. Ireland, with apparent locational disadvantages, could take advantage of this trend by specialising in activities that do not require daily contact with corporate headquarters but need to be close to the market (backoffice locations). In software, the Irish location advantage is represented by the proximity with the EU markets.

Why then software did not take off in Spain or Portugal? The reason is the large supply of an English-speaking, well educated labour force. Skills endowment and a comparatively good infrastructure (air transportation and telecommunications) make Ireland an attractive location for multinational corporations aiming to establish an export platform to serve the EU markets. A combination of 'good luck, good timing, and good policy' has then given to Ireland an initial advantage t as an export platform for multinational corporations.[35]

On the other hand, there are scholars who claim that growth in Ireland has been primarily driven by a 'flexible developmental' set of institutions, themselves the outcome of a "development strategy" pursued by the State (O'Riain, 2000). The strategy consists of linking Irish firms with global business networks, either directly or indirectly through MNCs. Since the end of the 1950s the Irish government has promoted development through policies of 'industrialisation by invitation' of foreign investments (Tallon and Kraemer, 1999). These policies have relied on different instruments - namely tax incentives, and investment in skills and infrastructure. [36] These measures were mostly centred on high tech, successful foreign firms ('picking-the-winner' approach). Enterprise Ireland is

[35] Krugman also submits the hypothesis that building upon these initial advantages, Ireland has probably benefited from agglomeration economies, associated with Marshallian externalities and demonstration effects ('follow-the-leader'), which have reinforced the initial advantages (Krugman, 1997, p. 51).

[36]Fiscal incentives fiscal incentives and grants are often cited as an important reason for the Irish success. The standard 28% corporate tax (25% for SMEs) in Ireland is the lowest in the EU (along with those of Finland and Sweden).

the most important government agency for the support of software firms. It controls a variety incentives: grants (R&D, employment and training grants), tax breaks (for exporters), consulting (e.g., the Target Marketing Consultancy), and seed capital (e.g., it holds a minority stake in Peregrine). It also helps Irish firms to establish contacts with foreign institutions and firms.

Why have Irish state agencies been effective in sustaining the development of high tech industries in Ireland? A crucial feature of public agencies such as IDA and Enterprise Ireland has been a relatively high autonomy from the central administration and the links with the business community. Although IDA and Enterprise Ireland share some key characteristics with the central bureaucracy (Breen et al., 1990), they have some degree of autonomy in the recruitment policy. More importantly, some top executives came from the business sector and have maintained their links with private firms. For instance, Jennifer Condon in the 1980s joined the National Software Centre after a long working experience in the software industry. She worked as a developer, a designer and a marketing manager at the ICL-Fujtsu's software development Centre in Dublin. She currently leads a small group of officers (about 10) at Enterprise Ireland, half of whom with private sector business experience.

5. Conclusions

This paper compares the development of software activities in two late comer countries (India and Ireland) with the Silicon Valley model. Compared with SV, most Irish or Indian firms focus on low tech activities such as professional services, localisation, outsorcing development and testing projects. Only few firms, many of which are university spin-offs, specialise in high tech products and solutions - e.g., financial and security software, air traffic telecommunications, software for device drivers, and chip design software. The latter category of firms has developed first in Ireland and more recently in India as well. These firms often occupy market niches that are not occupied by US firms. In both countries there are examples of service firms that have moved up the value chain by focusing increasingly on higher quality services and products or business solutions.

Multinational corporations and large domestic firms have played a much less important role than in SV. This is largely due to the fact that the most important markets are the external ones and for the most part, the most innovative and creative activities of these MNCs take place close to those markets. MNCs and large domestic firms, however, have contributed to the formation of skills. In some cases they have also helped domestic start-ups to enter the foreign market.

Affirmative public policies have not played a crucial role. In India the government has helped largely by simplifying rules and regulating with a light hand, as well as by helping firms with physical and communication infrastructure. But the State in Ireland has been much more active in providing public goods that facilitate the development process (e.g., skills, fiscal incentives, infrastructures, capital and consulting to new start ups).

The Indian and Irish software sectors have grown despite a relatively narrow range of activities, and without strong links among the firms in the sector. Our analysis points out the importance of the international demand of IT, the supply of skills at the right time, and low opportunity costs of skilled people. Apart from these initial advantages, there also some agglomeration effects that have emerged over time - e.g., , imitation of early successful firms, and the inflows of foreign venture capital.

The absence of horizontal links (with complements in other industries and rivals) and vertical links (with input suppliers and customers) marks an important difference with the SV model. It also may handicap innovative firms and raises questions about the ability to sustain growth once the initial source of advantage – the excess supply of trained English speaking engineers – diminishes in importance. But it appears that the head start enjoyed by India and Ireland will be very helpful in staving off the challenge from other followers. It may also permit sustained growth by encouraging entry of new and innovative firms that follow the early successful comers. This particular form of agglomeration economy should be monitored carefully in future research. Another issue that requires a special attention in future research is the role played by multinational corporations in these countries. The issue is particularly important for Ireland because of its high dependence on MNCs exports. Our analysis provides mixed evidence on this issue. Though many Irish firms do not recognise the importance of MNCs as a source of skills, a large fraction of Irish software managers we interviewed had previously worked in MNCs. But, with a few exceptions, it is not clear what kind of knowledge they have accumulated from their previous working experience (technical, managerial or marketing capabilities).

A final topic that needs more exploration in future research is about the characteristics of migrants and the specific roles they have played in the growth of the software industry in their home countries. Finally, the role of returning emigrants also needs more careful analysis. What factors determine the decision to return, and what roles returning migrants have played remains an important question for further research.

Bibliography

Arora, A. et al. (2000), "The Indian Software Services Industry", *Research Policy*, forthcoming.

Arthur, B. (1990), 'Silicon Valley Locational Clusters: Do Increasing Returns Imply Monopoly?', *Mathematical Social Sciences*, 19, pp. 235-251.

Betts, P. (2000), "A High-Tech Eruption in Etna Valley", *The Financial Times*, October 17.

Birkinshaw, J. and Hood, N. (2000), Characteristics of Foreign Subsidiaries in Industry Clusters", *Journal of International Business Studies*, 31, 1, pp. 141-154.

Bannerjee, A., and Duflo, E., 1998, "Reputation effects and the limits of contracting: A study of the Indian software industry", unpublished paper, MIT, Cambridge, MA.

EC (1997), *Panorama of EU Industry 97*, vol. 2, European Commission, Brussells.

EC (1998), *Job Opportunities in the Information Society*, European Commission, Brussells.

Enterprise Ireland (2000*), Business Opportunities in India. A Guide for Irish Software and IT Companies*, National Software Directorate, Enterprise Ireland, Dublin.

FAS (1998), *Manpower, Education & Training Study of the Irish Software Sector*, Foras Aiseanna Saothair (Training & Employment Authority), Dublin, April.

Forfas (1995), *Research and Development in the Business Sector: findings from the 1993 Census of R&D Performing Enterprises in Ireland*, The National Policy and Advisory Board for Enterprise, Trade, Science, Technology and Innovation, Dublin (www.forfas.ie).

Forfas (2000), *Research and Development in the Business Sector: findings from the 1997 Census of R&D Performing Enterprises in Ireland*, The National Policy and Advisory Board for Enterprise, Trade, Science, Technology and Innovation, Dublin (www.forfas.ie).

Gomolski, B. (2000), "More High Tech Visas Not a Solution to the IT Skill Shortage", *Management Strategies & Directions*, Gartner Group, October 6, www.gartnergroup.com.

Heeks, R. (1999*), Indian Software Labour: Cost Breakdown and Comparison*, IDPM, University of Manchester, Manchester, UK (http://www.man.ac.uk/idpm/isicost.htm.

IASH (1999), *Israel Software and Computing Industry*, Israeli Association of Software Houses, (www.org.il).

ITAA (2000), When Can You Start? Building Better Information Technology Skills and Careers, Information Technology Association of America, Arlington, VA (www.itaa.org).

Krugman, P. (1991), 'Increasing Returns and Economic Geography', *Journal of Political Economy*, vol. 99, 3, pp. 483-499.

Krugman, P. (1997), 'Good News from Ireland: A Geographical Perspective', in Grey, A. W. (ed.), *International Perspectives on the Irish Economy*, Indecon Economic Consultants, Dublin, pp. 38-53.

Kumar, B. (2000), Betting on Productised Software, *The Hindu Business Line*, Internet edition, www.hindubusinessline.com/stories, November 10.

Lewis, W. A. (1954), "Economic Development with Unlimited Supply of Labour", *The Manchester School of Economic and Social Studies*, vol. 22, May, pp. 139-191.

Mahroum, S. (1998), "Europe and the Challenge of the Brain Drain", *The IPTS Report*, IPTS-JRC, N., 29, Seville, November.

Miller, M. (1998), 'Indian Software: A New Renaissance', *Global Tech Ventures*, September, www ????.

Moore, G. (with Kevin Davis) (2000), Learning the Silicon Valley Way, SIEPR, Stanford University, mimeo.

Noronha, P. (2001), "L&T Infortech Plans IPO nNext Year – Unveils Insurance Software", The Hindu Business Line & Indiaserver.com.

NSD (1998), *Ireland as an Offshore Software Location*, National Software Directorate (downloaded from the website: www.nsd.ie).

NSD (2000), *Survey of the Software Industry*, National Software Directorate (downloaded from the website: www.nsd.ie).

O'Gorman, C., O'Malley, E. and Mooney, J. (1997), *Clusters in Ireland. The Irish Indigenous Software Industry: an application of Porter's cluster Analysis*, NESC, National Economic and Social Council, Research Series, Research Paper N. 3, November.

OECD (2000), *Education at a glance. OECD indicators,* Paris

OECD(2000b), *OECD Economic Outlook*, 67, Paris, June.

O'Riain, S. (1999), *Remaking the Developmental State: The Irish Software Industry in the Global Economy*, unpublished PhD dissertation, University of California, Berkeley, Spring.

O'Riain, S. (2000), 'The Flexible Developmental State: Globalisation, Information Technology, and the "Celtic Tiger"', Politics & Society, 28 (2), June, pp. 157-193.

Pearce, R. D. and Singh, S. (1992), *Internationalisation of R&D among the World's Leading Enterprises*, MacMillan, London.

Porter, M. E. (1998), 'Clusters and the New Economics of Competition', *Harvard Business Review*, Nov.-Dec., pp. 77-90.
Ramarao, P.,1998, "Reshaping Postgraduate Education and Research in Engineering and Technology", Review Committee of the AICTE on PG Education in Research and Development in Engineering Technology, p126-127, Government of India.
Rhoads, C. (2001), "U.S. Technology Slowdown Starts to Tame the Irish 'Tiger' ", *Walls Street Journal Europe*, March 3, p. 10.
Rosenberg, N. and Birzell, L. E. (1986), *How the West Grew Rich. The Economic Transformation of the Industrial World*, Basic BooksNew York.
Saxenian, A. (1994), *Regional Advantage. Culture and Competition in Silicon Valley and Route 128*, Harvard Business Press, Cambridge, Mass.
Sterne, J. (1999), "Irish Software - An Unauthorized Biography", paper presented at the *ShannonSoft Meeting*, Limerick, October 21th (dowloaded from: www.newsmail.ie/Biography.htm).
Stewart, J. (1989), "Transfer Pricing: Some Empirical Evidence from Ireland", Journal of Economic Studies, 16, 3, 40-56.
Storper, M. (1993), 'Regional "Worlds" of Production: Learning and Innovation in the Technology Districts of France, Italy and the USA', *Regional Studies*, 27, pp. 433-55.
Tallon, P. P. and Kraemer, K. L. (1999), "The Impact of Technology on Ireland's Economic Growth and Development: Lessons for Developing Countries", *Hawaii International Conference on System Sciences Proceedings*, IEEE, Maui, Hawaii, January 5-8.
Torrisi, S. (1998), *Industrial Organisation and Innovation. An International Study of the Software Industry*, Elgar, Cheltenham.
Travers, J. (1999), 'The Role of Information Technology in Attracting Foreign Investment, Creating Industrial Zones and Developing Human Resources', *World Competitive Cities Congress*, World Bank, Washington D.C., May 19-21.
Treacy, N. (2000), *Opening address of Version 1 Software Ltd*, East Sussex St., June 29, Dublin.
U.S. Department of Commerce (1998), *America's New Deficit: The Shortage of Information Technology Workers*, Washington Office of Technology Policy, January (www.ta.doc.gov/reports).
U.S. Department of Commerce, (1999), *The Emerging Digital Economy*, Washington, D.C., June (http//www.ecommerce.gov).
U.S. Department of Commerce, (1998), *America's New Deficit*, Washington, D.C., January (http//www.ecommerce.gov).
Venkataraman, R. and Gopal Menon, B. (2001), Interview with J. Rajagopal, CEO, Ways India, *India Infoline*, January 6 (India Infoline.com).
World Bank (1997), *Global Economic Prospects and the Developing Countries*, The World Bank, Washington, D.C.

Appendix: Research methodology

The analysis of the Irish software industry draws on different sources of information. Apart from the survey of the existing literature, we collected new data. First, we constructed a database containing information about the population of software firms operating in Ireland (both domestic firms and foreign-owned firms). This dataset was obtained by downloading information from the National Software Directorate (NSD) website, a division of Enterprise Ireland (NSD, 2000) (**http://www.nsd.ie/companies**). Supplementary data were drawn from Dun and Bradstreet's Who Owns Whom, Bureau van Djik's Amadeus and companies web sites.

After this stage of data collection we conducted a field analysis based on over 64 interviews with representative firms and sector experts. A first round of 8 face-to-face interviews was conducted in April 2000 (five domestic firms, one multinational corporation and two market analysis companies (CIRCA Group and Indecon International Economic Consultants) located in Dublin. The sample firms were selected from the NSD dataset.

A second round of telephone interviews was conducted between May and July 2000. A sample of 100 firms was selected from the population of firms reported in the NSD dataset according to the following stratification criteria: firm size (number of employees), specialisation (software products, SIC 7372, or services, 737x excluding 7372), nationality (domestic or foreign-owned firms), location (Dublin area or elsewhere). 41 firms accepted to participate in the survey (28 domestic firms and 13 foreign-owned firms). To these firms a semi-structured questionnaire was submitted to analyse the origin of the firm, its products or services portfolio, the strategy, the type of labour force employed, the sources of firm competitive advantage, the advantages and costs of localisation, the links with large firms and with public agencies.

A third round of 12 telephone interviews was conducted between September and October 2000 to explore more qualitative issues related to the firm development and commercialisation activities, the internationalisation strategy and the business model adopted. Of these interviews, 8 were follow-up interviews while 4 were interviews with firms that had not taken part in the earlier survey.

The final round of 5 interviews was conducted in October. These were face-to-face interviews to a panel of experts which were invited to discuss some results of earlier stages of our field analysis and to provide an assessment of the software industry in Ireland (domestic firms and MNCs) and the future growth perspectives. These interviews were conducted with experts of the following organisations located in Dublin: ESRI (Economic and Social Research Institute), Computer Science Dept. UCD, NSD, Enterprise Ireland, Dublin Business Innovation Centre, IBM International Treasury Services.

Our analysis of the Indian software industry is based on field visits to over 40 Indian firms in Bangalore, Bombay, Hyderabad and Delhi, where we interviewed nearly 75 senior managers and software professionals, in two separate visits in 1997-98 and then again in 1999. These firms were selected to be broadly representative of the Indian software industry. These interviews were loosely structured around a questionnaire that we developed in consultation with industry experts and were followed by interviews with fifteen U.S. based firms that had outsourced software development to these firms in India. We complemented the field research with publicly available data on firms (NASSCOM, 1994-99), as well as information from a questionnaire survey administered to over a hundred Indian software exporters. Complete detail on the list of firms and people interviewed is provided in Arora et al. "The Indian software industry", submitted to the Sloan Foundation, June 2000, available at http://www.heinz.cmu.edu/project/india, which also provides details of the questionnaire used, along with other background information about the project.

Table 1. The growth of the software and computer services industry in India

Year	Exports in $M	Employment	Total Revenues $M
1993-94	330	90000	557.9
1994-95	485	118000	825.8
1995-96	734	140000	1249.4
1996-97	1085	160000	1765.8
1997-98	1800	180000	2700
1998-99	2650	250000	3900
1999-00 (Est.)	*3900*	*n.a.*	*5600*
2000-01 (Est.)	*6300*	*n.a.*	*8600*

Source: Nasscom (various years)

Table 2 The growth of the software and computer services industry in Ireland

	Number of firms				
	1991	1993	1995	1997	1999
Domestic firms	291	336	390	561	690
Foreign firms	74	81	93	108	132
Total	365	417	483	669	822
	Number of employees				
	1991	1993	1995	1997	1999
Domestic firms	3801	4495	5773	9200	11100
Foreign firms	3992	4448	6011	9100	13791
Total	7793	8943	11784	18300	24891
	Revenues	US$m			
	1991	1993	1995	1997	1999
Domestic firms	234	368	616.66	795.52	1283.25
Foreign firms	2465	2739	4171.23	5925.72	6375.45
Total	2699	3107	4787.89	6721.24	7658.70
	Exports as a share of total revenues				
	1991	1993	1995	1997	1999
Domestic firms		49	58	69	62
Foreign firms		98	99	98	90
	Average number of employees				
	1991	1993	1995	1997	1999
Domestic firms	13	13	15	16	16
Foreign firms	54	55	65	84	105

Source: Elaborations of National Software Directorate (NSD) database

Table 3 Distribution of Indian Software Firms by Type

Type of Firm Comparison Criterion	Domestic Firm (sample = 121)	Export Oriented Firm (sample = 163)	Multinational Firm (sample = 22)
Age (yrs)	8.27 (7.46)	6.63 (5.33)	6.32 (4.67)
Revenue in Rs. M. (1996 – 97)	51.55 (121.99)	230.66 (705.36)	249.97 (314.03)
Manpower (96-97)	99.08 (255.92)	295.34 (806.46)	195.55 (166.31)
Revenue per employee (Rs. M/emp)	0.533 (0.647)	0.571 (0.61)	2.31 (4.85)

Note: 1 USD = Rs 45 approx. Standard deviation in parentheses. All figures are averages.

Table 4. Irish exports of software and computer services (NACE 7200)

	1993	1994	1995	1996	1997
	Exports by destination (percentages)				
Germany	0.287	0.239	0.204	0.19	0.151
UK	0.239	0.274	0.244	0.225	0.203
France	0.171	0.141	0.154	0.117	0.103
Italy	0.056	0.054	0.06	0.052	0.05
EU	0.916	0.902	0.888	0.794	0.686
US	0.011	0.004	0.002	0.026	0.051
Canada	0.003	0.002	0.001	0.003	0.004
ROW	0.069	0.091	0.109	0.177	0.259
Total	100	100	100	100	100

Source: Eurostat-Comex, 1999

Table 5. Destination of Indian software exports, 1997-98

Destination Region	*% of Export revenues*
USA	58
Europe	21
SE Asia	6
Japan	4
Australia & New Zealand	2
West Asia	2
Rest of the world	7

Source: Nasscom

Table 6. Distribution of R&D expenditures in Ireland by sector ($m)

	1993	%	1995	%	1997	%
All firms						
Sector	377.48	100	528.73	100	764.99	100
Foreign-owned firms	261.83	70	403.97	77	490.39	64
Electr.&Electron. Equip	136.44	36	226.42	36	277.36	36
Pharmaceuticals	68.16	18	87.39	14	110.01	14
Food, Tobacco & Drinks	49.36	13	73.86	12	82.32	11
Software	21.36	6	28.65	5	73.80	10
Of which (1):						
Irish-owned firms	13.60	12	20.09	9	49.42	18
Foreign-owned	7.76	3	8.56	2	24.38	5

(1) Shares calculated on total R&D expenditures of Irish-owned firms and foreign-owned firms respectively
Source: Forfas (1995 and 2000)

Table 7. Representative firms: *Ireland*

Firms	Employees 1999	Year of Foundation	Specialisation
DOMESTIC FIRMS			
Baltimore Technologies	700	1976	Security software solutions
Kindle Banking Systems	460	1978	Bank software applications
Financial Courseware	56	1985	Computer-based training software
Trintech Manufact.	130	1986	Financial software applications
Allfinanz	70	1987	Application solutions for the insurance market
Euristix (Marconi)	150	1990	Telecom software
Iona Technologies	650	1991	Object-oriented integration tools
International Financial Systems	80	1992	Financial risk management application software
Peregrine Systems	70	1992	Card payment software
Software Architect Internat.	70	1992	ERP services for banking, finance and e-commerce
Piercom	45	1993	Professional services
Airtel ATN	40	1998	Software for aircraft communication
Courseware Interactive	Na	1993	Computer-based training software
Vistech	17	1994	Telecom software
Web Factory	40	1995	Web development and e-commerce services
Massana	45	1996	Telecommunication software
DLG	62	1996	Localisation services
FOREIGN FIRMS			
Digital Equipment	750	1971	Hardware/packaging
Amdhal	270	1978	Hardware /packaging
Ericsson	900	1979	Hardware/telecom software
Apple	Na	1980	Hardware/packaging
Motorola	164	1981	Chip design
Siemens	150	1983	Hardware/software
IBM	4000	1983	System software
Lotus (now IBM)	600	1985	Applications, tools, localisation
Lucent Technologies	350	1985	Telecommunication software
Microsoft	900	1985	Mass-market packages, localisation
Oracle	450	1987	Database management systems
Symantec	350	1991	Security software, system utilities
Corel	250 (16)	1993	Graphics software
Sun Microsystems	220	1993	System software
American On Line	120	1997	Internet software and Services

Table 7 (*continued*). Representative firms - *India*

Name of Firm (Service Exporters)	Employees in 1999	Year Founded	Specialization
Tata Consultancy Services	11495	1968	Financial, Manufacturing, Telecom, Transport and Govt. Services
Wipro Infotech Group	4841	1981	E-commerce, Telecom, ERP –Datawarehousing, IT support
Infosys Technologies	3389	1981	Web Technologies, Telecom, Re-engineering, Software Maintenance and Migration
Tata Infotech	3187	1978	System Integration, Education and training, Hardware manufacture, and software products
Satyam Computers	3106	1988	Application Software, Legacy systems, CAD-CAM, E-commerce
HCL Technologies	2087	1998	Telecom, Embedded software, ERP, Legacy systems
Rolta India	1800	1982	GIS, CAD-CAM, Networking, Plant design solutions
Patni Computers	1650	1978	ERP, Embedded software, Legacy systems, E-commerce
NIIT Ltd	1600	1981	Software services, software education
DSQ Software	908	1992	Software services
Ramco Systems	800	1993	ERP Software
Aditi Software	170	1994	Talisma e mail software, software development services
CMC	1650	1976	Hardware maintenance, Banking, stock exchange, Systems Integration
Electronic Corp of India	120	1967	Turnkey solutions, Communications products
Silicon Automation	378	1989	Speech compression, ADSL modem, Microprocessor design tools
Newgen Software	250	1992	Document Management
Persistent Systems.	91	1990	Database internals, systems software
FOREIGN FIRMS			
Hughes Software Systems	542	1991	Telecom
Citicorp Overseas Software Ltd	508	1985	Banking software
Motorola India Ltd.	647	1991	Electronics
Baan InfoSystems		1989	ERP systems
Texas Instruments		1986	Chip design

Table 8: Specialisation of domestic and foreign-owned firms in the Irish SW industry (1999)

		Custom Software	Other Services	Business services	Multimedia services	Internet Services	Localisation	System software/ tools	Software products
Irish	N	76	300	3	77	135	70	54	227
	%	0.15	0.58	0.01	0.15	0.26	0.14	0.10	0.44
MNCs	N	25	115	0	24	52	42	34	67
	%	0.14	0.66	0.00	0.14	0.30	0.24	0.20	0.39
Total	N	101	415	3	101	187	112	88	294
	%	0.15	0.60	0.00	0.15	0.27	0.16	0.13	0.43

- Bespoke software (customised development services)
- Other services (professional services including customer support)
- General business (e.g., general management consulting)
- Multimedia services (e.g., outsourced video, voice, printed information services)
- System software/tools (e.g., case tools, C++ or Java compilers)
- Internet-related services (on-line services, Internet-access services, development of enterprises portals)
- Software products (mass-market products e.g., CAD packages, and enterprise applications, e.g. ERP)
- Localization

Source: Elaborations on the NSD database and websites information

Table 9. Composition of Indian software development and services(domestic and exports)

Software Activity	Domestic (%)	Export (%)
Turnkey Projects/ Custom Software	28.6%	31.5%
Professional Services	4.1	48.4
Products and Packages	52.0	8.8
Training	6.1	1.5
Support and Maintenance	3.2	3.0
IT Enabled services	6.0	6.8

Source: NASSCOM

Table 10. Computing-related higher education in Ireland, 1996

Level of education	N	%
Computing degrees	617	33.5
Joint comp./other degrees	141	7.7
Computing Graduate Diplomas (1)	422	22.9
Computing Diplomas	236	12.8
Computing Certificates	424	23.0
Total	1,840	100

(1) including conversion graduate diplomas for people with degrees in other disciplines

Source: FAS (1998)

Table 11 Labour costs comparisons

	USA	%	Canada %	UK%	Ireland %	Greece %	India %
Project Leader	54,000	100	72.22	72.22	79.62	44.44	42.59
Systems Analyst	48,000	100	66.67	70.83	75.00	31.25	29.17
Development Programmer	41,000	100	70.73	70.73	51.22	31.71	19.51
Support programmer	37,000	100	70.20	67.57	56.75	40.54	21.62
Network Analyst/Designer	49,000	100	65.31	63.27	53.06	30.61	28.58
Quality Assurance Specialist	50,000	100	56.85	66.00	58.00	30.00	28.00
Test Engineer	47,000	100	53.19	51.06	-	27.66	17.02

Note: labour costs expressed in 1995 US$.

Source: Heeks (1999) from H.A. Rubin et al. (1996) *Worldwide Benchmark Project*, Rubin Systems: Pound Ridge, NY.

Table 12 Location advantages in Ireland

A. Domestic firms (N=28)

	Demand (1)	Customers	Competitors	Partners	busin serv	phys infrast	comm infrast	Distribution	Skills	univer
Average	2.96	2.68	1.68	2.32	2.96	3.54	3.74	2.25	4.54	2.93
Mode	1	1	1.00	2.00	3.00	4.00	4.00	200	5.00	3.00
Sd	1.62	1.33	0.77	1.16	1.14	0.92	1.21	1.24	0.69	1.12

(1) size and quality of domestic demand

B. Factors of location – Foreign-owned firms (N=13)

	Demand	Competitors	Partners	Busin. Serv.	Phys. Infrastru	Comm. Infrastru	Distribut. Channels	Skills	Labour cost	Subsid &tax
Average	2.31	2.54	2.54	2.54	3.54	3.77	2.46	4.54	3.33	3.67
Mode	1	3	3	3	5	5	1	5	3	5
Sd	1.55	1.13	1.20	1.33	1.61	1.54	1.33	1.13	1.37	1.30

Source: telephone interviews

Table 13: Number and Capacity of Engineering Colleges in India, Approved up to 1998-99, by region

Region	Number of Colleges	Sanctioned Capacity (# of students)	% of Sanctioned Capacity at Self-Financed Colleges
Central	**50**	**9470**	**0.52**
East	**25**	**4812**	**0.26**
North (incl. North-West)	**140**	**25449**	**0.42**
West	**140**	**34165**	**0.74**
South (incl. South –West)	**308**	**82597**	**0.79**
Total	**663**	**156493**	**0.69**

Source: Ramarao, 1998.

Table 14 Benefits from the relationships with large firms for Irish SW firms

	Revenues	Reputation	Technology	Mkt/manag. Practices	Corporate VC	Spin off	Skills	Access to foreign mkts
Average	4.15	4.11	2.59	2.48	1.96	2.44	2.78	3.30
Mode	5	5	1	3	1	2	2	3
Sd	1.13	1.19	1.28	1.05	1.09	1.15	1.19	1.23

N=28 (indigenous firms)