Emerging Clusters in the International Production of Software: Evidence from Patents, Trademarks and Linkages

Novos clusters na produção internacional de software: evidência de patentes, marcas registradas e suas ligações

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RESUMO

Este trabalho analisa o desempenho de firmas localizadas em em três economias emergentes - Índia, Irlanda e Israel. A análise empírica, baseada em uma amostra de 876 empresas, faz duas perguntas principais. Primeira, pergunta-se que fatores afetam a decisão da firma para entrar no mercado internacional. Utiliza-se marcas de software software registradas pelo USPTO como uma proxy para entrada. O tempo de entrada é representado pelo ano em que a firma registra sua primeira marca no bando de dados do USPTO. A segunda é sobre os fatores que determinam a sobrevivência da firma em mercados internacionais. Deseja-se saber se estes fatores são semelhantes ou diferentes daqueles que afetam a entrada. A pesquisa usa as renovações da marca registrada e o uso de novas marcas como uma proxy para a sobrevivência em mercados internacionais. A análise empírica indica que há diferenças significativas entre os fatores que afetam a entrada e os fatores que afetam sobrevivência.

Palavras-chave: Software. Inovação Tecnológica e P&D. Reconhecimentos de crescimento regional.

ABSTRACT

This paper analyses the evolution of software clusters in three emerging countries. The analysis draws on novel empirical evidence over the period between the 1970s and the 1990s. USPTO patents and trademarks owned by domestic firms indicate that there are significant differences across these three clusters in terms of comparative advantages and product specialisation. The patent activity of the subsidiaries of multinational firms reflects these different comparative advantages. We analysed the contribution of multinationals to local technological activities by examining their share in the stock of local patents, the citations of their patents in domestic firms' patents, and the mobility of inventors. Finally, we analysed their formal linkages (M&As, JVs and strategic alliances) with domestic firms over the period 1998-2002. The majority of multinational corporations located in these countries do not carry out formal R&D activities neither set up formal linkages with domestic firms. Our data show that there are few subsidiaries of multinationals engaged in substantial R&D activities. However, these innovative foreign firms contribute to the formation of skills and establish links with domestic firms.

Keywords: Software. Technological Innovation and R&D. International business. Regional growth.

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Introduction

This paper analyses the patterns of software clustering in three countries - India, Ireland and Israel - which perform exceptionally well compared with other developing regions. Within these three countries software clusters are concentrated in metropolitan areas, such as Bangalore, Dublin and Tel Aviv, where are also located important universities and technical colleges. Due to the limited size of the domestic market, foreign sales, especially to the US and Western Europe, represent the largest source of revenues for software firms located in these clusters.

The development of these clusters has been spurred by the dramatic growth of IT demand in the advanced industrial regions during the 1990s. Two implications of this growth are particularly important to explain the entry of newcomers in the international arena. First, the unbundling of hardware from software which is in line with a more general trend towards vertical disintegration of IT products and the growth of many complementary industries (from semiconductor devices to computer peripherals, communication equipment and support services). Second, the human capital intensity of software and the rising IT skill shortage in leading countries. Together with the rapid improvements in data communications, these conditions opened a window of opportunity for regions that were below the technology frontier but rich in human capital with limited opportunity costs.

Moreover, the limited flows of material inputs and products which characterise the software industry reduce transportation costs and mitigate the disadvantages of remoteness.

Earlier works on software clusters in emerging countries have mostly focused on one of the regions analysed in this paper and have tried to explain the reasons behind their success (Arora et al., 2002; De Fontenay and Carmel, 2002). This paper offers a comparative perspective and focuses on the relationships between domestic firms and the subsidiaries of multinational corporations (MNCs). We ask what is the contribution of MNCs to the accumulation of technology of these clusters and whether MNCs establish linkages with domestic firms. This paper provides novel empirical evidence about the implications of MNCs for the development of high tech clusters in emerging regions.

The paper is organised as follows. Section 2 provides a brief survey of the literature and introduces the research hypotheses. Section 3 describes the data and Section 4 discusses the empirical results. Section 5 concludes the paper.

1 Literature review and hypotheses

This paper draws on two streams of the literature which focus on: i) industrial clusters and agglomeration economy; and ii) MNCs and their effects on host countries.

2.1. Cluster s and agglomeration economies

Agglomeration economies have been analysed formally in models that have explored the association between local externalities, localisation and growth (Romer, 1986; Krugman, 1991). The literature on clusters has also explored the reasons for the formation of geographical clusters of related industries and their effects on firms' competitiveness and regional comparative advantages (Porter, 1990 and 1998; Storper, 1993; Saxenian, 1994). This body of the literature documents the importance of different sources of Marshallian agglomeration economies – demand, skills, inputs and knowledge spillovers - which reduce transaction costs and spur innovation within industrial clusters.

A fundamental dimension of clusters and regional growth is represented by institutions that support entrepreneurship and innovation. Two different types of institutions can be found in high tech clusters. The first is represented by established firms, industrial R&D centres and university laboratories. These institutions can play the role of 'incubators' of entrepreneurship through the supply of skills, capital, idle technological and managerial resources and personal relationships. Empirical studies have pointed out the importance of academic institutions as a source of technological spillovers, especially for smaller firms (cf. Acs, Audretsch and Feldman, 1994). These various institutions may also attract new talented individuals from outside the cluster and new firms formation ('technology seed institutions'). Clear examples of these institutions are Xerox PARC and IBM San Jose Laboratories (Saxenian, 1994). A different set of institutions, such as venture capital firms and legal consultants specialised in high tech businesses, explicitly aim at the creation and growth of new firms (Kenney and von Burg, 1999).

1.2. Multinational corporations and emerging clusters

Regional development policies have often tried to attract high tech firms from abroad to stimulate the birth of an indigenous industry. The regions analysed in this paper have been particularly successful in this respect. However, the evidence about externalities produced by MNCs, especially in backward regions, is quite controversial.

Most studies on the effects of MNCs on the host economy focus on productivity spillovers (e.g., Aitken and Harrison, 1999) while other studies analyse different externalities such as backward linkages measured with the ratio of local to total purchases (Wilson, 1992). More recently the analysis has been centred on entrepreneurship – i.e., the entry of new domestic firms in the same sector of the MNC or in upstream sectors (Gorg and Strobl, 2002).

Conventional wisdom and economic theory suggest that the intensity of spillovers depends on sectoral characteristics (such as capital intensity), the technological gap between MNCs and local firms, the skill endowment of the host region and other location characteristics such as the density of firms, institutions that favour entrepreneurship, and public incentives to R&D (Rodriguez-Clare, 1996; Caves, 1974; Liu et al., 2000).

Another stream of the literature distinguishes between *market-seeking* or *market-based* FDIs and *non-market seeking* investments. The former category of FDI provides access to the host country market or may function as export platforms.

Non-market based FDIs include *resource-seeking* investments (aiming at exploiting the traditional comparative advantage of the host country), *scanning units* (e.g.. R&D laboratories aiming at monitoring and absorbing technological progress that occurs in specific locations such as scientific parks or the like) and *world mandate subsidiaries* (or strategic leaders) which are assigned the role of server of the global network of subsidiaries for specific intermediate products (e.g., key components or subsystems) or final products - cf. Porter (1990) and Bartlett and Ghoshal (1989).

Non-market seeking FDIs may give rise to two patterns of linkages with the domestic firms of the host country - a *developmental model* of FDI and a *dependent model* of FDI. World mandate subsidiaries or strategic leaders bear high potential opportunities for the host region while resource-seeking FDIs have a low growth potential. The latter category of FDIs is highly mobile and may produce excessive dependence on the MNCs (Young, Hood and Peters, 1994; Turok, 1993; Coe, 1997).

The streams of the literature discussed before bear some interesting testable implications:

i) in backward economies, where supporting institutions like established firms are lacking, MNC may contribute to the formation of new domestic firms and the agglomeration of high tech activities;

ii) the type of local activities carried out by MNCs reflects on the characteristics of the host region. Emerging clusters endowed with scientific and technical infrastructures should attract high tech activities from abroad;

iii) other things being equal, the linkages spawned by MNCs with domestic firms in emerging regions depend on the activities carried out by the local subsidiaries of MNCs. MNCs that conduct high value added activities (like R&D) should spawn more linkages compared with MNCs which conduct low value added activities (such as software packaging or on-line customer support).

3. Data and methodology

The empirical analysis draws on different data sources. First, information collected from the National Software Directorate (NSD), a division of Enterprise Ireland (NSD, 2000), the National Association of Indian software firms (NASSCOM, 1994-99) and the Israeli Association of Software Houses (IASH, 2002). Supplementary data were drawn from Dun and Bradstreet's *Who Owns Whom Linkages (2001 edition)*, and companies web sites. These datasets were used to analyse the entry patterns of domestic firms and MNCs in India, Ireland and Israel. The following data were extracted for each firm: primary and secondary SIC code (industry) of the firm, number of employees, year of establishment, name and country of the ultimate parent company. For our purposes here, we selected all domestic firms operating in the software and IT services industry (SIC 737x). We also selected all foreign firms with local subsidiaries operating in IT sectors (including computers, telecommunications equipment and services, microelectronics).

Second, we collected data on firm-level events, such as the establishment of new subsidiaries, M&As and joint ventures, from the Gale Group's InfotrackWeb database (*Business and Company Resource Centre* and *Expanded Academic ASAP*) over the period 1998-2002. InfotrackWeb database reports articles in English from various press sources.

Finally, we collected information on patents and trademarks granted by the US Patent and Trademark Office (USPTO)[2]. Patents are used to analyse the technological activities of the sample clusters and the MNCs located in these clusters. Trademarks of domestic firms are used as a proxy for marketing activities. Both indicators have merits and drawbacks. Patents are widely utilised in the economics and management of technical change. Their importance for software has

[2] Our patent counts start from 1976 due to USPTO access restrictions. The first trademarks registered by firms located in our clusters date back to 1983.

increased over time. For example, the number of software patents granted to US inventors by the USPTO raised from 829 in 1986 to 7,398 in 2000. Trademarks have not been paid enough attention in the literature on technical change. They are single (or combinations of) 'words, phrases, symbols or designs, that identifies and distinguishes the source of the goods (or services)' (source: http://tess.uspt.gov). Like patent owners, US trademark owners have to pay the USPTO different types of fees for each class of goods/services for which a trademark is registered: initial application fees, statement of use fees, extension request fees and periodical renewal fees. The registration of trademarks is cancelled if trademarks are not used in commerce for five consecutive years after the registration date. Therefore, besides the payment of fees, owners have to bear administrative costs to maintain the registration of the trademark. Then they have to expect that the economic benefits from the sales of trademarked products and services trademarked exceed the direct, monetary costs and the transaction costs. These considerations lead to the conclusion that trademark are a potentially good signal of product differentiation or an indicator of firms' market performance. In our case, trademarks represent also an effort to establish an international brand for software products and/or services.

4 Results and discussion

4.1. Industry growth and the contribution of MNCs

Software has grown very fast in India, Israel and India especially during the 1990s - 37.8 per cent in India, 14.7 per cent in Ireland, and 23.8 per cent in Israel (see tables 2, 3 and 4). In roughly the same period (1990-2000) gross domestic product has increased at 6 per cent in India, 7.3 per cent in Ireland, and 5.1 per cent in Israel.

By 2000 software revenues reached $9.3bn in Ireland and $8.3bn in India. In Israel the software industry has reached a similar size (about $4.2bn in 2001) (NASSCOM, 2002; NSD, 2002; IASH, 2002).

Table 1. Indian software industry

Year	Revenues $M	Exports $M	Employment
1993-94	557.9	330	90000
1994-95	825.8	485	118000
1995-96	1249.4	734	140000
1996-97	1765.8	1085	160000
1997-98	2700	1800	180000
1998-99	3900	2650	250000
1999-00 (Est.)	5600	3900	n.a.
2000-01 (Est.)	10000	6300	500000

Source: Nasscom (various years)

Table 2. Irish software industry

	Domestic firms	*Foreign firms*	*Total*
Employees			
1991	3801	3992	7793
1993	4495	4448	8943
1995	5773	6011	11784
1997	9200	9100	18300
1999	11100	13791	24891
2000	14000	16000	30000
revenues ($m)			
1991	234	2465	2699
1993	368	2739	3107
1995	616.66	4171.23	4787.89
1997	795.52	5925.72	6721.24
1999	1283.25	6375.45	7658.7
2000	1288	8050	9338

Source: NSD(various years)

Table 3. Israeli software industry

	Revenues ($M)	Export ($M)	Employees
1991	540	110	5000
1992	600	135	5500
1993	700	175	6200
1994	800	220	7000
1995	950	300	7700
1996	1300	600	8500
1997	1780	1000	10000
1998	2350	1500	11500
1999	2950	2000	13000
2000	3700	2600	14500
2001	4100	3001	15000

Source: IASH (2002)

Moreover, the software industry in these countries is large when compared with other industries. For instance, in Israel ICT services account for 3.7 per cent of total employment and about 11 per cent of national exports in 2000 (De Fontenay and Carmel, 2000). In India software and IT services accounted for almost 2 per cent of the country's GDP in 2000 and are expected to reach 7.7 per cent by 2008 (NASSCOM, 2002). During the 1990s employment has increased at a 24 per cent annual growth rate. Software accounts for 16.5 per cent of India total exports (NASSCOM, 2002). And, with a 55% annual growth rate during 2000-2001, software exports represent the fastest growing sector in India. In Ireland software accounted for only 1.63% of total employees but employment in this 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).

Much of software growth in these countries is accounted for by exports which represent about 75% of Indian's total sales and about 84% of Irish sales (NASSCOM; 2002, and NSD, 2002). The Israeli software industry exhibits similar figures, with exports amounting to 73% of total sales (IASH, 2002). The importance of exports is due to the fact that, despite their different size (India's population is 846.3 million, Israel's about 6 million and Ireland's 3.5 million), the domestic market for software is small in all these countries.

What about the contribution of MNCs to this growth? In Ireland about 90 per cent of Irish exports are accounted for by MNCs. And 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 product development takes place elsewhere (Stewart, 1989). Instead, in India the bulk of exports is accounted for by international contracts with large customers (on site or offshore development projects). According to recent estimates the 20 largest Indian firms accounted for 28 per cent of the industry's exports. Although the majority of exporters are Indian-owned firms, foreign affiliates in 1998-99 accounted for about 27 per cent of India's software revenues ($10-bn) and 19 per cent of software exports (source: *The Hindu*, 18 September 2002).

Even if we are not aware of any estimates of the share of MNCs in Israeli software exports, it is reasonable to expect that the bulk of these exports are accounted for by packages developed by domestic firms while multinational corporations mostly focus on R&D activities that probably generate limited flows of intra-firm trade.

The number of MNCs varies substantially across these countries (Table 4). In Ireland MNCs (IT sectors) account for about 33 per cent of all sample firms against about 16 per cent in India and only 11 per cent in Israel. Moreover, US MNCs dominate the scene in all countries, especially in Israel where they account for about 85% of all MNCs.

Table 4. Location of firms by county

India (1996-97)	Ireland (1999)	Israel (1999)
Bangalore (21%)	Dublin (72%)	Tel Aviv (19.5)
Mumbai (21%)	Cork (6.6%)	Herzlia (9.5%)
New Delhi (18%)	Galway (4.8%)	Petah Tikva (7.2%)
Total firms: 462	Total firms: 690	Total firms: 431

Note: in parentheses percentages of firms (calculated on the total number of firms for which the location was available from our sources). **Source:** NASSCOM (1996-97); NSD (2000); Arora et al. (2000); Who Own Whom (2000)

Figures 1 and 2 illustrate the entry time of domestic firms and IT MNCs respectively (see the definition before). It is important to note that there is a marked difference in entry time between MNCs and domestic firms across our countries. In Ireland, many MNCs entered before the start up of a domestic industry while in India and Israel a process of endogenous growth begun before the entry of a significant number of MNCs.

Porter (1998) defined industrial clusters as 'critical masses – in one place – of unusual competitive success in particular fields … (or) geographical concentrations of interconnected companies and institutions in a particular field' (p. 78). The agglomeration of software activities described in this paper shows some fundamental characteristics of industrial clusters. So far we have focused on the entry of firms. We now turn to the spatial concentration of these firms. The software industry is concentrated in a limited number of counties and metropolitan areas as table 5 illustrates. These areas are characterised by a population density above the country average and the location of important academic institutions. Moreover, these clusters have grown around important higher education institutions such as the network of Engineering Colleges concentrated in the western and southern regions of India, the Trinity College and the University College in Dublin, and the Tel Aviv University.

Table 5. Firms by nationality of the parent company

India		*Ireland*	
Home country	*Firms*	*Home country*	*Firms*
India	412	Ireland	529
United States	59	United States	136
Germany	5	England	49
France	4	Japan	16
Netherlands	3	Canada	13
Korea	2	Germany	12
Sweden	1	Netherlands	12
Japan	1	France	5
Finland	1	Italy	2
China	1	Sweden	2
Total	489	Switzerland	2
		Belgium	2
		Korea	2
		Others	5
		Total	787
Israel			
Home country	*Firms*		
Israel	457		
United States	50		
Japan	3		
England	2		
Germany	1		
France	1		
Canada	1		
Australia	1		
Total	516		

Source: Elaborations on Who Owns Whom, NSD and NASSCOM datasets

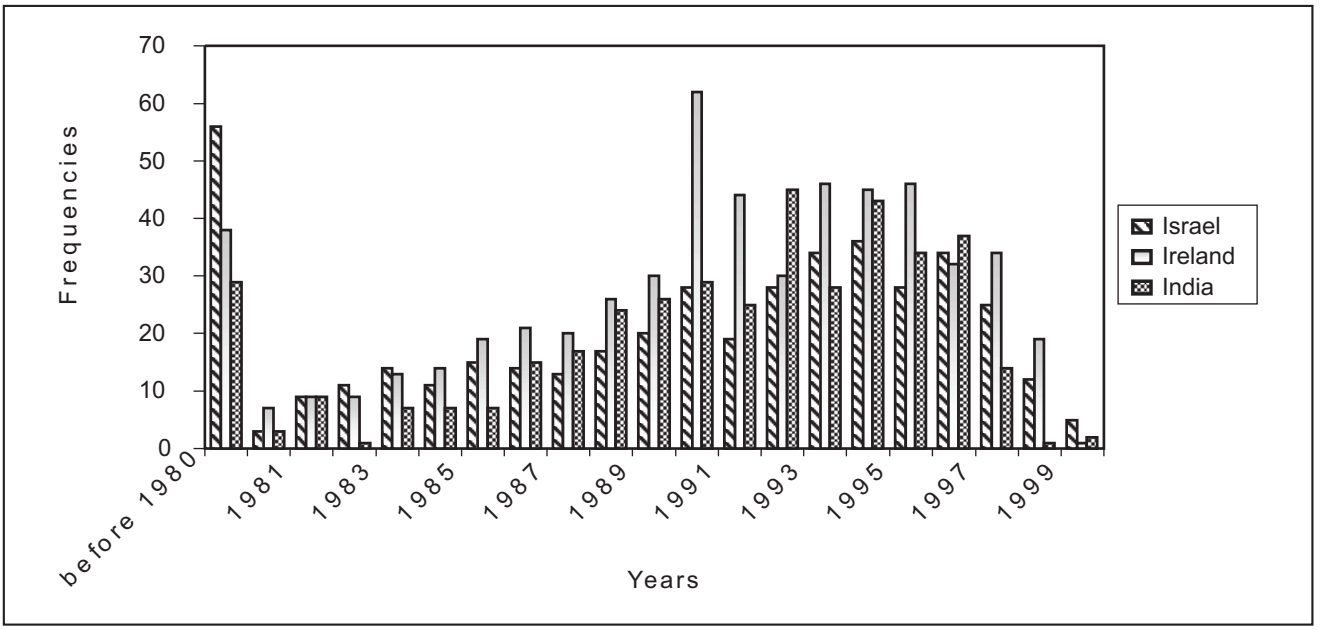

Figure 1. Entry by domestic firms

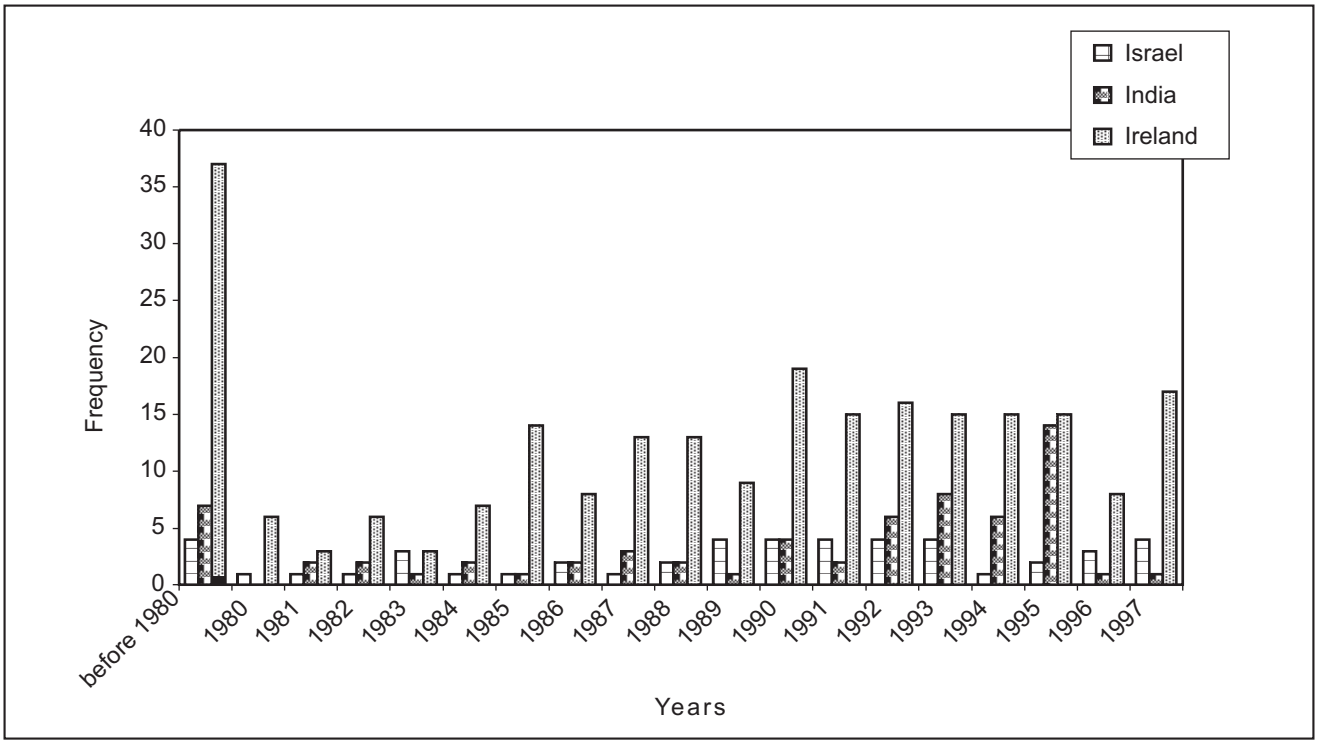

Figure 2. Entry of it MNCs

The growth of software activities raises the question of why these emerging regions in particular have succeeded while others, such as Portugal or South Italy, have not. Earlier works have pointed out several factors among which there are skills endowment, international openness and MNCs (Fellstein, 1997; Arora et al. 2001; De Fontenay and Carmel, 2001). This literature shows that there are limited knowledge spillovers or firm networks in these clusters. In the case of Ireland, MNCs have favoured the access to foreign markets. These studies also indicate that *international linkages* have played a stronger role in the development of software activities in these clusters when compared with *local linkages*. The small size of the domestic market, the language and historical linkages with the communities of expatriates in established high tech clusters make these clusters exceptionally open to international exchanges.

4.2. Technological activities of domestic firms and MNCs

This section addresses two issues. First, the importance of MNCs as a source of technology for the host regions (*Hypothesis 1*) and, second, the relationship between the skills endowment of the host regions and the technological activities of the MNCs (*Hypothesis 2*).

India and Ireland appear to be less endowed with skills and technological infrastructures as compared with 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, 2002). India's scientific infrastructure appears to be weak also when compared with that of Ireland (Arora et al., 2001). However, Indian software firms have started to move up the value chain by devoting more resources to high tech activities such as IT consulting and system integration ("America's pain, India's Gain", *The Economist*, 9/01/03, p. 63).

To analyse the differences in technological activities across these clusters, we focus on a popular measure of technological output – the number of patents granted by the US Patent and Trademark Office (USPTO) between 1976 to 2002. We also explore trademarks as an indicator of local firms' marketing capabilities.

Israel's technological performance, measured by patents granted during the sample period is well above that of Ireland and India. As Table 6 shows, the number of patents (all technological classes) granted to Israeli inventors in the sample period is over six times larger than that of Irish inventors. Column 2 and 5 of Table 6 report the number of patents in IT (including software) and indicates that in this case the differences between Israel and the other two countries are much larger.[3] The sum of patents in columns 4 and 5 yields the stock of technological activities of MNCs in these countries. Overall there are 91 foreign assignees that represents over 50% of total patents granted to domestic inventors. MNCs' share of total patents and IT patents is significantly lower in Israel (below 50%) compared to India and Ireland (above 60%). This indicates a stronger technological independence of Israel from foreign technology, especially in the case of IT, as shown by column 5 (patents assigned to 61 MNCs in electronics and software technology).[4]

Table 6. Comparative technological performance 1976-2002

Country	(1) Patents with domestic inventor (all tech classes)	(2) Patents with A domestic assignee and inventor in selected USPTO classes**	(3) Patents with a domestic assignee and inventor in other USPTO classes	(4) Patents with a foreign assignee and a domestic inventor (all tech classes)	(5) patents assigned IT MNCs* (domestic inventors **
India	1648	32	564	835	217
Ireland	1841	73	486	982	300
Israel	11214	1257	4507	4736	714
Total	14703	1362	5557	6553	1231
India	0.112	0.019	0.342	0.507	0.132
Ireland	0.125	0.040	0.264	0.533	0.163
Israel	0.763	0.112	0.402	0.422	0.064
Total		0.093	0.378	0.446	0.084

*IT MNCs as defined in Section 3 (data and research methodology)

**The first 30 USPTO classes in which electronics (or ICT) MNCs were granted a patent plus all patents in USPTO class 700 (software) (including 704 e 702 classes)

A closer look at the data leads to the following considerations:

- software accounts for a significant share of total patents to domestic assignees in the three countries, especially in Ireland and India (Table 7);
- Israeli firms (assignees) started to patent in electronics and software in the 1970s while the number of patents to Irish assignees start to be significant in the 1980s. In the case of India, domestic assignees were granted only 32 patents

[3] Columns 2 and 5 report the number of patents in software (USPC class 700) and 30 technological classes that account for over 80% total patents granted to 61 IT MNCs in the sample countries. Column 4 reports the number of patents granted to other foreign assignees - non-IT MNCs and IT foreign firms without subsidiaries in the sample countries).

[4] For a wider analysis of the role of MNCs see also Giarratana et al. (2005).

in electronics technologies (16 in software technology) through the 1990s (Figure 3). Moreover, the top assignees are all public research institutions (Table 8). More recently, in India few firms have started to invest systematically in R&D, with the aim of developing proprietary technologies in areas such as mobile telecommunication software and chip design software;

- The concentration of patents varies across countries. Israel shows the smallest concentration of patents (the top 3 assegnees account for about 17% of total patents to domestic assegnees) while India has the largest concentration (the top 3 assegnees account for about 75% of patents) (Table 8);
- The marketing capabilities or investments in the establishment of an international brand by domestic firms have increased only in recent years.[5] In line with his superior technological performance, Israeli firms have started before (at the end of the 1980s) and continued to outperform their Irish and Indian counterparts in terms of trademarks (Figure 5). As expected, the most active owners of trademarks are the most successful domestic firms such as Alladin Knowledge Systems (Israel), Iona Technologies (Ireland) and Tata Infotech (India). This confirms the that trademarks represent a fairly good indicator of marketing capabilities.
- Measures of relative technological and marketing strength show that Israel and Ireland have a "revealed technology advantage" and a "revealed marketing advantage" in software while India shows a "revealed technology disadvantage" and a weak "marketing advantage" in software. To measure "revealed technology advantages" we calculated the share of software in a country's total patents over the share of software in the world total patents. A value over 1 (below 1) indicates a relative technical strength (relative weakness) in software. This index takes value 1.17 for Israel, 1.24 for Ireland and 0.5 for India. The same index calculated with trademarks takes values 3.06 for Israel, 2.1 for Ireland and 1.03 for India.
- MNCs have begun to localise their technological activities in Israel and, to a lesser extent Ireland, since the 1980s. However, the number of patents granted to MNCs in these countries have increased considerably only during the 1990s. As expected, technological activities follow the establishment of subsidiaries by MNCs. In Ireland, as mentioned before, many MNCs entered before the 1990s. Instead, the number of patents granted to MNCs in India have increased considerably during the 1990s, in line with the localization of new subsidiaries in these years. In recent years in India technological activities in electronics and software technologies by MNCs have increased dramatically compared with Ireland although domestic firms have continued to introduce very few patented inventions (see Figures 3 and 4). This suggests that MNCs may anticipate the development of endogenous technical activities rather than being simply attracted by the existing scientific and technological infrastructure of the host region.
- Only few MNCs conduct formal R&D activities. The concentration of patents among MNCs is very high. The two largest MNCs for number of patents account for about 50% of total patents granted to MNCs in Ireland and Israel. Similarly, in India 50% of total MNCs patents is accounted for by three firms. The largest foreign contributors to local technological activities are firms specialised in semiconductors (e.g., Intel) and computers (IBM) while MNCs specialised in software (e.g. Microsoft and Symantec) are very poor contributors. Moreover, the technological activities of software MNCs measured by patents are exclusively located in Israel (Table 9).

Table 7. Patents of domestic assignees 1976-2002

Country	Patents in IT classes	Patents in class 700 (software)	%	Inventors	Mean (St.dev) (patents/inventor)	Assegnees	Mean (St.dev) (patents/assignee)
Israel	1257	362	0.287	1761	1.62 (1.52)	513	2.45 (6.23)
Ireland	73	37	0.506	142	1.21 (0.61)	53	1.37 (1.26)
India	32	16	0.500	83	1.2 (0.65)	12	2.66 (5.44)

Patents in the top 30 classes of IT MNCs and software (7XX)

[5] Data on trademarks refer to both product and services trademarks. We downloaded from the USPTO all trademarks which contained the word 'software' in the good/service description

Table 8. Most important assignee for patent granted 1976-2002

Israel	Patents	Ireland	Patents	India	Patents
Elscint	94	Loctite	9	Council of Scientific & Industrial Research	20
Scitex	70	Parthus Technologies	4	National Research Development Corporation	2
Yeda Research	45	University College Cork	3	Department of Science and Technology, Goverment of India	2
Total top 3	209	Total top 3	16	Total top 3	24
Others	1048	Others	57	Others	8

Table 9. Top MNCs by number of patents

	Israel		India		Ireland
IBM	219	Texas Instruments	75	Analog Devices	99
Intel	213	General Electric	48	Logitech	47
National Semiconductor	92	IBM	35	Compaq	30
Microsoft	18		0		0
Symantec	3		0		0
SAP	2		0		0
Adobe	0		1		0
Top 3	524		158		176
Other	190		59		124
Total (61 MNCs)	714		217		300

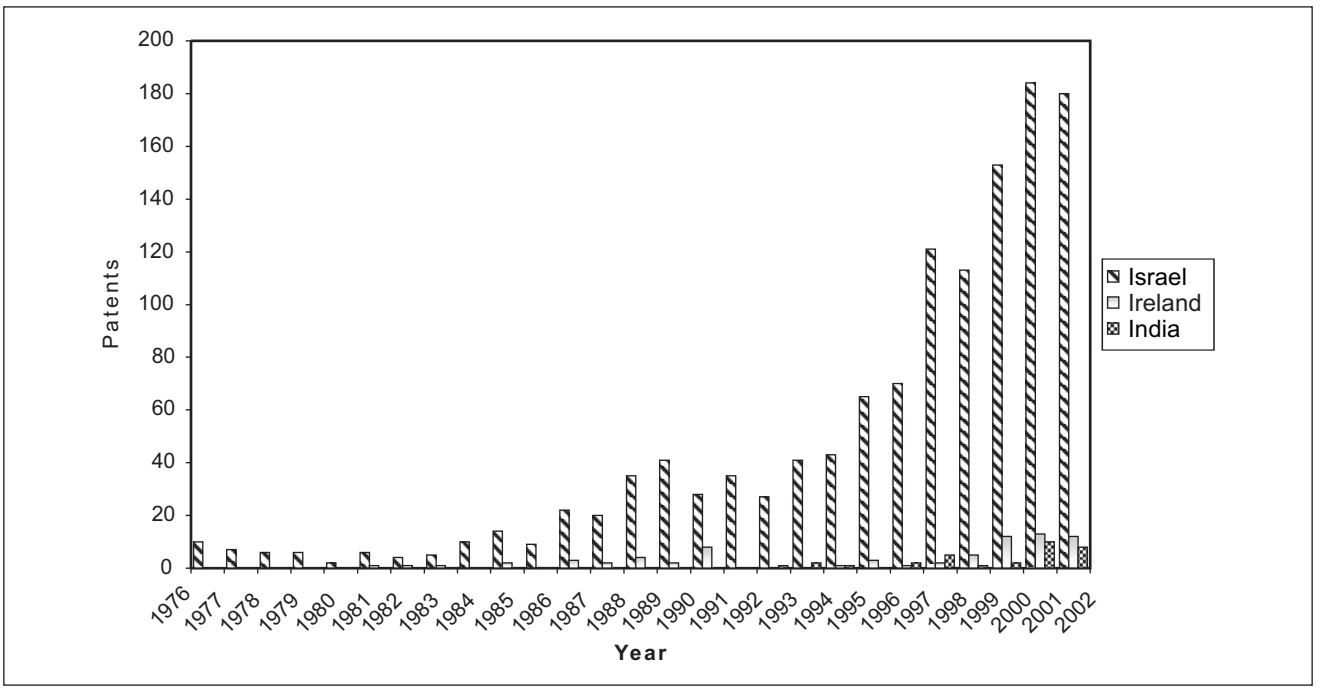

Figure 3: Patents to domestic assignees (electronics and software technology)

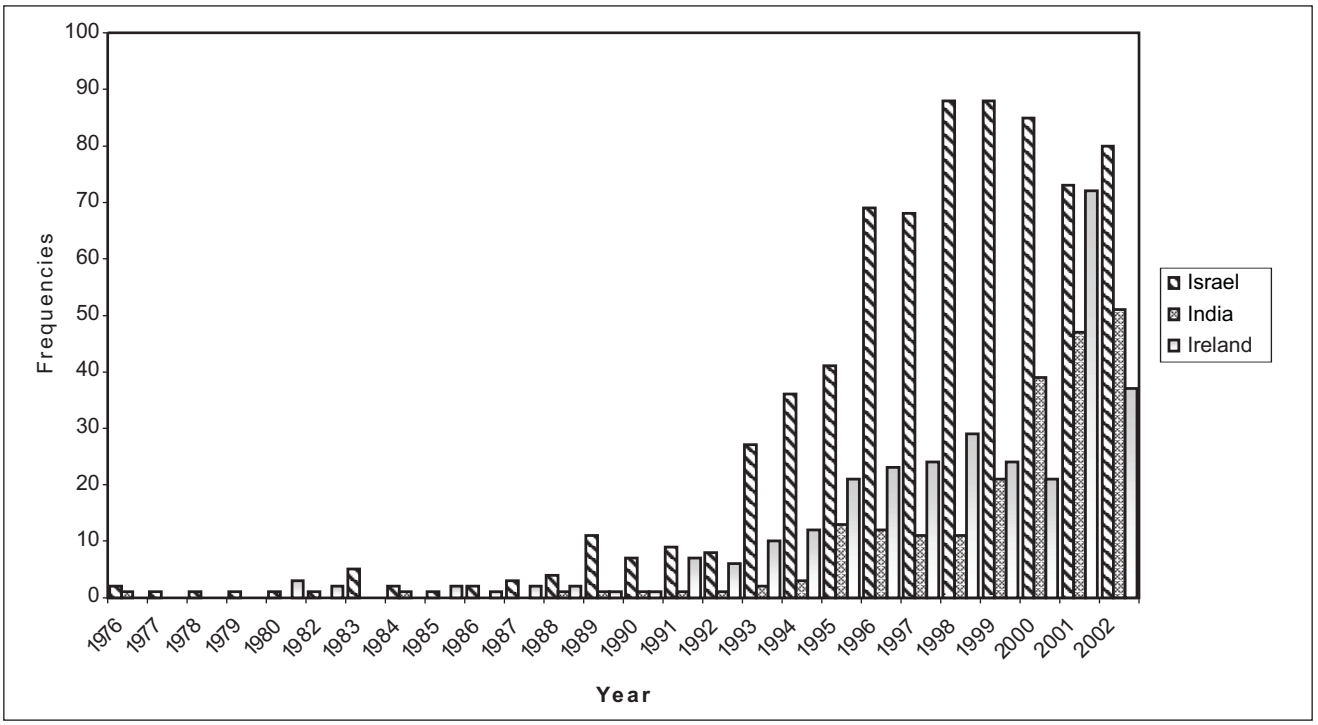

Figure 4: Patents granted to IT MNCs (electronics and software technology)

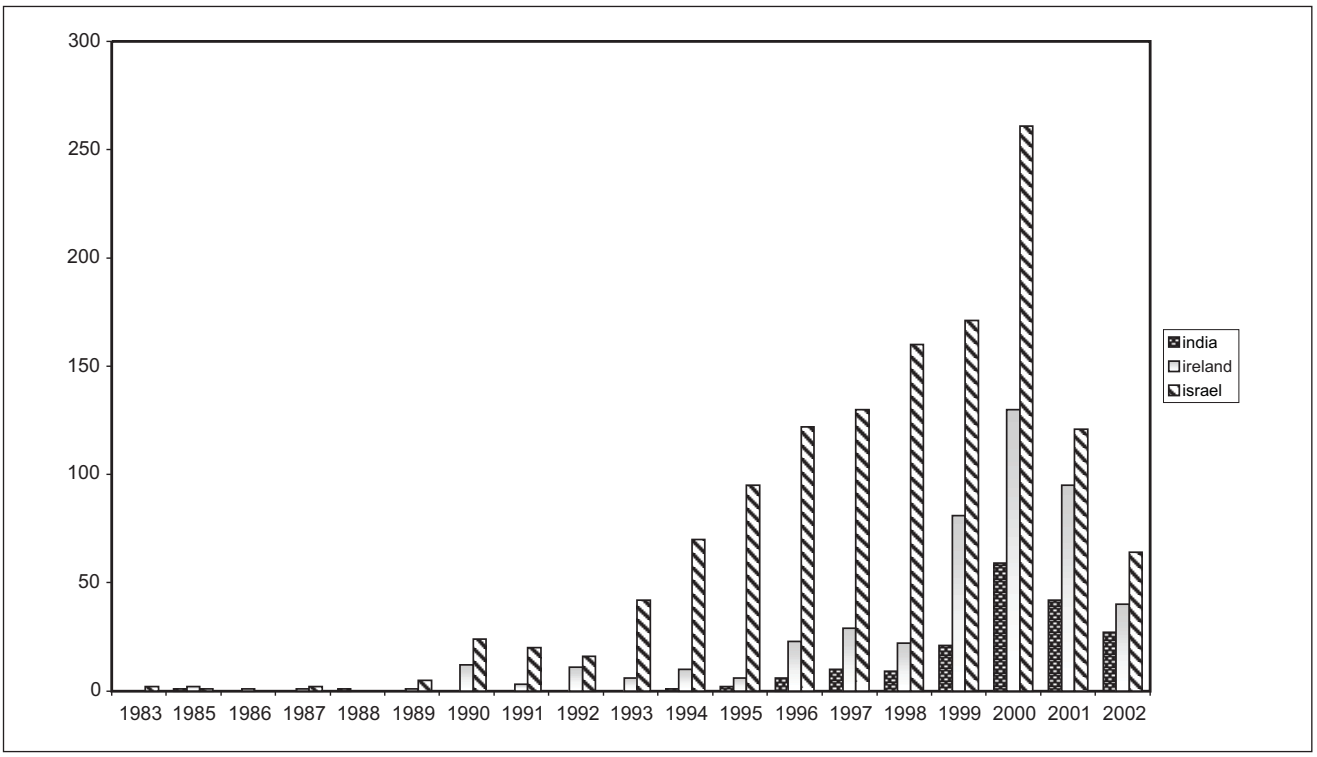

Figure 5. Trademarks registered by domestic firms

To summarize the results presented so far it is useful to recall that: i) only few MNCs contribute to technological activities of the software clusters analysed in this paper; they account for a share of IT patents which varies between 6% (Israel) to over 16% (Ireland); ii) the level of technological activities of MNCs reflects the resource endowment of the host region – the level of technological activities (patents) by MNCs is much higher in Israel (where the domestic firms show

a very high technological performance) than in India (where the domestic business enterprises are not very active in the production of technology) or Ireland (where domestic firms are moderately active and have started to be productive more recently).

4.3. The connections between MNCs and domestic firms

The literature on MNCs emphasises the role of MNCs as a source of spillovers or technological externalities that affect the performance of domestic firms – e.g., on total factor productivity. Our data do not allow to analyse these effects. Instead, we analyse the potential effects of MNCs by focusing on the citations contained in patents granted to domestic firms and the mobility of inventors between MNCs and domestic firms. Moreover, we analyse the formal linkages between MNCs and domestic firms – strategic alliances, joint ventures and M&As.

Worth to remind that our hypothesis is that MNCs that carry out higher value added activities spawn more spillovers and linkages with domestic firms of the host region (*Hypothesis 3*).

The 1,362 patents granted to assignees who reside in our sample countries cite over 16,700 different patents. But only 20 citations refer to patents resulting from the local R&D activities of MNCs and 418 concern patented granted to domestic assignees (Table 10).

Table 10. Citations by domestic patents

	Citations of MNC patents	Number of MNCs Patents cited	Total citations	Total patents cited	Citations of domestic patents	Domestic Patents cited
N°	20	17	22334	16724	418	222
%	0.000	0.0138			0.0187	0.032

On the other hand, the 1,231 patents granted to the sample MNCs cite 8,264 patents, only 17 of which were granted to an assignee from one of our countries.[6] These data clearly show that there are very limited knowledge flows between MNCs and domestic firms. For example, Texas Instruments' R&D laboratories in India are very productive in terms of patents granted (see Table 9). However, the majority of Indian firms' patents never cite patents granted to Texas Instruments India. There are also limited knowledge flows among domestic firms.

R&D activities of both domestic firms and the local subsidiaries of MNCs then appear to draw mostly on knowledge sources external to the clusters rather than knowledge exchanges within the cluster.[7]

Obviously, our data miss an important dimension of technology flows which is represented by tacit knowledge and informal exchanges of information. These exchanges occur more likely within the same geographical space. Instead, patent citations tend to be more representative of formal, codified knowledge flows. However, earlier studies based on large samples of patents have found that patent citations are a good indicator of localised knowledge spillovers (Jaffe et. al., 1993; Singh, 2002). Our data suggest that in this industry geographical proximity by itself does not favour knowledge flows and spillovers. This may be due to the fact that in these clusters there is still not a critical mass of inventors compared with clusters in advanced countries.

Another indirect measure of knowledge flows between MNCs and domestic firms is represented by people mobility. To this purpose we analysed the inventive history of all domestic inventors that at some point of their career have been employed by local subsidiaries of MNCs. We found 57 inventors who have worked for a MNCs and later on moved to a domestic firm. This category of inventors represents a small fraction of all domestic inventors in Israel (about 2%) but they account for a quite significant share of investors in Ireland and India - about 10% and 6% respectively (Table 11). It is worth to note that the inventive productivity of these inventors is higher than the average productivity of the 1,114 domestic inventors employed by a domestic assignee. These data then show that in Ireland and India MNCs represent an important source of high level skills. In Israel the contribution of MNCs to both skill training and inventions appear to be more limited in relative terms but the scale of patents and inventors arising from MNCs located in Israel is larger than that of the other two countries together.

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[6] 13 patent cited were granted to Israeli assignees, 3 to Indians and 1 to Irish.

[7] It is possible that, for example, patents granted to IBM India cite a number of patents granted to IBM US. But our data show that these knowledge flows within IBM corporation have limited implications for the innovative activities of Indian software firms.

Table 11. Domestic inventors formerly employed by MNCs

	Inventors	As a % of total domestic inventors	Patents	Patents (with a domestic assignee)	Patents (MNCs assegnee)	Average productivity (1)	Average (St. Dev) productivity all domestic inventors (1)
India	5	0.060	36	32	4	7.200	1.2 0 (0.65)
Ireland	14	0.099	30	25	5	2.143	1.21 (0.61)
Israel	38	0.022	83	64	19	2.184	1.62 (1.52)

(1) average productivity=average number of patents per inventor over the sample period

Another potential source of spillovers for domestic firms arises from formal linkages with the local subsidiaries of MNCs and other firms. Table 12[8] shows that there is limited number of linkages that involve MNCs in the three clusters.

Table 12. Most important linkages spawned by MNCs

	MNCs with linkages	*Total MNCs' linkages*	*JVs*	*M&As*	*Strategic alliances*
India	14	15	8	1	6
Ireland	10	12	0	12	0
Israel	41	62	4	51	7
Total (1)	65	89	12	64	13

(1): Four of the 61 sample MNCs have set up linkages in all three countries
Source: elaborations on InfotrackWeb database

We compare these linkages with the links that domestic firms have established with non-MNCs over the same period. The latter are foreign firms without subsidiaries in our sample clusters. As Table 13 shows, Irish or Indian software firms are less likely to establish linkages with MNCs than with other foreign firms (non-MNCs). Israeli firms have the same probability to establish linkages with MNCs and non-MNCs.

Table 13. Links between foreign firms and domestic firms

Host country	Foreign firm	Links
India	MNC	0.181*
India	Non-MNC	0.819*
Ireland	MNC	0.262*
Ireland	Non-MNC	0.738*
Israel	MNC	0.487
Israel	Non-MNC	0.513

(*) 0.01 p-values obtained from the test of differences between probabilities.

MNCs as such then have not any advantage compared with non-MNCs in establishing linkages with domestic firms. This may be due to the transportation and communication costs mentioned before. The immateriality of most inputs and the declining communication costs may then spur software firms to rely on partners located abroad. For similar reasons MNCs may decide to source their inputs from global suppliers located in other regions rather than local suppliers. Apparently these data confirm that the importance of physical proximity is quite limited in this industry. But we must warn against the generalisation of these results because our dataset does not tell about linkages established before 1998. It is possible that MNCs have already established linkages with domestic firms before the sample period. It is also possible that non-MNC have established long-term, formal linkages with domestic firms to reduce the disadvantages of the geographical distance. Finally, our dataset does not account for informal linkages among firms and employees.

[8] There are 3 spinoffs and 3 supply linkages that have been excluded from this table.

An alternative explanation is that MNCs carry out low value added activities locally and therefore do not need to interact with domestic suppliers. As discussed before, the theory of multinational corporations and regional development suggests that there is a positive association between the nature of activities carried out by MNCs and their embeddedness in the local networks of linkages. In order to test this hypothesis we analysed the correlation between MNCs' patents in the host country and their linkages with domestic firms and we found that there is a positive and significant correlation between these two variables.[9] Obviously this could well be a spurious correlation generated by a third unobservable variable that affects both MNCs' patents and their localised linkages. However, to our purposes here it is enough to say that technological activities of MNCs and their linkages with domestic firms are two faces of the same process of localisation which is in line with the "developmental model" of FDI.

The InfotrackWeb dataset provides several examples that illustrate the positive correlation discussed here. For instance, IBM Haifa Research Lab set up an agreement with Verisity of Israel while Microsoft Israel (R&D activities) signed a collaborative agreement with CommTouch. It is important to recall that IBM's R&D laboratories in Israel have been granted 219 patents and Microsoft's local laboratories have been granted 18 patents between the 1970s and the 2000s. On the other hand, Microsoft Ireland, which conducts low value added activities in this host country (its local subsidiary has never been granted any patent), has established no linkages with domestic firms. These examples illustrate there is a small group of MNCs that contribute to the growth of these clusters on many grounds – patenting, people mobility and linkages with domestic firms.

5. Conclusions

This paper illustrates the evolution of software clusters in India, Ireland and Israel. These clusters have grown very rapidly especially over the 1990s around few metropolitan areas such as Dublin, Tel Aviv and Bangalore.

The presence of MNCs varies across these countries in line with their different location advantages. The comparative advantage of India is represented by the relative abundance of skilled, English-speaking programmers. This is demonstrated by its leading position in the world market for outsourcing services, such as offshore software development, maintenance and on-line customer support. Only recently, the largest Indian firms have started to increase the value added of their activities. MNCs have mostly located relatively low R&D-intensive activities in India. Even when, as in the case of Texas Instruments, MNCs carry out some R&D activities these appear to be quite isolated from the host country's environment.

The relative abundance of English-speaking IT skills has provided an important initial advantage to Ireland as well, even though this advantage has declined over time. The most important location advantage of this country is probably represented by the relative proximity to the EU market. This advantage and fiscal incentives have spurred most MNCs to locate in Ireland low value added activities which are primarily dedicated to packaging and distribution of legacy software products. Compared to India, however, the technological and marketing capabilities of domestic software firms have evolved more rapidly, as demonstrated by some distinguished software products introduced during the 1990s.

The location advantages of Israel are clearly centred on scientific and technological capabilities that have attracted a great deal of R&D activities by MNCs. In this case, the interactions between domestic firms' technological capabilities and MNCs resources have favoured the international growth of an high value added domestic industry which has produced several globally successful software products.

Beyond these differences across countries, our analysis identified a group of MNCs that provide a quite significant contribution to the development of our clusters in terms of technological activities measured by patents, skilled people mobility and linkages with domestic firms. MNCs that conduct high value added activities (R&D) have also established linkages with local firms. Future research should further explore this correlation.

This study is useful for the formulation of regional technology policies and incentive schemes to the location of MNCs in developing regions. To R&D managers this paper provides information about the strategy of R&D international location in emerging clusters by large high tech MNCs.

[9] The Pearson correlation coefficient is 0.357 (p-value= 0.000, n=120).

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