For Official Use **DSTI/IND(2008)27**

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development **13-Oct-2008**

English - Or. English

DIRECTORATE FOR SCIENCE, TECHNOLOGY AND INDUSTRY
COMMITTEE ON INDUSTRY, INNOVATION AND ENTREPRENEURSHIP

DSTI/IND(2008)27
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CHAPTER 2. R&D AND THE MARKET ENVIROMENT IN THE SOFTWARE SECTOR

OECD PROJECT ON INNOVATION IN THE SOFTWARE SECTOR

This document is submitted for information and discussion under Item 6 a) of the CIIE agenda. It does not incorporate feedback received from the meeting of the Software Advisory Expert Group that took place in Tokyo on 7 October 2008.

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JT03252775

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CHAPTER 2.
R&D AND THE MARKET ENVIROMENT IN THE SOFTWARE SECTOR

Introduction and Main Findings

1. The software sector is one of the sectors most dependent upon research and development (R&D) to fuel innovation. Although R&D and innovation[1] are closely related, they can and do diverge. Not all R&D will lead to innovation, and not all innovation requires R&D. Nevertheless, in general, the introduction of improved software functionality or quality requires greater expenditure on R&D and production (*e.g.* in terms of deeper testing in order to detect and fix potential problems). This is a costly endeavour, a point confirmed in the literature on the topic.[2] Since the marginal costs of software production are comparatively small, the main costs that software developers face in attaining appropriate quality standards are experienced in the R&D phase.[3]

2. This Chapter looks at R&D and the market environment in the software sector. It examines R&D indicators, globalisation of software markets and R&D, R&D in a collaborative context and national frameworks for R&D. Building on a review of available evidence, this chapter highlights the importance of R&D processes in the software sector as a key contributor to the very dynamic pace of innovation in the sector, while also signalling evolution and change in those very processes. The analysis points to five main findings:

- *Increasing intensity and extensiveness of R&D* – The intensity of R&D activities in the software sector is high and tending to rise (*e.g.* in terms of key expenditure indicators). At the same time, the extent of R&D processes is broadening (*e.g.* geographically and in terms of the range of stakeholders directly involved). The combination is fuelling a significant increase in software R&D activities through internationalisation, collaboration and openness, among other developments.

- *Human capital is at the heart of the R&D process* – While human capital is generally important in the software sector (see also Chapter 1), it appears particularly important in the R&D activities of the sector. This involves the knowledge, skills and aptitudes of participants, and the way they interact. Networks are critical, both inside of multinational enterprises and among more disparate collaborators.

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1 As noted in Chapter 1, OECD (2005) defines innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations."

2 For example: Kemerer (1987); Mukhopadhyay and Kekre, (1992); Banker *et al.*, (1993); Maxwell *et al.*, (1999); Krishnan *et al.*, (2000).

3 On a theoretical level the concept of costly quality was introduced in early economic analysis (Hirshleifer, 1955). This idea was further developed in subsequent applied studies (Groocock, 1973, Freeman, 1995; Besterfield, 1979; Dale and Plunkett, 1991).

- *R&D processes take place in the context of dynamic interplay between technological progress and market demand* – As the software industry matures and technological progress continues (expanding the possibilities for new software functionality), the R&D processes increasingly take into account user input as well as the technical possibilities afforded by improved hardware capabilities. This dual approach may help to better ensure market-relevance of the output of R&D processes. For example, new technical possibilities via the Internet are being considered in light of user demand for secure, reliable, powerful and integrated systems, leading to new developments in software-as-a-service and, more broadly, cloud computing.

- *Tremendous potential for economies of scale via software R&D* – Globalisation, the mainstreaming of software throughout the devices associated with modern life, and the low marginal cost of reproduction of software mean that there are tremendous opportunities to leverage R&D. This can be via collaboration on the input side to reduce costs or expand the potential for results (*e.g.* better resulting functionality) and via reuse or broad application of the results on the output side (*e.g.* in many products across global markets). Ecosystems of participants are engaging in multidimensional co-operation to drive forward the R&D processes in the sector.

- *Much of this activity is taking place under the auspices of the private sector* (enterprises and other institutions). Still, from case studies and other evidence, it appears that policy can influence the environment for innovation in important ways, such as promotion of human capital development or basic research, or seeding development of quasi-public goods like the Internet.

R&D investment in the software sector

3. Existing data at the national-level and firm-level point to the large scale and intensity of software-related R&D activity, as well as its international scope. The following two sections treat these two levels, each in turn, followed by a discussion of software-related patents as one indicator of R&D output.

National-level estimates

4. The OECD Research and Development database contains data on Business Expenditure R&D (BERD),[4,5] which highlight the large scale of investment in the broad sector "computer and related activities" (Figure 1). The United States accounts – by far – for the largest absolute amount of expenditure on R&D for this area,[6] followed by Israel, Japan and Germany. The data for the subcategory "software

4 The OECD data presented here are based on the definition of R&D provided in the OECD *Frascati Manual* (OECD, 2002a). This manual is devoted to measuring R&D inputs. R&D covers both formal R&D in R&D units and informal or occasional R&D in other units. However, interest in R&D depends more on the new knowledge and innovations and the economic and social effects *that result* than on the activity itself. Unfortunately, while indicators of R&D output are clearly needed to complement input statistics, they are far more difficult to define and produce. In the context of innovation, R&D alone really is too narrow a measure. Ideally a broader framework on intangible investments, which covers not only R&D and related science and technology activities but also expenditures on software, training, organisation, among other areas, should be considered.

5 It should be noted that although R&D expenditure tends to be positively associated with innovation, there is not a consistent relationship in indicators for the two phenomena over time, space and fields of activity. R&D spending may vary from the actual rate of innovation, for example, due to differences in the productivity of the various R&D investments or problems in statistical estimation.

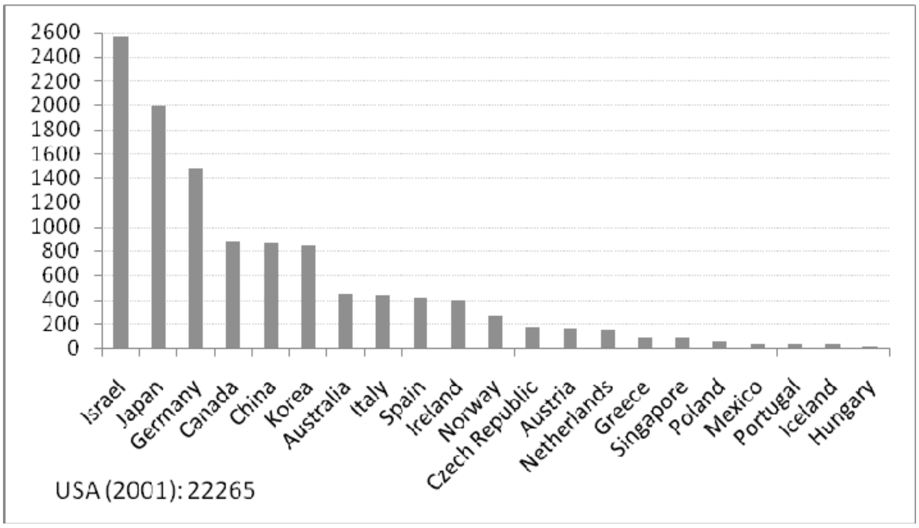
6 For the United States, statistics on funds for industrial R&D performance by for-profit businesses are provided by the National Science Foundation (NSF) through its Survey of Industrial R&D (SIRD) that

consultancy and supply" are shown in Figure 2. Here again the United States is the leading country, followed by Germany and Canada. China, notably, is also highly placed terms of business expenditure in R&D, ranking 5th in computer and related activities and 4th in the latter software consultancy and supply.

5. Another approach toward estimation of aggregate spending on R&D in software builds on a research finding from the literature that the share of software R&D in overall software investment is approximately 25% (Khan, 2004). Based on this estimate, the importance of R&D in software in total R&D is estimated to range from around 34% in New Zealand to around 5% in Ireland and Portugal (Figure 3). These estimates are illustrative of differences between countries in terms of the importance of software R&D in relation to their overall R&D efforts. That is, they highlight the relative importance of software R&D within a country's overall R&D investment, but do not consider the overall size of the investment in absolute terms.

Figure 1. Business Expenditure on R&D, Computer and Related Services[1,2]

(millions PPP Dollars, current prices)



Notes:

1) Data are for most recent year available, generally 2005, except as follows: Canada, Israel, Italy: 2006; Australia, Austria, Spain: 2004; Germany, Greece, Portugal: 2003; China: 2000.

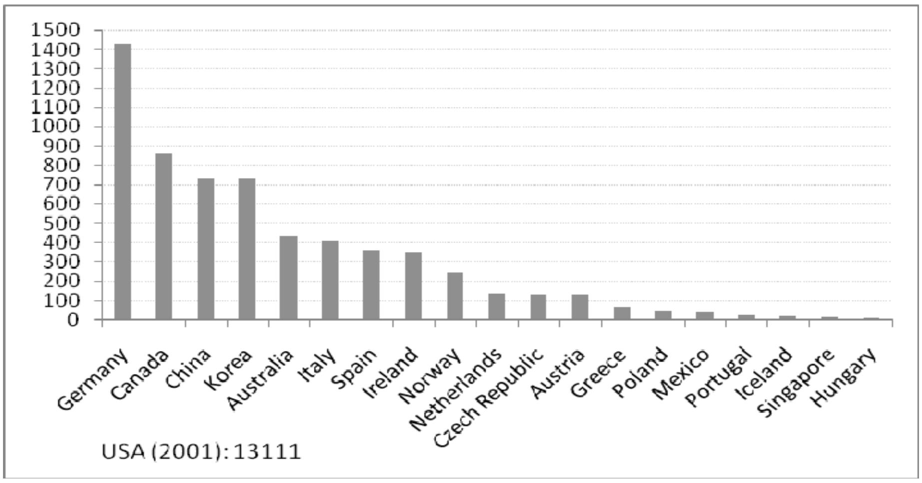
2) The comparable figure for the United States is 22265 for the year 2001.

Source: OECD Research and Development Database, preliminary.

covers Federal funding for that purpose, company and other funding, and total industrial R&D. The U.S. data shown in Figure 2 are not for "software publishing" (NAICS 5112) also known as packaged software. Software publishing R&D funding statistics are not disclosed for the years 2002 –04 and are aggregated in the Information Publishing (NAICS 511) category for 2005. The NSF data also exclude software R&D data on start-up or firms in the process of developing their first products since it classifies these early stage companies in the R&D services category (NAICS 5417).

Figure 2. Business Expenditure on R&D, Software Consultancy and Supply[1,2]

(millions PPP Dollars, current prices)



Notes:

1) Data are for most recent year available, generally 2005, except as follows: Canada, Italy: 2006; Australia, Austria, Spain: 2004; Germany, Greece, Portugal: 2003; China: 2000.

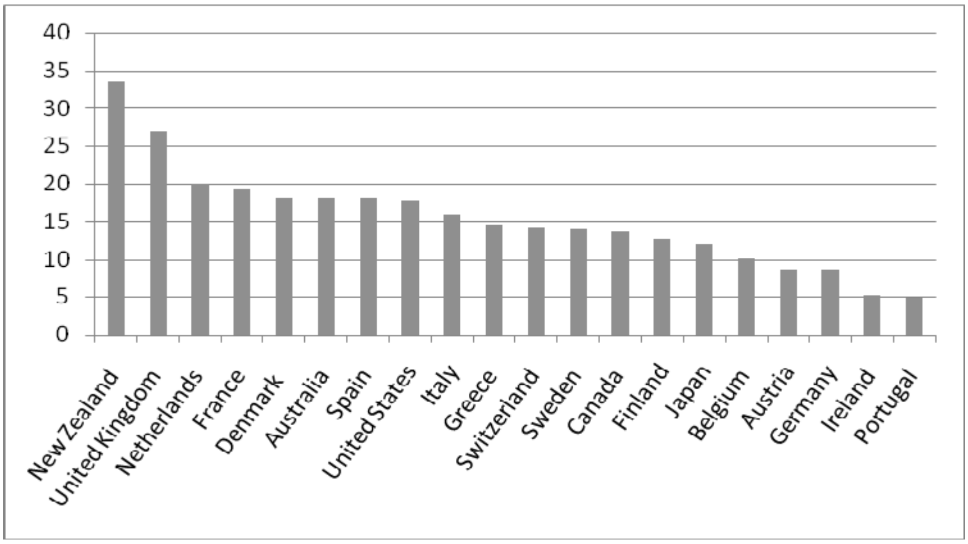
2) The comparable figure for the United States is 13111 for the year 2001.

3) Data for Israel and Japan are not available for this subcategory. For Mexico, all of computer and related activities is comprised of software consultancy and supply. The percentage of computer and related activities accounted for by software consultancy and supply in the countries shown in Figure 2 varies between 100% (Mexico) and 19% (Singapore).

Source: OECD Research and Development Database, preliminary.

Figure 3. R&D in software[1] as a share of total gross domestic expenditure on R&D[2, 3]

(per centages)



Notes:

1) R&D in software was estimated by the Secretariat as 25% of total software investment (based on a finding by Khan, 2004).

2) Gross domestic expenditure on R&D amounts to between 0.6% (Greece) and 3.5% (Finland) of GDP.

3) Data refer to 2005, except 2004 for Australia, Belgium, Greece, Japan, Switzerland and 2006 for Canada, France, Germany, Ireland, Sweden and the United States.

Source: OECD Capital Services Database.

Firm level estimates

6. Although the data on R&D activity in the software sector are not always consistent in their coverage or treatment of software, they nonetheless paint a picture of a sector that his highly R&D focused.[7] Table 1 presents indicators based on firm-level data from a global R&D investment database sponsored by the European Commission (EC, 2007b, c).[8] As shown in the Table, the broad category "software and computer services" places 5th among the 22 sectors represented by the top 1400 companies in terms of absolute volume of R&D expenditure. In terms of the R&D expenditure as a percentage of sales (R&D intensity), the sector ranks 2nd beyond pharmaceuticals and biotechnology. The R&D intensity of the sector is nearly three times the average for the top 1400 firms as a group.

Table 1. R&D Performance, By Sector, Top 1400 Companies, 2006

	Aggregate R&D Investment (Euros, millions)	Share in Total R&D Investment	R&D intensity (% of sales)
Top 5 Sectors			
Pharmaceuticals & biotechnology	70523.5	19.3	15.9
Technology hardware & equipment	64531.5	17.6	8.6
Automobiles & parts	60807.1	16.6	4.1
Electronic & electrical equipment	27138.9	7.4	4.4
Software & computer services	26522.8	7.3	9.8
Combined results, 22 Sectors	365823.9	100.0	3.4

Notes: The table is based on the top 1400 companies in terms of absolute volume of investment in R&D during 2006. The categories are based on the ICB industry classification system. The category software and computer services refers to ICB 9530, which covers computer services, Internet services and software.

Source: EC (2007b), Table 2.

7. Table 2 considers the top 150 software publishers in the world among the firms in the EC-sponsored R&D investment database (EC, 2007b). The table presents the average profitability of firms (as a percentage of sales) in relation to indicators of their R&D activity. The largest investors in R&D are the most profitable as measured by both aggregate R&D investment and R&D investment per employee. This does not imply causality (R&D could fuel innovation that drives profits or vice-versa, or other factors may be at work). It does provide an indication that scale effects may play a role; large firms able to mobilise more resources for R&D may also turn out to be more profitable.[9]

7 For example, data are not always available at the level of the software sector, which is sometimes lumped with other activity as part of a broader category such as "computer and related activities". Furthermore, in some databases the data on the sector cover software-related activities across the economy, whereas in others it refers exclusively to the software sector.

8 R&D investment as defined for purposes of the database includes cash investment funded by the companies themselves, while excluding R&D done under contract for others or R&D done by associated companies and joint ventures. It is based on the amounts disclosed in the annual reports and accounts of the firms.

9 For the top 150 software publishers, the correlation coefficient between the aggregate R&D investment indicator and the profitability indicator is very weakly positive 0.16, though this is stronger if the calculation is made for the top 25 firms, for which the coefficient comes in at 0.53.

Table 2. Profitability and R&D Indicators for Top Software Firms, Ranked by Volume of R&D Investment, 2006

Firms	Average Profitability (% of sales)	Average R&D Intensity (% sales)	Average R&D per employee (Euros, thousands)	Average R&D Expenditure (Euros, millions)
Top 10	19.5	20.5	50.2	1132.4
Top 25	13.2	19.2	41.3	551.1
Top 150	3.7	20.1	31.5	118.2

Note: The data refer to ICB Sector 9537, software publishers and distributors of computer software for home or corporate use. They exclude Internet service companies and computer service companies as well as computer game producers.

Source: EC (2007b), authors' calculations.

8. Table 3 presents data on the leading firms (in terms of R&D investment) in software publishing, computer services and the Internet services (EC, 2007a). The firm-level data highlight the massive investments in R&D made by these leading firms. Moreover, many of the firms – particularly the Internet services and software publishing firms – have moved to substantially increase their R&D investment, with double-digit compound annual rates of growth (triple-digit growth in the case of Google).[10]

9. While the table reflects the strong presence of American firms among these R&D leaders, it is important to note that these data do not give an indication of the geographic location of the R&D investments; the investments of all establishments are attributed to the firm and the country of registration of its headquarters irrespective of where the actual investment took place. Nevertheless, the data seem to suggest some role for the domiciliation of the firms. In 2006 (EC, 2007b), only 7 of the top 25 software publishing firms in terms of R&D investment were headquartered outside of the United States: 1 in Germany, 3 in France and 3 in the United Kingdom. Similarly, among the top 25 firms in the database in terms of net sales in 2006, only 8 were headquartered outside of the United States.

10 Rates of growth are shown as 3 year averages since R&D flows can vary substantially from year to year as projects are completed or launched.

Table 3. R&D investment by top companies operating in the fields of software, computer services and Internet, 2005

	Company	Country	R&D Investment		Net Sales		Employees		R&D Intensity	
			Euros (millions)	CAGR 3 Yrs %	Euros (millions)	CAGR 3 Yrs %	Number	CAGR 3 Yrs %	R&D as % of sales %	R&D per Employee € (thousands)
Software										
1	Microsoft	USA	5,581.52	12.2	37,540	11.2	71,533	9.2	14.9	78.0
2	Oracle	USA	1,586.97	16.6	12,191	14.9	56,133	11.4	13.0	28.3
3	SAP	Germany	1,088.63	6.2	8,512	4.7	34,550	5.3	12.8	31.5
4	CA	USA	662.09	3.5	3,226	6.9	16,000	0.0	20.5	41.4
5	Symantec	USA	578.27	51.2	3,513	43.3	16,000	55.0	16.5	36.1
6	Cadence Design Systems	USA	358.88	3.0	1,127	0.9	5,000	-1.1	31.8	71.8
7	Adobe Systems	USA	309.70	14.1	1,667	19.1	5,734	19.7	18.6	54.0
8	Sega Sammy	Japan	298.73	n.a.	3,704	n.a.	5,407	n.a.	8.1	55.2
9	Intuit	USA	285.34	14.4	1,727	14.4	7,000	2.5	16.5	40.8
10	Synopsys	USA	271.27	12.1	841	3.0	4,756	3.8	32.3	57.0
Computer Services										
1	IBM	USA	4,559.15	4.3	77,258	3.9	329,373	1.4	5.9	13.8
2	Unisys	USA	330.28	-1.9	4,882	0.9	36,100	-0.3	6.8	9.1
3	SunGard Data Systems	USA	207.53	12.0	3,318	15.7	15,000	19.5	6.3	13.8
4	DST Systems	USA	110.88	-3.7	2,132	1.8	10,500	-3.5	5.2	10.6
5	Indra Sistemas	Spain	85.90	6.0	1,202	11.2	7,584	7.6	7.1	11.3
Internet										
1	Google	USA	508.23	145.5	5,204	140.7	5,680	n.a.	9.8	89.5
2	Yahoo!	USA	498.07	56.0	4,457	76.7	9,800	39.6	11.2	50.8
3	Check Point Software Technologies	Israel	42.85	20.7	491	10.7	1,414	5.5	8.7	30.3
4	United Online	USA	33.92	17.3	445	46.3	900	28.9	7.6	37.7
5	F5 Netwoks	USA	26.58	20.3	239	37.5	792	n.a.	11.1	33.6

Notes: n.a. = not available; CAGR = compound annual growth rate.

The Table refers to the top companies in terms of expenditure on R&D.

Source: European Commission (EC, 2007a).

Indicators for ICT and R&D[11]

10. The classification "ICT" includes software, but also a number of neighbouring sectors. That is, ICT is a broader classification. Nevertheless, in the absence of internationally comparable data on some dimensions of R&D, consideration of indicators for the broader sector can at least provide an indication of the environment in which the software sector operates. For example, it can help to shed some light on the case of employment in R&D activities in the "neighbourhood" of the software sector and on the case of publicly funded research.

ICT Employment in R&D Activities

11. As noted in Chapter 1, the software sector in general depends heavily on its human capital. There are indications that this is particularly true with respect to R&D in the sector, despite the scarcity of internationally comparable data. One indication can be found in data for the broader ICT sector, of which the software sector is a part.[12]

12. R&D employment data for the ICT sector reflect the large scale of human resources deployed in these activities; across 25 developed countries in 2006, ICT R&D employment amounted to 943 000.[13]

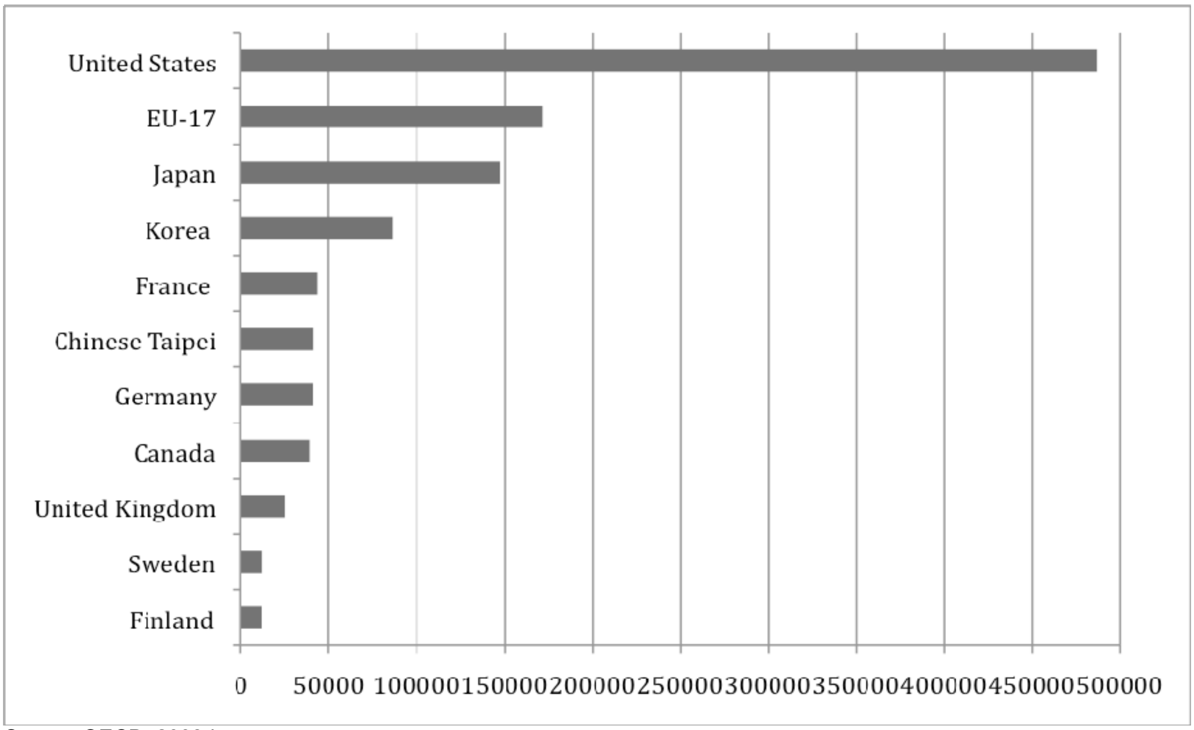
11 This section draws heavily on OECD (2008d), as well as other sources.

12 It is notable that in most OECD countries the availability of high-quality research personnel for the ICT industry is an increasing policy concern. See, for example, Eutema, 2007 for Austria; BMWI, 2007 for Germany; MTI, 2007 for Norway; PCAST, 2007 for the United States; MIC, 2005 for Japan.

13 This calculation includes 24 OECD member countries (Mexico, Poland, Switzerland, Spain, Hungary, Netherlands, Germany, United Kingdom, Czech Republic, Norway, Greece, Belgium, Australia, Italy, Japan, Austria, France, Portugal, Denmark, United States, Canada, Finland, Korea and Ireland) plus Slovenia. Data are partly estimated and may underestimate the actual totals.

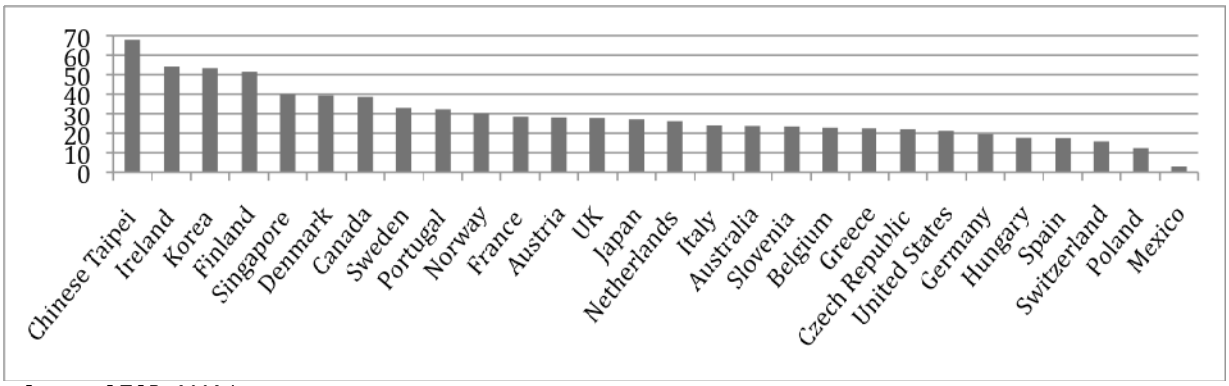
With nearly 487 000 researchers, the United States accounted for just over ½ of the total (Figure 4), followed by EU-17 countries, Japan and Korea.[14] Figure 5 highlights the share of ICT R&D workers in the total for each economy. The OECD countries with the largest share of ICT R&D personnel by this measure are Ireland (54%), Korea (53%), Finland (51%), Denmark (39%), and Canada (39%). Among non-OECD economies Chinese Taipei (68%) and Singapore (40%) exhibit a relatively high degree of specialisation of their researchers in ICT.

Figure 4. ICT R&D researchers 2006 or latest available year (full time equivalents)



Source: OECD, 2008d.

Figure 5. Share of ICT R&D researchers in total R&D researchers, 2006 or latest available (in percent)



Source: OECD, 2008d.

14 This ranking is quite similar to that of 2002 (OECD, 2006a). Also, figures for non-OECD countries are available only for Chinese Taipei (41000), Singapore (6400), and Slovenia (500). Chinese Taipei had just slightly fewer ICT R&D researchers than France but more than Germany.

ICT and the Continuing Importance of Publicly Funded Research

13. When it comes to ICT inventions, the move from initial basic research to applied use can take decades. In some cases, unanticipated research results from fundamental research can provide important building blocks for subsequent innovation. Publicly-funded research has long been a stimulus for related business R&D and has contributed to the development of key technologies such as semiconductors or networking technologies (NRC, 2003; MIC Japan, 2005).[15] In particular, national space and defence R&D programs have funded a significant amount of ICT research, including in relation to hardware and software. Other examples of innovations drawing on publicly-funded basic research include the Internet, graphical user interfaces, global positioning systems and web search technologies.

14. The ICT sector has relied to some extent on publicly-funded R&D and on complex partnerships among government, public sector research organisations and industry, as well as long-term fundamental scientific research performed at universities.[16] Firms conducting ICT-related research often cluster close to universities, benefitting from the positive spill-overs associated with public ICT-related R&D. In the United States, for instance, 70% of R&D performed by all domestic and foreign computer and electronic firms in 2005 was located in four locations[17] with proximity to public research institutes and major universities (National Science Board, 2008).

15. In recent years, OECD member countries have substantially increased overall public funding for R&D (OECD, 2008d). Data on government budget appropriations or outlays for R&D show that between 2000 and 2006, government R&D budgets in the OECD area expanded by 6.8% annually; this rate is greater than the rate of GDP growth. However, there is considerable inter-country variation in terms of the level and composition of R&D funding.[18] For example, the defence R&D budget of 0.6% of GDP in the United States is well in excess of those in United Kingdom or France (both at 0.2% of GDP).

16. Despite the importance of public research to the ICT sector, official figures on total funds allocated to publicly-funded ICT-related R&D are not available in an internationally comparable manner.[19] Public R&D spending data (*i.e.* government appropriations for ICT-related R&D) generally do not permit assessments specific to the ICT sector or detailed socio-economic objectives specific to ICTs. Although broad socio-economic objectives such as "Non-oriented research in Mathematics and Computer Science" are directly or indirectly related to ICT research, exact ICT-related figures are hard to produce.

17. While comprehensive data are not available, OECD governments are formulating ICT R&D funding programmes to promote research and (international) cooperation between the private and public sector. ICT R&D budgets in the United States (NITRD), Japan (Council for Science and Technology Policy's ICT-related R&D budget), and at the EU-level (ICT-related funding in FP7) are particularly

15 See van Pottelsberghe (2008) on the linkages between publicly and privately funded R&D.

16 Some private sector ICT firms do invest heavily in basic or exploratory research of their own as a means of gaining comparative advantage. For example, HP Labs recently moved to allocate 1/3 of its budget to such research, up from 10%. IBM is adding "big bet" projects in exploratory research and expanding collaboration, for example, with its customers (Anthes, 2008).

17 The four clusters include Cambridge and Route 128 in Massachusetts; the Silicon Hills of Austin, Texas; Champaign County in Illinois; and Silicon Valley in California.

18 Since 2000, the broader category of government budget outlays or appropriations for R&D grew by 8% annually across the OECD, from USD 197 billion in 2000 to USD 293 billion in 2006 (in current PPP USD) (OECD, 2008d).

19 GFII (2007) has produced estimates, with on-going European Commission–sponsored projects aiming to produce further estimates.

notable in terms of absolute spending (over USD 1 billion annually).[20] In certain other countries, funding programmes for ICT research also receive high priority, either as stand-alone policies (*e.g.* Germany's ICT 2020) or as a major pillar of wider science, technology and innovation policies (*e.g.* Spain's "Ingenio 2010" and Canada's "Mobilizing Science and Technology to Canada's Advantage"). Most of these programmes represent only a subpart of total public funding available to ICT-related research and are often complemented by public research funding on a sub-national or national level. General public policy measures (*e.g*. R&D tax concessions in various forms) are also important for the promotion of ICT-related research. Non-OECD countries such as China and India are also increasing support for ICT-related research. These programmes are usually part of national science and technology agendas, but in comparison to the United States, Japan and the EU, absolute annual funding for explicit ICT-related research in non-OECD countries is still relatively low.

18. Finally, national ICT diffusion strategies entail plans to boost ICT R&D as a driver of innovation. Examples include the u-Korea Master Plan (2006-2010) and the Information Society Strategies in Turkey and Switzerland. Non-OECD member economies are also embedding R&D promotion into national ICT strategies (*e.g*. Singapore's Intelligent Nation 2015).

R&D and Software-Related Patents[21]

19. Patent data can be considered as providing an indication of the output from R&D activity. However, the links between patenting and commercial innovation are complex and subject to variation across time, business environments and subject areas, among other dimensions. There is not necessarily a one-to-one relationship. Thus, patents are an imperfect indicator of innovative activity in the software sector.

20. A variety of issues may arise in the use of patents as such an indicator. One concerns the pace of innovation in the sector. Patent applications take substantial amounts of time for review and approval by the authorities, which may prompt some software innovators to rely on other more-expeditious means of protecting their innovative advantage (*e.g.* copyrights, trade secrets or time-to-market advantages in their innovative processes). The utility of these alternative approaches may vary depending on the market environment and nature of the innovation. Hence, software innovators may not behave consistently in their recourse to patent protection. Furthermore, the increased importance of open innovation and open source software may influence the use of patenting. Innovators using open approaches may invoke intellectual property rights and employ various licensing schemes (*e.g.* to defend the open nature of their creations), but they appear to have a much lower propensity to seek software-related patents than innovators using, for example, proprietary or hybrid approaches. There is also an issue of patent content; the number of patents granted does not provide an estimation of the quality or impact of the associated innovations. Finally, international comparisons are complicated by the fact that the treatment of software-related inventions may differ in the details across various countries; the ease with which firms may obtain patents for software-related innovations also varies among countries.

21. Despite the measurement challenges, research has shown that the stock of patents is correlated with firm success in the software industry (Merges, 2006). For example, use of patents may boost innovation in software by increasing possibilities to appropriate returns from R&D, raising productivity of R&D, and yielding more efficient transactions in knowledge (*e.g.* Smith and Mann, 2004). Software-related patents have been found to be useful for new, small, entrants to the software sector. Such firms may

20 All three cases enjoy high priority due to their situation at the highest policy-making level (US: Executive Office of the President, Japan: PM's Cabinet Office, EU: European Commission, adopted by the European Parliament and European Council).

21 See Chapter 1 for a discussion of intellectual property rights in the software context.

use patents to signal their expertise to third parties, negotiate cross-licensing arrangements, increase their value to potential buyers and convert tacit knowledge into a verifiable and transferable form (Mann, 2004).[22] Patents may help small firms attract venture capital or other finance, acting as a signal to potential investors. Patents can also facilitate intra-industry technology transfers in the case of cumulative innovation processes. They may facilitate outsourcing to independent parties as they represent codified information which may be transferred more easily (Arora and Merges, 2004).

22. Consequently, it is perhaps not surprising that the stock of software-related patents has been growing. In 2004, 4 695 software-related patents were issued to inventors in the US, more than the combined number for the rest the world (2 811). The average annual growth in software-related patenting between 1988 and 2004 was also greater in the US than in all other G7 economies: such patenting by US inventors grew at an average annual rate of 19.5%, compared to 16.1% in Japan and 18.0% in other G7 economies.

23. Looking at the leading recipients of US patents by country of inventor, Arora *et al*. (2007, Table 7) note that US firms (such as IBM and Intel) are the leading recipients of US software patents in China, India, Ireland and Israel, whereas in Germany, Japan and Korea, domestic firms are the main recipients (all domestic firms in the case of Japan and Korea). Overall, the US accounts for most of US software patents, followed by Japan, Germany and the United Kingdom. More generally, patent data for the US and Europe suggest that inventive activity in software development is concentrated in the US and dominated by US-owned firms. Although there is some evidence that some inventive activity by US firms has started to shift abroad, at present the shift is small and this remains a small share of US firms' overall inventive activity.

24. Data from the OECD Patent Database provide further insights on the trends and patterns in patenting. In many countries the share of software-related patents in ICT patents and in total patents increased between 1999 and 2003 (Figure 6), although Australia and Israel saw a decline in the share. In China the share of software patents in ICT patents declined while increasing as a share of total patents. The US largely dominates the worldwide distribution of software-related patents, although its share decreased slightly between 1999 and 2003 (Figure 7). The EU-25 countries collectively place second, while Japan accounts for the second largest individual country share.

25. The bulk of software-related patents are filed by firms whose primary activity is not software. There is no official definition of a software-related patent though as it is not recognised in the international patent classification system. Analysts have adopted several methods to try to identify software patents. One is to identify software-related patents as those that fall in a particular International Patent Classification (IPC) class, subclass or group (*e.g.* Graham and Mowery, 2003). Another approach has been to search for keywords. Thus, Bessen and Hunt (2004a, b), for example, defined software patents as those that include the words "software" or "computer" and "program" in the patent document description.[23] Hall and MacGarvie (2006) propose a definition that combines the two previous methods with one constructed on the basis of the patent classes and subclasses that contains patents assigned to fifteen of the largest software firms. A recent study for Europe, based on a combination of these three methodologies, shows that the

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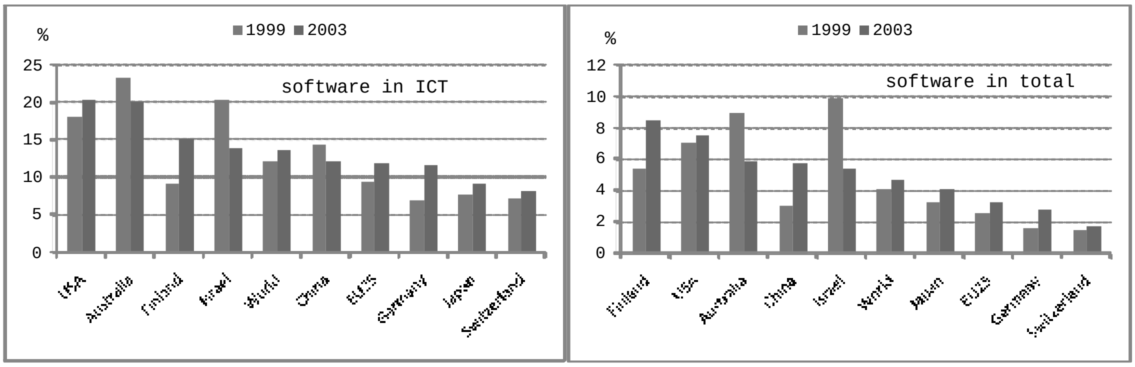
22 At the same time, patents may impact on entry and exit of firms in markets. Controlling for firm and market characteristics, Cockburn and MacGarvie (2006) find that firms are less likely to enter product classes where there are more software-related patents, although firms that actually hold such patents are more likely to enter these markets. They also find that patents also increase the chances of survival after market entry.

23 They then excluded those patents that had the words "semiconductor", "chip", "circuit" or "bus" in the title on the assumption that these patents were more likely to refer to the device used to execute the program rather than the software program itself.

software sector accounted for only 1.3% of software-related patents. The sector "electronic instruments and telecommunications equipment" alone accounted for 61.9% of software patents, followed by "telecommunications" with 8.2% and "motor vehicles" 3.9%.

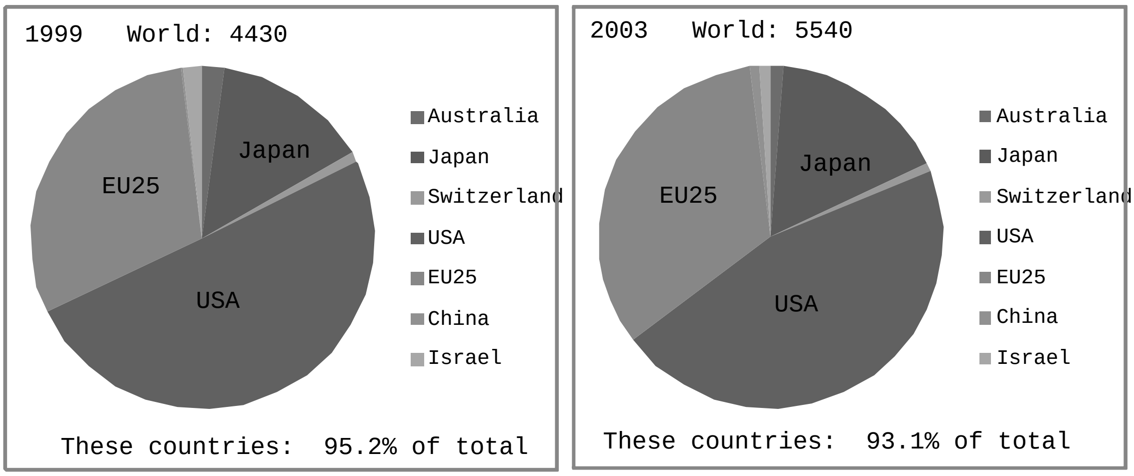
26. Bessen and Hunt (2004a, b) in a study for the US found that between 1994 and 1997, software-related patents tended to be US owned (70%), by firms (88%) rather than government (2%), and to have a US inventor (69%). After the US, the top countries are Japan (18%), Germany (3%), the UK (2%) and Canada (2%). Some 75% of software-related patents in their sample were obtained by manufacturing firms, especially in the electronics and machinery industries, which include computers. Only 5% were acquired by software publishers (SIC 7372); other software service firms, excluding IBM, accounted for 2%. IBM alone accounted for 13% of software-related patents in the sample, being consistently the largest software patentee.[24]

Figure 6. The share of software-related patents in ICT and total patents, 1999 and 2003



Source: OECD Patent Database.

Figure 7. Share of world software-related patents, 1999 and 2003



Source: OECD Patent Database.

24 Bessen and Hunt (2004a, b) separate out IBM as they do not consider it representative of the software services industry.

The Market Environment for R&D

27. The market environment for R&D and innovation in the software sector is increasingly characterised by the globalisation of software activities. Rapid developments in ICTs and the roll-out of high-speed broadband Internet and communications networks enable these changes and create opportunities for new business approaches such as "software as a service" (as discussed in Chapter 1). Globalisation in the sector is partly reflected in increased numbers of firms and communities (*e.g.* universities, institutes, governments) collaborating across national borders, but also increased trade in software goods and services, international movement of software engineers and other IT specialists, offshoring of software activities, and expansion of the international operations of large multinational enterprises (MNEs).

28. Business sector R&D, in general, is rapidly internationalising. This is largely driven by the changing strategies of MNEs, which account for the bulk of global business R&D. In the past, most MNEs had the tendency to keep R&D "at home", where the headquarters were located, while globalising other activities. Now, they increasingly are adopting strategies of global technology sourcing. Software sector firms are increasingly situating their R&D activities strategically at various locations around the world, tapping into regional strengths or positioning themselves in key markets. This can be in the form of research laboratories or, for example, on-site with other collaborators such as clients. Indeed, development for some types of software requires physical proximity to the client.

International Competitiveness

29. A recent report by the Economist Intelligence Unit (EIU, 2007) reviewed the competitiveness of key countries with respect to the information technology sector (Table 4). The report identified the United States as the top location for firms in the sector, with particularly high scores for availability of highly skilled ICT-related human capital and a sound legal environment. The attractiveness of the US market is illustrated by the fact that such a large portion of leading software firms are headquartered there (as discussed above). Many of the factors that drive a country's attractiveness as a location for IT investment have also been identified as enabling and enhancing innovation (*e.g.* Jaumotte and Pain, 2005).

30. Japan and Korea ranked second and third, due in part to strong scores with respect to the environment for R&D according to the EIU definition (based on R&D expenditure, patenting and revenues from royalties and license fees). There are five European Union countries among the Top 15 locations. A number of emerging countries, including South Africa, India, Russia and China also figured in the listing, although lagging behind the other countries by a fairly wide gap. India and China have exhibited strong improvements ICT sector performance in recent years, fostered by favourable factors such as relatively low wages and large workforces with growing pools of skilled ICT professionals.[25] Relative to OECD economies, they still have some distance to go in order to catch up on factors such as ICT infrastructure, skills, and the legal environment to further improve overall ICT sector competitiveness and increase their attractiveness for investment in software including R&D activities (van Welsum and Xu, 2007).

31. Among the various elements influencing ICT competitiveness, the importance of human capital to successful innovation in the software sector is frequently underscored by stakeholders and analysts,

[25] The government of China has made it a priority to shift the economy towards higher value-added activities (Connor Linton, 2008). The recent 15-year science and technology plan calls for increase in R&D investment to 2.5 percent of GDP, reduction in dependence on imported technologies, improvement in the contribution to economic growth made by technological advances and joining the world's top five countries in terms of number of patents granted for domestic inventions and citations in international science papers. Software R&D figures prominently in this effort, particularly in relation to support for service industries, large-scale applications and basic software for core electronic components.

including with respect to R&D. This is true more broadly in the economy, as can be seen in the evidence from macroeconomic studies on the determinants of innovation and the outcomes of various innovation studies. But it is particularly true with respect to the software sector, which remains particularly human capital-intensive despite substantial technical progress in such areas as software engineering and development tools. The responses to an OECD Business Questionnaire addressed to software developers also highlighted the importance of human capital (OECD, 2008a).[26]

Table 4. IT Industry Competitiveness Index 2007, selected countries

	Overall index score	Business Environment[1]	IT Infrastructure[2]	Human Capital[3]	Legal Environment[4]	R&D Environment[5]	Support for IT industry Development[6]
Category weight=>		**10%**	**20%**	**20%**	**10%**	**25%**	**15%**
United States	77.4	97	81.3	96.4	92	39.8	86.8
Japan	72.7	82	52.3	67.4	79	84.3	77.1
Korea	67.2	80	61.7	74.8	66	56.6	74.3
United Kingdom	67.1	95	69.4	81.6	88.5	23.2	84.9
Australia	66.5	92	75.9	76.2	87	21.1	86.2
Canada	64.6	88	87.5	65.9	82	15.5	86.8
Netherlands	62.9	91	72.4	59.1	87	23.5	86.1
Germany	58.2	88	58	59.4	85	28.9	68
France	55.8	83	54.3	60.3	83.5	20.6	73.6
Israel	54.5	83	45.8	64.8	75.5	24.9	68.8
Spain	46.1	80	29.6	61	78	6.6	70.1
South Africa	33.4	77	8.9	40.8	63.5	1.5	60.6
India	29.1	60	0.5	49.6	48	0.7	54
Russia	28	48	8.6	56.8	38.5	6.3	31.5
China	27.9	47	8	44.7	49	2.2	48.1

Notes:

1) Business environment includes government policy towards foreign capital, degree of private property rights protection and freedom to compete.

2) IT infrastructure covers market spending on hardware, software and services, desktop per 100 people, broadband connections etc.

3) Human capital includes enrolment in tertiary level science programs and employment in technology sector.

4) Legal environment measures the comprehensiveness, transparency and enforcement of IP legislation, together with the status of national cybercrime laws.

5) R&D environment includes gross government and private sector expenditure on R&D, number of new patents registered and receipts from royalty and license fees.

6) Support for IT industry development covers access to medium term finance for investment and government policies.

Source: The EIU (2007).

32. Access to finance, and venture capital in particular, is very important for highly innovative and rapidly evolving sectors such as the software sector, especially since the development of software is costly and time consuming. Small software firms in particular tend to be venture-backed (Mann, 2005). The share of high-technology sectors in total venture capital (Figure 8) is indicative of the innovative potential generated by venture capital. According to Lumpkin and Thompson (2006), just over half of venture capital investment goes into high-technology firms in OECD22[27] economies, but there are large disparities

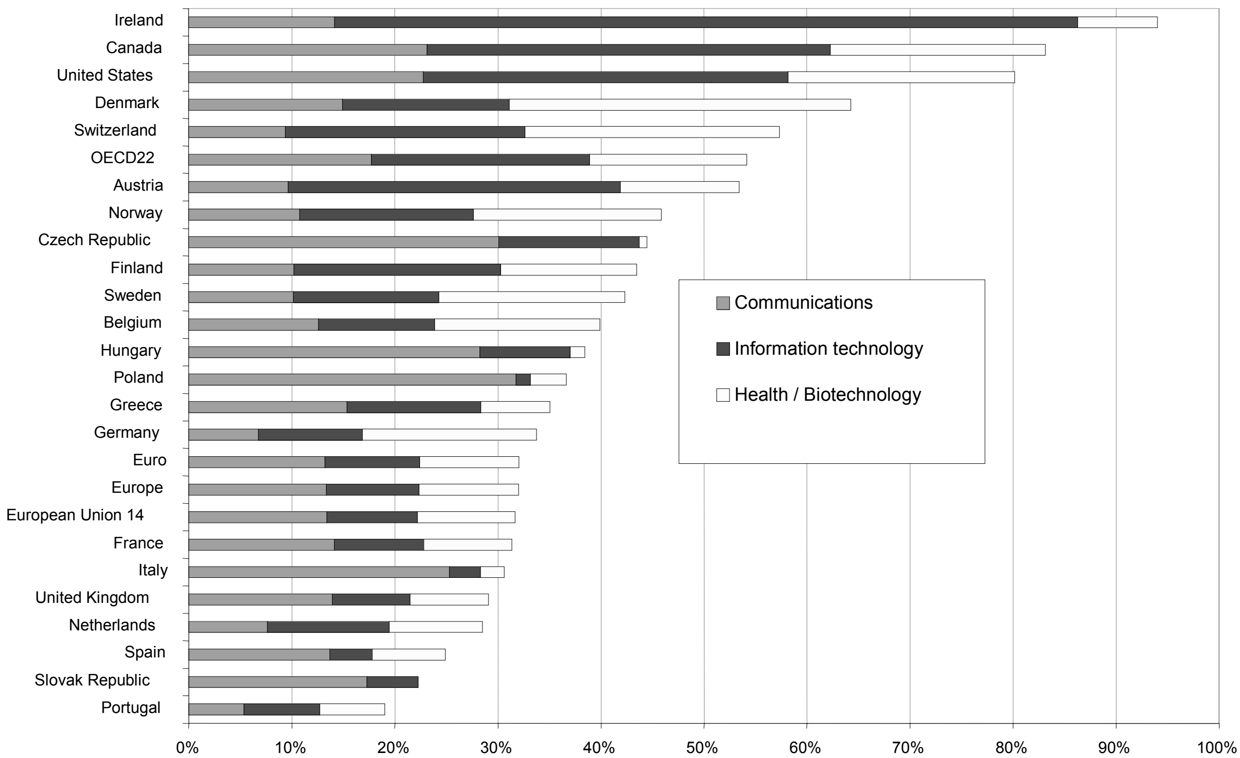
26 See Chapter 1 for further discussion of the human capital dimension of software innovation, as well as software engineering tools and the OECD business questionnaire.

27 See the note to Figure 8.

among countries. The share is highest in Ireland, Canada, the United States and Denmark, which all score above the OECD22 average. The IT sector accounts for the largest share in several countries, including Canada, Ireland and the United States. The high-technology share is also relatively high in some smaller countries which have relatively low overall levels of venture capital to GDP, such as some of the East European countries, but there the share is largely dominated by the communications sector.

Figure 8. Share of high-technology sectors in total venture capital

As a percentage of total venture capital investment, 2000-03



Note: Total venture capital investment consists of early and later stage venture capital as well as, except for the United States, buyouts. European Union 14 comprises data from Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Denmark, Sweden, and the United Kingdom. OECD22 comprises data from European Union 14 countries as well as from Norway, Switzerland, the Czech Republic, Hungary, Poland, the Slovak Republic, Canada and the United States.

Source: Lumpkin and Thompson (2006) based on data from EVCA (Europe); NVCA (United States); CVCA (Canada).

33. The United States stands out in terms of inputs of financial capital to emerging software firms, although the amount has at times fluctuated. According to a Price Water House Coopers report (2007), overall venture capital in software in the United States came to over USD 5.1 billion in 2006 and close to USD 4.9 billion in 2005. The National Venture Capital Association estimates venture capital software investments in the United States during 2007 at USD 5.4 billion (NSVD, 2008). Globally among ICT industries, the software industry received the most venture capital funding annually throughout the 2000-2006 period. Using a more narrowly specified methodology, one comparison by Arora *et al.* (2007) of *disclosed* rounds of venture capital financing for software products and services confirmed the United States to be a leader in this form of financing. In 2005, for example, the amount of such financing in the United States came to USD 138 million while the amount in the remaining G7 countries combined came to

around USD 2 million and also to about USD 2 million in a combined country group of emerging software innovators including India, Ireland, Israel, Brazil and China.[28]

Locational advantages

34. In the context of ICT competitiveness and globalisation of the market environment for innovation, two factors that are sometimes raised as being of particular interest include: wage differentials and infrastructure. While relevant, both factors have limitations in terms of promotion of investment in R&D.

Wages

35. Wage differentials are often mentioned as a driver in the locational decisions of firms. Table 5 presents the example of average salaries for software programmers across selected countries, highlighting the large differences. To some extent, wage differentials reflect differences in productivity. However, with regard to R&D activities (and many other aspects of business), simple wage differentials – even normalised for productivity differences – may not be enough to drive such locational decisions. In sizing up availability of human resources for R&D, other quality factors such as education, skills, language, experience and talent also count as they may influence the creative processes.[29] As noted by respondents to the OECD Business Questionnaire (OECD, 2008a), the availability of trained human capital is a critical input to the software development process.

Table 5. Average Salaries of Software Programmers

Country	Salary range (USD)
Poland and Hungary	4 800 - 8 000
India	5 880 - 11 000
Philippines	6 564
Malaysia	7 200
Russian Federation	5 000 - 7 500
China	8 952
Canada	28 174
Ireland	23 000 - 34 000
Israel	15 000 - 38 000
USA	60 000 - 80 000

Sources: van Welsum and Xu (2007); CIO Magazine (2002), Smart Access Survey, November; Bardhan and Kroll (2003).

ICT-Infrastructure

36. The availability and quality of basic ICT-related infrastructure are also important for determining the location of globalised software activities. The quantity and quality of infrastructure and their prices vary greatly across countries. Some countries have large absolute amounts of infrastructure, which is one

28 Arora *et al.* (2007), based on the Venture Economics VentureXpert database.

29 In the case of China, for example, anecdotal evidence suggests that Chinese students have good ICT skills and problem-solving capabilities. NASSCOM (2006) estimates that the suitable graduate talent pool for ICT services in China constituted over 727 000, compared to 1.7 million in India (in 2003), with “suitable” defined to mean those “with skills to be directly employed, without considering willingness or accessibility of talent”.

indication of national capacity for receiving ICT-enabled offshored software and R&D activities. For example, China has more PCs than Germany and more Internet subscribers than the United States. Brazil, India and Russia each have about as many PCs as Canada or Italy, and Brazil and India have slightly fewer Internet subscribers than Canada. However, apart from China, these economies' broadband subscriber numbers are much lower, and broadband costs in all of them are much higher than in most OECD countries.[30] Respondents to the OECD Business Survey (OECD 2008a) ranked infrastructure as being of medium importance for the software development process, suggesting that it may be a necessary but not sufficient condition for locational decisions. This may be particularly true in the specific case of R&D, which may have high technological requirements, but which may also require the availability of high calibre human capital in order to deliver expected results.

Globalisation: Shaping the Market Environment for Innovation in the Software Sector

37. Globalisation now plays a key role in shaping the market environment for innovation in the software sector, by expanding the scale of the market for software products and by expanding the options for enterprises in term of their structure and inputs including in relation to R&D. Globalisation of software activities contributes to increased access to foreign knowledge and inventions, which has been identified as an important driver of innovation at the aggregate level (Jaumotte and Pain, 2005a, b, c and d).

38. While there are many manifestations of globalisation in the sector, this section focuses on selected aspects in order to provide an illustration of developments in relation to the market environment and R&D. The section begins with consideration of the extent of software sector globalisation in light of trade developments. It then moves to consider the role of MNEs, which play a key role in relation to globalised R&D processes in the sector. Also, the role of outsourcing is then considered. Next, locational advantages are addressed in terms of attractiveness for investment. The penultimate section considers the relationship of the software sector to R&D in other sectors in a globalised market. Finally, the section briefly returns to considers open innovation (see discussion in Chapter 1 as well) in the context of globalisation.

Trade in software goods and services

Software goods

39. Software cannot be directly identified in trade data (Box 1), but one estimate has put the total OECD exports of software goods at about USD 17 billion in 2004 and imports around USD 16.4 billion (OECD, 2006a). Between 1996 and 2004, exports increased by 5% a year, while imports increased by 6.5% a year. Figure 9 shows data for 2004, for selected OECD countries. In that year, Germany and the United States were the leading exporters, with exports of over USD 3 billion each, while Germany and the United Kingdom were the leading importers with imports of over USD 1.5 billion each. Italy, Canada,

30 Furthermore, while some of the numbers appear very favourable for some countries, e.g. China, when they are scaled to the population it is obvious that the potential for further growth in the diffusion of ICTs and ICT infrastructure is huge. Overall the stock of ICT-related infrastructure in countries often seen as potential recipients of offshored services activities suggests enormous potential, but there is still a long way to go before these countries, including the largest, can match OECD countries in terms of the intensity and quality of infrastructure. Furthermore, India, the major supplier of ICT-enabled services, has neither the largest stock of ICT-related infrastructure nor the cheapest broadband costs among the BRICs. The source of India's comparative advantage lies instead in the availability of ICT-trained engineers, entrepreneurial domestic firms, linguistic advantages, global ties, recent economic liberalisation, among other factors (OECD, 2006a).

Spain and France experienced the largest trade deficits in software goods, while the United States, Ireland and Germany recorded the largest surpluses.[31]

Computer and information services

40. Data on trade in software services are not widely available, so the category "computer and information services" is used as a proxy.[32] Between 1996 and 2004, OECD exports of computer and information services increased on average by 23% a year, from around USD 13 billion to USD 69 billion. OECD imports increased by 15% a year from USD 12 billion to USD 37 billion (OECD, 2006a). In 2004, Ireland, the United Kingdom and the United States were the leading exporters, with volumes of over USD 8 billion each (Figure 10). Germany and the United States were the biggest importers, with volumes of about USD 6 billion or more. While Ireland, the United Kingdom and the United States experienced relatively large surpluses in trade in computer and information services, other countries, *e.g.* Japan and Italy, saw a trade deficit.

41. The case of Ireland as the largest exporter merits further explanation. The large export volume and large surplus on trade in computer and information services is partly a product of statistical measurement and tax issues. As for statistics, the volumes for Ireland are somewhat inflated because the data include software license fees in computer and information services, while other countries record them separately under "royalties and license fees" (OECD, 2006a). Nevertheless, taking into account computer and information services, software goods and software-related royalties and license fees, it can be said that Ireland is a major producer and exporter of software and IT services. As for taxes, Ireland has established an advantageous tax regime and a number of software firms use Ireland as a location to set up export operations, in part to benefit from its provisions (OECD, 2006a).

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31 The data for Ireland may be somewhat misleading as the majority of Ireland's software exports come from US-based MNEs who use Ireland as a base to ship products to the European Union (Arora *et al.*, 2007).

32 The computer and information services category too aggregated to provide insights into the specifics of software trade. More detailed data available for the US are available, but entail different types of measurement problems. Thus, the US Bureau of Economic Analysis (BEA) publishes unaffiliated general use computer software trade data, but aggregates the affiliated part in royalties and license fees. The BEA does not include custom software and programming services in its general use software data and does not break it out in its computer and information services data. The US Census publishes software publishing (NAICS 5112) exports data, but not imports, in its Service Annual Survey.

Box 1. The Challenges of Measuring Software Trade

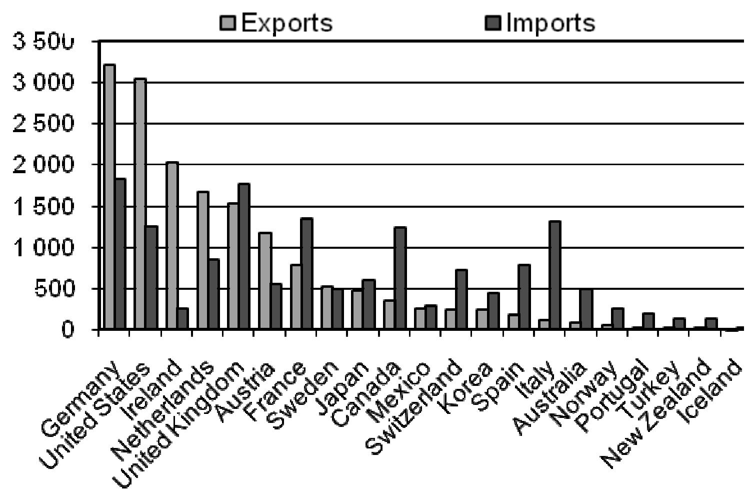
There are many measurement issues associated with software trade. First, as border valuations are based on physical media (diskettes, CD-ROMs), rather than on content (the software), the value of the software traded is likely to be significantly understated. Second, the bundling of software with hardware leads to significant mis-measurement (equipment trade is overstated and software trade is understated). Third, trade statistics do not measure the value of copyright works sold in foreign markets. This is referred to as the so-called "gold master" problem in cases where only the original software product is counted in international trade, but it is then copied many times for sale in the importing country. Fourth, trade statistics do not measure the value of software transmitted electronically across borders, which accounts for a rapidly increasing share of sales, or the rise of application service providers of software (ASPs). Many of these issues, such as the treatment of software in the Balance of Payments and in National Accounts (*e.g.* through royalty payments for use of intellectual property), are receiving greater scrutiny as the value of these payments increases rapidly.

Some countries, like the United States, publish more detailed software trade data. For example, the US Bureau of Economic Analysis publishes general-use software trade data (*e.g.* data on software publishing sales to foreign persons by U.S. MNEs), although they do not include affiliated transactions. The US Census Bureau publishes data for packaged software shipped on media, but the data may include the value of other intellectual content (*e.g.* movies) on the media in certain cases.

Source: OECD (2006a).

Figure 9. OECD software goods trade, 2004

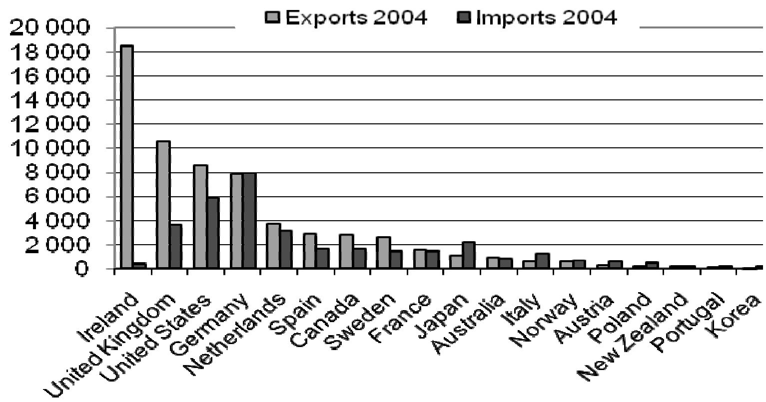
(USD millions)



Source: OECD (2006a) based on OECD ITS database.

Figure 10. Computer and information services trade, 2004

(USD millions)



Source: OECD (2006a), based on OECD-Eurostat statistics on international trade in services.

The role of multinationals in globalisation of software and R&D

42. In the context of globalisation, MNEs provide a natural mechanism to foster, select and co-ordinate R&D projects and activities (OECD, 2008c). Firms rely on specific competencies, learning processes, and communication systems that reduce the cost of co-ordinating different individuals and parts of the organisation. They can develop competitive advantage via operation of effective learning processes, capabilities to co-ordinate and integrate internal activities, and the ability to modify strategies and competencies according to the changing market environment (Teece *et al.,* 1997).

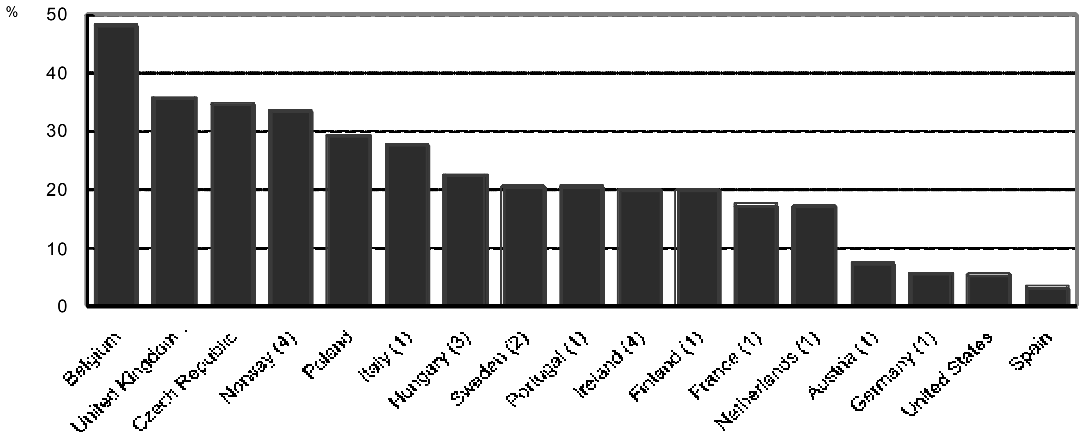
43. Business sector R&D is rapidly internationalising, largely driven by the changing strategies of MNEs which account for the bulk of global business R&D. While in the past MNEs tended to keep core R&D in their home countries, now these firms are increasingly shifting to a mixed strategy of global technology sourcing (OECD, 2008c). Nonetheless, proximity continues to play a role in part because relay of tacit knowledge tends to rely on proximity, practice and learning-by-doing. By locating close to each other, people can access information, monitor other people's behaviour, and foster communication among individuals, thereby reducing the complexity and uncertainty of the innovation process. At the same time technological developments in ICTs are enabling a broader and faster exchange of codified knowledge and ideas across international or even global networks of collaborators.

44. In the case of software, international expansion is one of the priorities of top software MNEs, often as a complement to other dimensions of growth strategies including such elements as internal product development and joint research with domestic institutions. Recent field studies have suggested that these firms now undertake substantial software R&D outside of their home countries. Many of the top software firms are establishing R&D centres in an increasing number of locations, including India, Ireland, and Israel (see the Annex for case studies of these countries). In other cases, they are partnering with foreign firms including small and medium size enterprises. Furthermore, whereas R&D undertaken abroad used to focus essentially on adapting products to the local market, these days foreign R&D goes much beyond that and also includes original and innovative development work, in some cases attempting to tap into local knowledge and sources of new technologies.

45. There many ways in which MNEs can expand their R&D operations abroad, including through affiliates, acquisitions and collaborative or partnership agreements with local companies. In many countries, foreign affiliates play an important role in total national R&D. In most OECD countries, the share of affiliates under foreign control in total business sector R&D expenditures increased between 1995

and 2003, except in Spain and Turkey. In Ireland in 2003, more than 70% of total business sector R&D expenditure is attributed to foreign affiliates. The share of foreign affiliates in total business sector R&D expenditures is lowest in Japan where business sector R&D is dominated by domestic firms. Comparable figures are not available for the software sector, but an indication of the extent of foreign affiliate presence is available from an OECD database on foreign affiliates (FATS). Figure 11 presents the share of foreign affiliates in the revenues of the Computer and Related Services sector for selected OECD countries as of 2002. The data confirm the active engagement of foreign affiliates in the sector in these OECD countries, with shares ranging from just a few percent in Spain to nearly 50 percent in Belgium.

Figure 11. The share of foreign-controlled affiliates in revenues of computer and related services enterprises (ISIC 72), 2002



Note: The figure refers to 2002, except: (1) = 2001; (2) = 2000; (3) = 1998; (4) = 1997.

Source: OECD, OECD Statistics on Measuring Globalisation, Volume II: Services (FATS), April 2005.

Trends in software offshoring

46. Rapid advances in ICTs are increasing the tradability of many business services, including software services, and are also creating new tradable services. As services become more tradable and increasingly independent of location, firms are starting to offshore certain business functions, such as administrative support units, IT-related activities, and research and consultancy services. Often, their objective is to refocus their operations on their core activities and thereby increase their competitive advantage. Attractive destinations include countries with relatively lower labour costs and a talented workforce. Due to the wage-cost advantage and the large pool of English-speaking skilled labour, India has become a prime location for ICT-enabled-services offshoring in recent years (OECD, 2006a). More recently, ICT-enabled offshoring of services has also moved into China (van Welsum and Xu, 2007). Offshoring of services increases access to foreign knowledge and talent, thereby potentially also stimulating and facilitating innovation.

47. Early evidence from these developments suggests that it was mainly the lower end of software services and production that were offshored rather than the core activities (Arora *et al.*, 2001). Thus, US firms were found not to offshore or outsource activities such as requirement analysis, specification, and high-level design, or larger scale system integration types of activities to India, although the leading Indian software firms had the ability to provide these high-end services. In fact, the need for proximity might hamper the offshoring of more highly value-added activities such as software design and R&D.

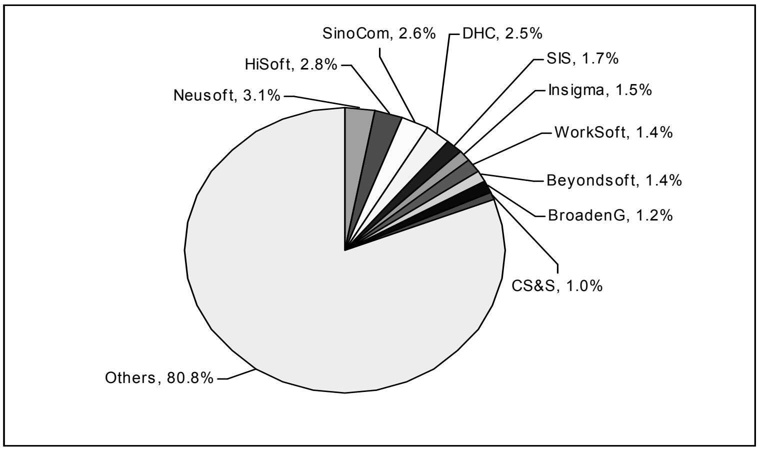
48. The impact of offshoring in the software sector is not clear cut. Some argue that it causes tensions in job market in the parent country of software MNEs, due to the perceived substitution effect of software professionals. Others, such as Arora *et al* (2001) argue that the Indian software industry is largely complementary to the US software industry. Indian firms provide essential maintenance and development services, enabling US firms to use their scarce in-house ICT staff for higher value added work, such as design and develop new types of applications. Indian firms often act as sub-contractors to established US software services firms and systems integrators. In addition, many of these U.S. firms rely on Indian programmers and have significant India based operations. More recently however, Indian firms have started to move up the value chain and perform more highly skilled activities with greater value-added (OECD, 2006a). This potential for moving up the value chain has also been analysed for other emerging countries, such as China (*e.g.* van Welsum and Xu, 2007, also Box 2). At the same time, there may be new opportunities for niches of low cost domestic sourcing of certain activities (ITAA, 2007).

Box 2. Software Services Outsourcing in China

China's software services outsourcing market amounted to around USD 0.3 billion by the first quarter of 2006. It is growing rapidly, but from a relatively small base. Neusoft, Hisoft and SinoCom are the top three Chinese software services outsourcing companies. The total market share of the top ten software offshoring and outsourcing companies is only 25%, and the Chinese software outsourcing industry is highly fragmented and lacks large firms dedicated to outsourcing (IFC, 2005). The largest Chinese software firms often engage in a wide variety of other business activities in addition to supplying software outsourcing services, such as software development and hardware distribution.

Despite rapid growth of Chinese software services suppliers, they remain small relative to the top Indian firms. The top three Chinese software firms had combined revenues of around USD 500 million in 2005 from all activities, with around one-fifth coming from providing outsourced services, some of which are offshored outsourcing services to foreign customers. This compares with USD 5.5 billion for the three top Indian software and IT consulting firms (Tata Consultancy Services, Wipro and Infosys) the major share from providing outsourced services, giving a good indication of the relative strengths of ICT services firms from the two countries. The large Indian firms are reaping economies of scale and establishing global strategies to both export their services and locate close to their customers in their main markets.

Box Figure. Supplier Shares of the Software Outsourcing Market in China



Source: Analysys International (2006).

By sector of demand, high-technology products, consumer electronics, telecommunications and finance account for 95% of the software outsourcing market. High-technology is the most important, accounting for 60% of the market for software outsourcing. The next is consumer electronics, accounting for 25%. Most software outsourcing services go to Japan (59% in the first quarter of 2006). The US and Europe account for 23% and Hong Kong (China) for 11%. Japan has also moved some of its software development work to China. China currently has six software-export bases: Beijing, Shanghai, Tianjing—the largest municipalities in China; Dalian (in Liaoning Province), Shenzhen (in Guangdong Province), and Xi'an (in Shaanxi Province).

Source: van Welsum and Xu (2007).

Collaboration and Open Innovation in R&D

49. As the complexity and range of application for software has grown, software developers have moved to expand collaboration as means of increasing the base of resources involved in R&D processes. Such expanded collaboration can take many different forms ranging from a closed initiative among two partners to an open project accessible by thousands. This section first considers evidence from innovation surveys in the European Union and Japan, to examine the nature of collaboration in two OECD economies.[33] The section then moves to consider open innovation more specifically, followed by an examination of the linkages between the traditional software sector and software development in other sectors.

Innovation Surveys

50. Indicators on some aspects of innovation can be obtained from so-called innovation surveys, although typically not at the level of the software sector. These data are available for the EU and several non-EU European countries including Japan, although they are not necessarily strictly comparable on an international basis.

51. For the European Union, data from the Community Innovation Survey (CIS)[34] provide some insights into R&D for business services, but the software sector cannot be separately identified within this category.[35] Among the various sectors between 1998 and 2000, the business services sector showed the largest share of enterprises with innovative activity (64%[36]), followed by financial intermediation (58%) and manufacturing (47%). Furthermore, 61% of success innovators in business services were both product and process innovators, while the rest focussed on either product or process innovation. Thus, the larger sector around software tends to be relatively innovative by this indicator.

52. Many enterprises with innovation activity also reported undertaking other strategic and organisational changes, and notably more than enterprises without innovation activity: strategy (67% vs. 30%), management (56% vs. 20%), organisation (71% vs. 37%), marketing (59% vs. 22%) and aesthetic or other subjective changes (54% vs. 16%). The importance of these changes and innovations is double fold as they not only reflect those made by firms in the software sector, but also those enabled by software in firms throughout the economy (*e.g.* new business methods, management practices, flexible working arrangements etc.).[37]

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33 They are referenced here in order to present information on the importance of collaboration and openness in relation to other factors in the innovation process (also discussed in Chapter 1).

34 The Community Innovation Survey (CIS) is a survey conducted every 4 years by EU member states. The first was carried out in 1992. CIS2 took place in 1996 and CIS3 in 2001. In most countries, CIS4 was launched in 2005.

35 The closest approximation available in the CIS3 data covering 1998-2000 (European Communities, 2004) is the business services aggregate composed of computer activities, R&D, engineering activities and consultancy, and technical testing and analysis (*i.e.* NACE sectors 72+73+74.2+74.3).

36 Of which 57% were successful innovators, and 7% reported ongoing or abandoned innovation activity.

37 This is also illustrated by data from the Australian Innovation Survey where in innovating businesses with 20-99 persons and 100 or more persons, the three leading skills sought for innovative activity (in addition to general business skills) were Information Technology (25.8% and 36.3% respectively), marketing (18.5% and 26.2% respectively), and engineering (14.9% and 23.6% respectively). Data available at: http://www.abs.gov.au/ausstats/abs@.nsf/mf/8158.0?OpenDocument (last accessed 10.10.2007).

53. The CIS provides some interesting insights into the role of collaboration for business service sector firms in Europe. The most important sources of information for innovation as cited by firms in the sector included: sources from within the enterprise (48%), clients or customers (40%), professional conferences, meetings, journals (24%), suppliers of equipment, materials, components or software (18%), competitors and other enterprises from the same industry (15%), fairs and exhibitions (14%), universities or other higher education institutes (12%), other enterprises within the same industry group (9%) and government or private non-profit research institutes (6%). Some 31% of business services sector firms with innovation activity reported having had access to public funding (any source), 17% from local or regional authorities, 16% from central government, 9% from the EU, and 8% from the EU's 4th (1994-1998) or 5th (1998-2000) Framework Programmes for RDT. Furthermore, 34% of business services sector firms with innovation activity were involved in innovation co-operation: 31% with national partners, 10% with EU/EFTA partners, and 1% with candidate countries. The largest reported innovation impacts reported by these firms were product oriented impacts (increased range of goods or services: 42%, improved quality in goods or services: 44%, and increased market or market share: 32%). Other effects included meeting regulations or standards (16%), increased production capacity (15%) and improved production flexibility (13%). Thus, these results confirm the heavy engagement of a range of innovation inputs beyond the walls of the firms in the larger sector surrounding software.

54. Problems and barriers to innovation were also reported among these firms in the European Union. Some 55% of business services firms with innovation activity reported that their innovation activity had been seriously delayed, 29% that it had been prevented from being started, and 24% faced other serious problems, including: too high costs (31%), lack of appropriate sources of finance (30%), excessive perceived economic risks (24%), lack of qualified personnel (24%), and insufficient flexibility of regulations or standards (13%). For those without innovation activity, the reported barriers included too high costs (18%), lack of appropriate sources of finance (18%) and perceived economic risks (14%).

55. The Japanese National Innovation Survey (NISTP, 2003) distinguishes the sector "computer and related services", and its sub-category "software consultancy and supply". It finds that for the period 1999-2001, 40% and 43% of firms, respectively, were innovators, the proportion rising with firm size (as much as 60% and 68% of large firms, respectively). Furthermore, 88% and 91% of innovating firms in these sectors were identified as product innovators, and 48% and 47% of the firms as process innovators. Innovators with new-to-market products accounted for 40% and 42% of innovating firms.

56. In software consultancy and supply, all innovating firms in the Japanese survey reported the implementation of management strategies, 90% knowledge management, 83% organisational changes, 11% marketing changes and 36% aesthetic changes; 64% reported conducting intra-mural R&D. The reported impacts of innovation included: improved quality of goods and services (41%), increased goods and services (38%), expanded market or increased market share (21%), improved production flexibility (17%), reduced materials and energy usage per production unit (15%), increased production capacity (14%), reduced labour cost per production unit (9%), satisfied regulations or standards (6%), and improved environmental impact or health and safety aspects (2%).

57. With respect to financial support from local or regional public authorities and central government in Japan, respectively, 8% and 4% of innovating firms in software consultancy and supply reported having received a grant or a subsidy, and 7% and 3% a loan or a credit guarantee, respectively. Partners in co-operation for innovation included: other enterprises within the industry group (18%), universities or other higher education institutes (16%), commercial laboratories, R&D enterprises, and suppliers of R&D support services (12%), government or private non-profit research institutes (10%), and consultants (10%).

58. In the Japanese survey, innovating firms in the computer and related services cited the following sources for important innovation and new innovation project ideas: the R&D department within the

enterprise (51%), clients (40%), the marketing department within the enterprise (30%), professional journals or academic journals (29%), suppliers of equipment, materials, components or software (28%), the production, manufacture or maintenance department within the enterprise (26%), trade fairs or exhibitions (17%), professional conferences or meetings (16%), competitors and other enterprises from the same industry (15%), consultants (12%), universities or higher education institutes (10%), government or private non-profit research institutes (6%), and commercial laboratories, R&D enterprises and suppliers of R&D support services (5%). Thus, in this software-related sector in Japan, innovators were also heavily engaging resources from beyond the walls of the firm in the innovation process.

59. Problems and barriers to innovation were also reported in the Japanese survey. Thus, 35% of innovating firms in computer and related services reported that their innovation activity had been seriously delayed, 16% that it had been prevented from being started, and 58% faced other serious problems, including: excessive economic risks (27%), too high innovation costs (25%), lack of information on markets (25%), lack of appropriate financial sources (22%), lack of information on technology (24%), lack of qualified personnel (22%), organisational rigidity within the enterprise (12%), lack of customer responsiveness to new goods or services (10%), and insufficient flexibility of regulations or standards (4%).

Collaborative Approaches and Small and Medium Size Enterprises (SMEs)

60. High-growth SMEs tend to be very market-oriented and respond to market changes with product innovations, often also closely related to process innovations (OECD, 2008c). They tend to aim for improved product quality and customer satisfaction rather than reduced costs. This is an example of how firms can create value from their intellectual assets. Most high-growth firms relied on networking and public-private relationships to develop innovative products and processes, and often operating without their own R&D department.

61. SMEs may strive to adopt collaborative approaches to invention when they do not hold sufficient internal competences and resources to develop an invention autonomously. Thoma (2008) looks at copatenting (across all sectors) to examine the extent of R&D collaboration among firms. Although copatenting is not a common form of collaboration, he finds that monoregional firms, occasional innovators, and firms from smaller countries tend to use copatenting relatively more than multiregional firms and serial innovators. It may be that these firms, employ such approaches to leverage their strengths, while engaging partners with complementary strengths in order to compete in the market place.

62. In the specific case of software SMEs, there seems to be an expansion of such activity. For example, Athreye (2005) and Arora and Surendrakumar (2006) find that India is experiencing rapid growth of R&D in small-sized companies, particularly in embedded systems. A portion of such growth is fuelled through collaboration with foreign partners.

Open source approaches

63. Open source software development contributes to the growth and structural change in the software sector. The guiding principle for open source software is that, by sharing source code, developers co-operate under a model of peer-review and take advantage of "parallel debugging" that may lead to innovation and rapid advancement in developing and evolving software products (Dempsey *et al.*, 1999). Broadband Internet connectivity has enabled and reinforced the open-source notion of cooperative, peer-reviewed software development that can be deployed on a global scale (Box 3). This model is inherently based on combining diverse sources of knowledge and talent and in this manner aims to be conducive to innovation.

64. One way to examine the geographical distribution of developers of open source software is to look at developers' contributions to source code through their identities in software project data (European Commission, 2006). The US, Canada, European Union, Australia and New Zealand have the highest number of open source participants, and their market concentration of open source software is reportedly high as well (European Commission, 2006). A large number of both public and private organizations report some use of open source software in most application domains.[38]

Box 3. Open Source Software – an example of global cooperative and innovative networks

Open-source software projects can serve as an illustration of applied ICT tools and broadband serving to facilitate innovation. With broadband-enabled infrastructures, participants in such projects can be located in any geographical location. Free and open source software projects are one relatively well-developed form of internet-based innovation community, where innovations are disclosed freely. Some open source software is created in communities rather than firms, and enhancements to the codes are available to everyone on an equal basis. It is a collaborative, community model based on a process that does not allow any contributor to exert a proprietary claim to intellectual property on any portion of the code being developed within the open source framework (de Backer, 2007). However, there are ample business opportunities surrounding this development, for example with respect to add-on software, services, consultancy and training.

Necessary tools and infrastructure available to participants in an open source project include email lists for specialized purposes that are open to all and are publicly archived. Programmers contributing to open source software projects tend to have essential tools, such as specific software languages, in common. These are generally not specific to a single project, but are available on the web. Basic toolkits held in common by all contributors also tend to greatly ease interactions. Furthermore, version-control software allows contributors to insert new code contributions into the existing project code base and test them to see if the new code causes malfunctions in existing code. If so, the tool allows easy reversion to the status quo ante. This makes "try it and see" testing much more practical, because much less is at risk if a new contribution inadvertently breaks the code. Toolkits used in open source projects have evolved with practice and are continuously being improved by user-innovators. Individual projects can now start up using standard infrastructure sets offered by sites such as Sourceforge.net.

Sources: von Hippel (2005) and de Backer (2007).

Software development and "non-software" firms

65. The tight links between the software sector and other industries are highlighted in several OECD studies (2002b, 2004, 2006b). These studies point to the relationship of the software sector to computer and communications industries through technological links and through the business activities of firms that are often present in multiple markets. This reflects, in part, the fact that software is produced both as a final product for end users and as an input for other industries. That is, a substantial share of all software produced is not developed in software companies for the general market, but rather by, or for, specific users creating custom software for their own needs.

66. Estimates produced early in the present decade indicated that already by that time the share of standard packaged software in overall software production was relatively small. Estimates of the share of software produced *in-house* ranged from 20% to 40% of software production and a further 40% to 50% of the market were estimated to be in *tailored software* (custom software produced for users by software

38 However, this does not provide an indication of the actual intensity of use. For an overview of studies on market penetration rates see Chapter 1, Annex 1.

service providers) (Parker and Grimm, 2000; Parker *et al*., 2002).[39] Thus, the standard packaged software industry was only a relatively small part of the economy-wide software activity.[40]

67. Although software R&D expenditures outside the software sector proper are often not clearly identified, there are several national surveys that provide some insight on the relevance of software-related R&D in other industries. According to Young (1996) at the beginning of the 1990s, about 40% of services firms in Japan and Italy undertook some form of IT research activities including software development. Furthermore, about 75% of all R&D investment reported by "other services industries" was computer-related in Denmark, and over half of all R&D in the services industries was software-related in Canada. Thus, R&D and innovation in the software sector is taken up and deployed in the non-software sectors, but also firms in these other sectors have become software innovators themselves.

68. Nowadays, many firms beyond the traditional software sector have embraced software development as a complement to their non-software products (Box 4); increased emphasis on integration of software is fuelling technological convergence between hardware, software and telecommunication technologies. Technology synergies and interdependencies across different segments are increasing and reinforcing R&D collaboration. Many non-software sector firms are engaged in some form of collaborative R&D initiatives and find that skill, experience, and cost are considered to be vital elements for the success of R&D collaboration. Beyond direct profits from any eventual product, benefits include mutual development in the area of human capital, access to intellectual property, and organizational support, among others.

39 These figures are supported by statistics reported by the US Bureau of Economic Analysis (BEA). BEA software investment data show the following volumes for three software segments in 2006: U.S. packaged software investment amounted USD 69.3 billion (nearly 30% of the three-segment total), in-house software USD 94.3 billion (40%) and custom software USD 71.2 billion (30%).

40 Software as a product is used and developed not just for other industries, but also for the software industry itself. This overlap is often not taken into account in the statistics.

Box 4. Embedded software development

Modern products, from aircraft and automobiles to consumer electronics, are becoming more dependent upon software embedded or bundled with hardware products. The amount of software in many products is growing at rapid pace. For example, the increased pervasiveness of digital in-vehicle components has become a main feature of today's automotive industry. It is expected that up to 100 million lines of code, double the size of Windows Vista with 50 million lines, will be used in cars by 2009 (IBM 2004). Consequently, spending on embedded software development is increasing at a fairly rapid pace. For example, a recent survey shows that embedded software development expenditure in Japan increased to JPY 3.27 trillion in 2006, representing almost 20% growth compared to previous year, and the amount is expected to continue increasing (METI 2007).

Embedded software can be found in a broad range of hardware systems, supporting functions ranging from infotainment to critical systems. For many industries, software is now at the heart of new products and contributes significantly to generating revenue, increasing overall product performance and adding new functionalities. For example, in automated production processes, software contributes to increasing productivity and decreasing costs by enabling more sophisticated and integrated process control.

There are a variety of strategies for innovation with respect to embedded software. In-house development is one option that may be of particular relevance to companies with large unit volumes such as producers of mobile phones. Large volumes may permit firms to capitalise on potential economies of scale that can make such an approach cost-effective. This option may also offer companies additional strategic advantages such as the ability to hold close critical technologies that are crucial to the success of their brands or ensure quality control for technologies that are related to safety and security such as flight control systems in aircrafts and medical devices.

However, the increased complexity and diversity of embedded software applications can be demanding in terms of software expertise and other resources for R&D. As a consequence, some firms turn to collaborative approaches, such as working together to develop common platforms or, more commonly, applications, features or specific functions. This may be seen as helping to reduce overall costs and leverage strengths. One significant example of this can be found in the initiatives such as Symbian and Android that aim to develop software for mobile devices. Software companies such as Symbian and Google, mobile operating companies and many of the leaders in mobile industries, including Nokia, Sony Ericsson, Motorola, NTT DOCOMO, Samsung, LG, are making their contributions to projects to create open mobile software platforms.[41]

There are other strategies employed by firms beyond the traditional software sector in order to meet their customer demands for enhanced embedded software. In some cases, they are able to buy non-critical software components off-the-shelf or they may subcontract the development to other IT-specialised companies. At the same time, some firms that outsource embedded software development have found a need to invest in close co-ordination in order to ensure delivery of that convenient user interfaces, reliability, and interoperability of systems from different vendors may need to be addressed (METI, 2007).

National case studies: policy frameworks and R&D

69. In order to consider national frameworks for R&D in the software sector, the analysis reviewed four country case studies: India, Ireland, Israel and Spain. These are presented in the Annex to this Chapter. In each of these four countries, policy initiatives play a significant role in fostering the national software sector. Each country displays a mix of direct and indirect measures to stimulate R&D and investment and, in some cases, to stimulate software sector specifically.

70. Beyond the economy-wide framework conditions, such as the general state of the economy and the IPR regime, the case studies point to at least three other factors that have contributed to growth of the software sector in these countries:

- *Human resources* – The software sector relies heavily on human resources. The skills and expertise of workers and a relatively large pool of software specific workers, such as software

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41 More information can be found at the respective websites of these two initiatives: http://www. symbianfoundation.org/ and http://code.google.com/android/ .

developers, have contributed to the strength of the software sector in each of these countries. IT education and training are seen as very important, and language skills have further contributed to their success.

- *Internationalisation* – International linkages form part of the success of the software sector in these countries. With respect to India, Ireland and Israel the approach has been to develop a largely export-oriented software sector, with strong and competitive multi-national companies, both indigenous and foreign. In the case of Spain, international collaboration has played an important role. In addition to traditional measures such as tax breaks and other financial and non-financial incentives for R&D and investment,[42] historical links[43] and migration flows have also contributed to strong international linkages. Encouragement of foreign direct investment has brought exposure to leading technologies, increasing skills levels and facilitating adaptation of best practices.

- *Clustering* – Clusters of software firms appear to be a common feature in countries where the software sector is particularly successful (like in the US, with Silicon Valley being the most notable example). In spite of the often talked-about "death of distance", proximity appears to still matter in the software sector where a flow of information and knowledge is essential. Further advantages include being able to exploit high quality infrastructures and tapping into pools of talent attracted by clusters of firms. Software firms tend to cluster in selective regions: Bangalore, Mumbai, Delhi, and Chennai in India; Tel Aviv, Haifa, and Jerusalem in Israel; Dublin in Ireland; and Madrid and Barcelona in Spain.

42 In the case of Israel, a well developed venture capital market constitutes one of the main financing sources for high-tech start-ups, especially in the IT sector, providing an area of comparative advantage.

43 For example, colonial ties have contributed to cultural affinities between the UK and India resulting in certain educational and professional qualifications similarities, and a very good level of English for many Indian graduates.

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ANNEX

COUNTRY CASE STUDIES

This annex presents cases studies of software sector developments in four countries, highlighting the market environment, R&D and government policy. The countries covered include India, Israel, Ireland and Spain.

1. India

India has a very well established and renowned software sector (OECD, 2006b). Even though in some competitive dimensions India lags behind OECD economies, it has become a very successful exporter of software products, both goods and services, as well as the services of its highly skilled IT and software engineers employed all over the world. These exports do not only come from the affiliates of foreign multinationals implanted in India, but also from a growing number of indigenous firms, often multinationals themselves. Indian firms were able to gather talented workforces and deliver technical services to meet diverse customer needs. Indian firms have also been very successful in attracting off-shored and outsourced IT and ICT-enabled services, such as business process services.[44]

OECD countries have been offshoring computer-related work to countries such as India and the Philippines, both of which had a good number of English-speaking graduates, as early as the 1980s. Paper documents and audiotapes were flown in for digitisation and transcription and relatively simple computer programming tasks were performed for foreign clients. Indian professionals with IT backgrounds were also brought to clients in OECD countries for software coding. However, with rapid developments in ICTs and trade and investment liberalisation, the Indian IT industry developed a “global delivery model”.

In the original model, a group of Indian professionals would be sent to the overseas client and worked together with a team based in India. The professionals at the client’s premises acted mainly as facilitators – they conducted negotiations, transferred information, supervised and implemented software solutions – while professionals in India provided most of the software coding and related tasks. Team members circulated between the client site and the Indian home office during the course of the project. With time, the model became more complex, with services sometimes provided from a number of locations, thus turning it into a global delivery model. While in the beginning the relative number of Indian professionals working at the client site was large compared to the number working from India, over time the onsite ratio decreased as the global delivery model matured and Indian companies became more experienced at managing increasingly sophisticated projects from overseas (OECD, 2006b).

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44 India has become a major supplier of ICT-enabled services even though it has neither the largest stock of ICT-related infrastructure nor the cheapest broadband costs among emerging economies. The source of India’s comparative advantage lies instead in factors such as the availability of ICT-trained engineers, entrepreneurial domestic firms, linguistic advantages, global ties, and recent economic liberalisation (OECD, 2006b). One other area where Indian firms have become leaders is in their ownership and operation of undersea cables. Collectively, Indian firms are now the largest player in this global market OECD (2007b).

India has also been very successful in attracting foreign multinationals wanting to benefit from local skills and cost structures. Approximately one-third of Indian exports of IT services and two-thirds of ICT-enabled services are estimated to be generated by foreign-owned companies (Business Standard, 2005). The most common type of establishment is the export-oriented affiliate. Companies that locate in India's software technology parks to serve foreign markets benefit from temporally limited but generous tax exemptions and various measures for facilitating investment and businesses' daily operations (see below).

Some foreign companies have expanded in the Indian market by buying local companies. For example, in 2004 IBM acquired Daksh eServices, India's third largest ITES company, and in 2005 Oracle acquired i-flex, India's leading software product company. Foreign companies have also expanded in India by adopting a build-operate-transfer (BOT) model. In this case, a foreign company agrees to let an Indian IT company establish, manage and expand a unit which is taken over by the foreign company after a few years. The model is dependent on a number of contract-based criteria and tends to work best for companies producing software products (OECD, 2006b).

Government initiatives

The Indian government has been very proactive and has placed much emphasis on developing its ICT sector, and software activities in particular. However, up until the early 1980s, India focussed on building a domestic hardware industry through import substitutions, with high import duties and complex rules and regulations for importers. At that time, software was considered as a sub-section of hardware which constrained the potential growth of software industry.

This changed in 1984, with the introduction of a New Computer Policy (NCP-84), which played a significant role in developing the Indian software industry. This policy comprised (*i*) a package of reduced import tariffs on software as well as hardware, (*ii*) permission for foreign firms to establish themselves in India, and (*iii*) projects to set up and ICT infrastructure, including the creation of software parks.

Some of the initiatives to promote the software sector that have followed include tax and related measures, further infrastructure development, export promotion, and Open Source development. For instance, revenues from software exports received tax exemptions as part of the implementation of the NCP-1984.

The Indian Government also initiated several schemes to attract and encourage (export-oriented) entrepreneurs in software sector, including the establishment of the Software Technology Parks of India (STP).[45] STP provided office space, computer equipment and access to high-speed satellite links as well as Internet. They also provided services such as import certification, software valuation, market analysis and training. One of the key contributions to the software-exporting sector is provision of High Speed Data Communication (HSDC) services which is designed and developed by STP and is available to software exporters at competitive price (MCIT, 2007). Export-oriented firms in Software Technology Parks (STP) were also given a tax breaks, in particular during the first eight years of operation.

The Electronics and Computer Software Export Promotion Council (ESC) was set up to stimulate development of the software sector.[46] The ESC's primary functions are to provide member exporters with

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45 Initiated in 1986, STP is a non-profit society under the Ministry of Information Technology whose primary objective is to promote and facilitate software exports from India. With over 40 centres spread across the country, STP is helping out some 6 500 software exporting companies in India.

46 ESC falls under the Department of Information Technology and has a membership base of over 23 000 exporters and manufacturers. Headquartered in Delhi, it has emerged as the centre for promotion of trade of information technology.

trade related information, to help them participate in international trade fairs and exhibitions, and to implement government programs. In addition, ESC has initiated special programs for SMEs. The Council creates awareness in foreign markets to highlight the potentials of Indian SMEs, conducts market surveys and organizes road shows and conferences (ECS, 2006).

The Centre for Development of Advanced Computing (C-DAC) is the core national R&D organisation of the Department of Information Technology. It is involved in the design, development and deployment of advanced information technology based solutions. C-DAC has also developed and supplied a range of high performance parallel computers, known as the PARAM series of supercomputers. The main R&D activities include High Performance Computing & Communication for scientific and business applications, Networking, Turnkey Solutions for Power, Telecom, Health, Financial Market etc., Geometrics, and eGovernance. C-DACC also runs IT-focused academic and training programs (Advanced Computing Training School).

Special attention has also been devoted to Free Open Source Software (FOSS) with the establishment of the National Resource Centre for Free and Open Source Software (NRCFOSS)[47] in Chennai in collaboration with C-DAC and Anna University. The Centre is engaged in design and development of FOSS products and technologies with special emphasis on e-governance, school education and SMEs. NRCFOSS has developed a localized product called Bharat Operating System Solutions (BOSS) in an effort to enable India to work as platform with a variety of languages in addition to English.

Human resources

The availability of a large number of skilled English speaking software workers has been a major advantage to the development of the Indian software sector. Indian workers who have worked abroad and then returned to India have also contributed, especially since many acquired business networks and Western corporate culture skills that have aided them subsequently in setting up companies in India (OECD, 2004, 2006b). Wage differentials are also often mentioned as a factor in India's attractiveness as a location for software-related activities. However, wage differentials to some extent reflect differences in productivity. Other types of costs, including overhead, organisational and transactions costs are also incurred when activities are sourced internationally and these are often relatively high in India.

Globalisation of R&D

Global sourcing of software R&D was not common until the mid-1980s when the independent software industry began to take off. Many MNEs then began to face difficulties in making in-house software development and management because hardware and software became very complex. The desktop workstation had the capacity for stand-alone programming and UNIX and the "C" programming language were widely adopted. Since then, many MNEs have started to outsource system integration and application work. Many MNEs now relocate part of their value chain to India, ranging from R&D to customer services (OECD, 2006b).

The need for global sourcing increased in the US and Europe in the 1990s, particularly as a result of Y2K preparations, ERP (Enterprise Resource Planning) installation, and the shift to online environments (*e.g.* e-commerce and e-business. The tremendous growth of this software and services segment created additional jobs for programmers, and Indian software workers had a competitive edge. Many software, and

47 www.nrcfoss.org.in (last accessed 06.08.2008).

other,[48] MNEs now have a R&D presence in India (Annex Table 1) and are establishing an offshore base in India for the development of application or embedded software.

Annex Table 1. Some of major MNC software R&D centres in India

Industry	Company	Year	Mission	Location and staff
Software sector	Oracle (India Development Centre)	1994	Application development tools, server and platform technologies, e-business application	Bangalore, Hyderabad
	EDS (EDS India)	1996	applications and business process outsourcing services	Chennai, Pune, Mumbai, Gurgaon 20 000
	Microsoft (MS India Development Center)	1998	Strategic and IP sensitive software product development	Redmond, 1 200
	SAP (SAP Labs India)	1998	Business solution (ERP, CRM, etc)	Bangalore, Gurgaon, Chandigarh, 3 000
	ADOBE (R&D Centre)	1998	Publishing software	Noida, 500
Other sectors	Samsung (Samsung India software Centre)	2002	Embedded software for electronics(LCD TVs, MP3, etc)	Noida, 300
	Sony Ericsson Mobile Communications	2007	Mobile Phone	Chennai
	Dell (R&D Centre)	2007	Servers, storage, software	Bangalore
	IBM (Software Lab)	2001	Works on all IBM software like WebSphere, DB2, Lotus, Tivoli and Rational. The centre has added many new areas of activities such as middleware and business intelligence.	Bangalore, Pune

Source: OECD, based on various company reports and other sources.[49]

2. Israel

Israel is a relatively small economy, but it figures among the most high-tech oriented economies in the world. Israel has the highest concentration of hi-tech firms in the world second only to Silicon Valley, US.[50] Israel has the third largest number of NASDAQ listed companies and the largest proportion of scientists and technicians in the workforce: 140 per 10 000 workers compared with 83 and 80 in the US and Japan, respectively.[51]

A breakdown of the software sector in Israel reveals a focus on sophisticated products and niche markets (Annex Figure 1). Israeli software companies and developers focus on very complex work and produce new products market niches such as security, telecommunications, engineering, education, and

48 Such as electronics, business consulting, and financial sector firms.

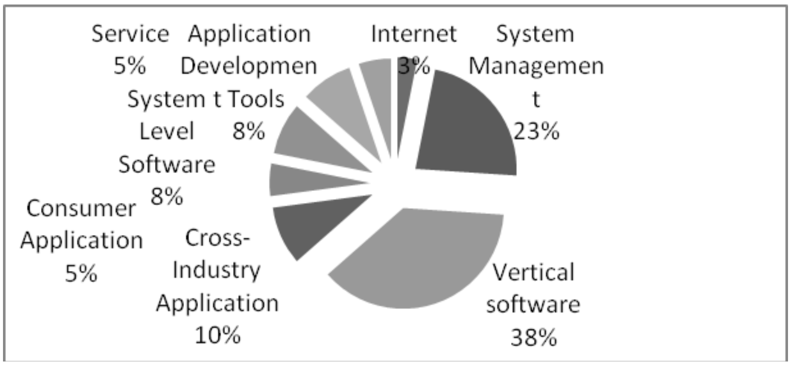
49 See for example http://www.expresscomputeronline.com/20030609/focus1.shtml (last accessed 22.11.2007): "MNC R&D Centres Mushroom in India".

50 See Israel Export and International Cooperation Institute, http://www.export.gov.il (last accessed 18.10.2007).

51 According to the State of Israel, 2005.

anti-virus software. The Israeli software sector is also closely associated with other high-tech industries not only in the work process but also geographically with clusters in Tel Aviv, Haifa and Jerusalem. This infrastructure has contributed to the rapid development of the software sector. Israel has a long tradition in software for defence, including aviation, imaging and control applications, but the application field now extends to business sectors. Israeli application software products are found in most of high-tech industries, including biotech, telecommunication, and the Internet.

Annex Figure 1. Israeli software industry export by application in 2003



Source: Israeli Association of Software House in Israel Export & International Cooperation Institute.

Government initiatives

Israel has a strong policy focus on supporting the high-tech industry, although not necessarily the software sector specifically. The *Law for the Encouragement of Industrial Research and Development* was passed in 1984 in order to promote investment in industrial research and development.[52] The Office of the Chief Scientist (OCS) in the Ministry of Industry, Trade and Labor is responsible for the implementation of government policies to support and encourage industrial R&D in Israel. The role of the OCS is to further the development of new technologies in Israel, to foster technological entrepreneurship, to support high value-added R&D to enhance the knowledge base of Israeli high-tech industries, and to promote co-operation in R&D, nationally and internationally. These policies should contribute to developing science-based, export-oriented industries to boost the economy and create employment opportunities.

The law provides a platform to expand and exploit the country's technological and scientific infrastructure and leverage its high-skilled human resources. Its most significant measures are the diverse range of programs with financial incentives. A number of programs have been created to specifically support entrepreneurial firms in developing high-tech innovations for commercial purposes. The OCS administers those programs and funds R&D projects, not only for established firms but also for start-ups.

52 Investment incentives are outlined in the *Law for the Encouragement of Capital Investment*, which has recently been revised to include two types of incentive programs: grants (administered by the Israel Investment Center – IIC – which is a department of the Ministry of Industry, Trade and Labor), and an Automatic Tax Benefits Program (administered by the Israeli Tax Authorities). In order to qualify for these programs, investment project must meet several criteria, including international competitiveness (legal definition), minimal designated investment, high value added, and registration of the company in Israel (Ministry of Industry trade and Labor, 2006). In order to complement this revised Law, the government has also established and Employment Grant Program which supports the establishment or expansion of industrial plants, call centres, computer service support centres and logistics centres, especially in remote areas or areas with high unemployment. Civilian expenditure on R&D in Israel is made by the business sector, general government, higher education and private non-profit institutions.

There is also a specific focus on the incubation of innovation. Government support not only covers financial support, but also physical premises, tools, professional guidance and administrative assistance. Details of each of these programs are listed in Annex 2.

Local-level programs include Pre Seed-Seed, Competitive R&D, and Pre-Competitive R&D. Some of these focus on promoting co-operation and technology transfer between business and industry (*e.g.* Magneton, Noffar). Others support technological entrepreneurship and innovation and a very early (and risky) stage of development (*e.g.* Tnufa, Technological Incubators). Some encourage start-ups (Heznek – Government Seed Funds).

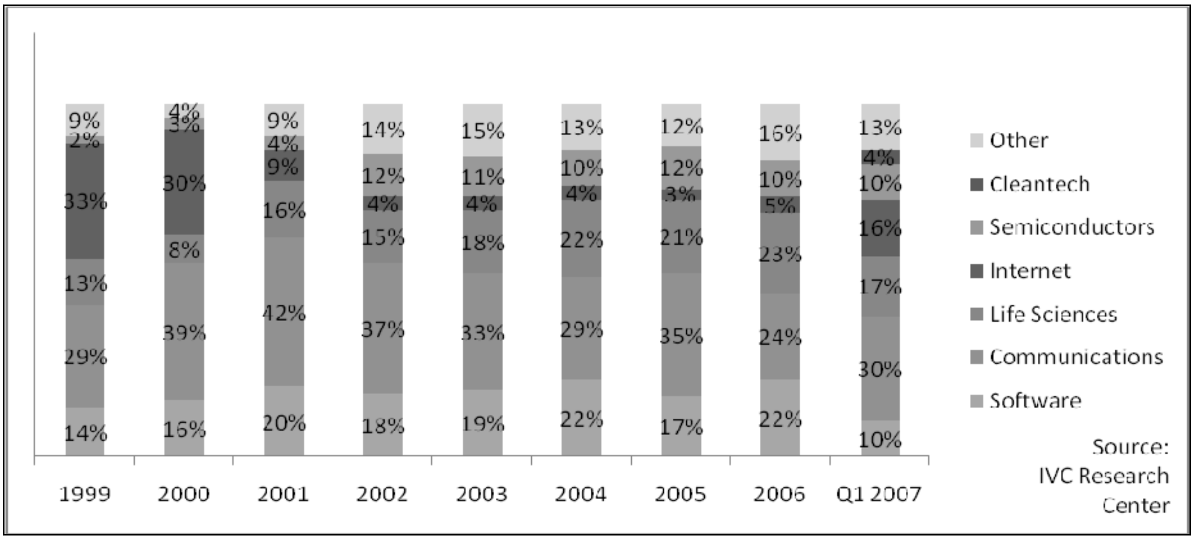
The R&D Fund, part of the Competitive R&D grants, supports companies' R&D programs. The intermediate stage between R&D and commercialisation is recognised as a very important part of the overall R&D process and is also given assistance as part of the R&D grant. If a supported R&D project leads to successful commercialisation of a product, firms have to pay royalties to the government. These are in turn re-invested to support further R&D projects. These royalties tend to be set as a percentage of the revenues derived from the commercialisation of the new product. Research Consortia and Research Institutes qualify for grants for specific R&D programs and, in particular, the development of generic pre-competitive technologies (*e.g.* Magnet Consortium, Research Institutes).

These are complemented by a range of international (bi- or multi-lateral) programs. These include programs that encourage the participation of Israeli firms in international R&D projects (Matimop) and ISERD, a program that encourages joint Israeli-EU R&D ventures within the EU's Framework Programs for R&D.

Venture capital

Venture capital is a critical element in helping start-ups bring innovative products and services to the marketplace, as illustrated by the case of the US which has a very well developed venture capital market that contributes to US competitiveness in the software sector. Israel's well developed venture capital market constitutes one of the main financing sources for high-tech start-ups, especially in the IT sector Annex Figure 2. In the late 1970s, when the Israeli capital market was not yet well-developed, and when high risks and the relatively small scale of the market made raising capital domestically difficult, Israeli software companies had to satisfy their capital needs overseas. As a result, software firms turned to foreign venture capital markets in the US. This trend has increased over time, as the high-tech and software sectors gained in importance. Foreign capital still accounts for 70% of venture funds, however (Baygan, 2003).

Annex Figure 2. Capital Raised by Israeli High-Tech Companies, By Sector



The ICT sector accounts for most of venture capital investments. Between 1999 and 2006, the software sector accounted for an average of 18.5% of total venture capital, second to communications sector. Innovative core technologies and market-oriented products gave Israeli software firms a competitive edge in attracting venture capital. Many Israeli software firms are now listed on the NASDAQ and Tel Aviv stock exchanges.

Human capital

The Israeli government has traditionally attached great importance to education, especially in science and technology, and to the training and maintaining of software talents. The state has also invested heavily in English as a second language, which is another vital element in the software sector's success.

The Israeli army plays a particular role in the software sector and has contributed to the creation of a new generation of high-tech entrepreneurs (NASSCOM, 2007). It provides talented young people opportunities to acquire high levels of training in cutting edge technologies and software development. The military runs several elite units and programs, including the software-oriented elite unit "the Central Computer Unit", or MAMRAM. The MAMRAM was created in 1960 to satisfy the specific computerisation needs in the Israeli defence sector, and since then it has grown in size and sophistication. Only those students especially talented in mathematics or science are admitted to this program. Students receive a specialised and advanced technical training for six months and are then employed on multiple projects (Breznitz, 2002). Thus, by the age of 21, participants in MAMRAM programs already have as much experience and knowledge as some professional career software developers. They are encouraged not only to work in areas that are closely related to military applications, but also on developing commercial applications. MAMRAM graduates form a dense network and many play leading roles in the Israeli software industry.

3. Ireland

Ireland is one of the world's leaders in computer and software related activities. The Irish software industry has become part of the Irish economic success story, establishing itself as one of Europe's premier locations for software development (Barry and van Welsum, 2005).

The mass-market packaged software sector in Ireland is engaged in the manufacturing, localisation and distribution (MLD) of software packages. The key players in the MLD sector (including Microsoft, Lotus, Oracle, Symantec, Informix and Corel) first established software manufacturing facilities in Ireland around the mid-1980s, duplicating and shrink-wrapping disk copies of software programs developed by the parent company and arranging for the printing and assembly of manuals. The second phase, again beginning with Lotus and Microsoft, saw these companies adding "localisation" activities –translation into other languages and cultural and technical formats appropriate to the destination markets – to their Irish operations. The third phase saw the transfer of the responsibility for distribution to the Irish operations, making Ireland an operations hub.

About half of the jobs in the foreign-owned software sector in Ireland are in highly skilled software development. This consists mostly of branches of major computing-services or IT consulting companies (including EDS, IBM, ICL and Accenture) or of activities of non-software electronics corporations, such as Motorola and Ericsson, with operations focussed on the production of embedded software and applications for products such as mobile phones. This latter segment can be seen as an unanticipated spin-off benefit from the country's success in attracting ICT hardware sectors.

The indigenous software sector produces custom software (which is provided for individual companies), niche software (written for specific business sectors) and other software services, which are provided both for organisations and consumers. The strong export orientation of indigenous firms is explained by the fact that about half of Irish indigenous software firms are engaged in the development and sale of niche products in sectors such as Banking and Finance, Telecommunications and computer/internet-based training. The emergence of this product-orientation is in part ascribable to the substantial presence of MNCs across all manufacturing and services sectors in Ireland.

The Irish software industry resembles the Israeli and Indian software industry in certain aspects. The indigenous industry's export orientation is similar to that of the Indian industry, even though the Indian software industry's export has focused more toward offshore development. Because of the limited size of domestic markets, Irish firms tend to seek foreign markets. The Irish software sector is similar to the Israeli software industry in that the focus is on providing specialised software products and support services, and avoidance of large-scale labour intensive contracting. Irish software companies have been successful in selecting appropriate worldwide niche markets, such as Banking and Finance, Telecommunications, Software tools, eLearning and computer/internet base training, and Online tools and applications.

Foreign direct investment and globalisation

Foreign direct investment (FDI) and globalisation, especially of services, have been a major factor in the development of the Irish software sector. Most of the world's leading software companies, including Microsoft, Oracle, and Cisco, have a base in or near Dublin. These MNEs clearly form an important part of Ireland's success in software sector, including through their contributions to exports and employment. In addition, FDI has brought exposure to leading technologies, increasing skills levels, and adaptation of best practices. Many of those with working experiences in MNEs have subsequently become successful Irish software entrepreneurs.

The Irish government actively works to attract FDI, mostly through tax benefits, and shows strong support for the ICT sector.[53] A skilled English speaking work force and access to the EU market further contribute to Ireland's attractiveness.

53 In 2005, Ireland's corporate tax rate was the lowest in Western Europe at 12.5%, compared to 30% in the UK, 26% in Germany, and 24% in Belgium (Enterprise Ireland, 2006). The favourable tax system has also

The Industrial Development Agency (IDA) promotes Ireland as a location for R&D for an increasing range of R&D functions and encourages firms in Ireland to maximize their involvement in global R&D activities to exploit international technology transfer opportunities. IDA is also responsible for providing foreign companies established in Ireland with adequate assistance, it liaises between industry and the educational sector, and it provides R&D grants. The distribution of grants is tied to well-defined objectives (*e.g.* in terms of employment, and R&D), and repayment is required in case of an MNE's failure to comply.

In addition to the existing grants and tax incentive schemes, telecoms liberalisation led to a large drop in rates for international phone calls. This has helped create the conditions for the rapid development call centres. At a later stage, firms with call centres in Ireland added additional functions, such as financial management and software development. As a result, Ireland has established itself as an important location for "shared services" back-office activities.

Supporting institutions

Support for the software sector in Ireland includes the development of a set of supporting institutions such as the National Software Directorate (NSD), the Irish Software Association (ISA), the Irish Internet Association (IIA), and Centre for Software Engineering. These were all founded in the 1990s in response to the emergence of Irish software industry. They played an important role in the industry's evolution, notably by facilitating networking events, disseminating information, conducting strategic studies, and allocating resources such as R&D funds.

Enterprise Ireland, formed in 1997, offered diverse supports and opportunities to emerging software firms during the late 1990s. Its network includes 13 offices in Ireland and 31 around the world. It focuses on five core activities: promoting exports, investing in research and innovation, promoting the industry's competitiveness and productivity, encouraging starting up and scaling up of regional enterprise.

The Office of Science, Technology and Innovation (OSTI), in the Department of Enterprise, Trade, and Employment, is responsible for the development, promotion and co-ordination of Ireland's science, technology and innovation policy, as well as Ireland's policy in European Union and international research activities. OSTI is also responsible for basic research funding allocated to Science Foundation Ireland (SFI) and policy issues arising from Ireland's investments through SFI, and applied research and the funding for commercialisation granted by Enterprise Ireland.

The National Software Directorate (NSD) was established in 1991 and constitutes the focal point for the software industry in Ireland. The agency is in charge of co-coordinating the government policy towards the software industry. The primary function of NSD is to provide information and statistics related to the industry and to initiate, facilitate and co-ordinate actions which result in the overall growth of the Irish software industry.

Science Foundation Ireland (SFI) is a newly established research agency with a view to upgrade research capability into world class in niche areas of ICTs and biotechnology. SFI provides peer-reviewed grants to research centres and collaborative research between academia and industry. The funds are not given to a particular project, but rather to researchers. SFI's research funding has gradually increased from EUR 10 million in 2001 to EUR 121 million in 2005 (Enterprise Ireland, 2006). A significant portion of this budget is earmarked for Irish university-based research centres of excellence that incorporate strong involvement from MNEs and local firms.

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contributed to the development of an indigenous industry as the MNEs provided both a source of revenue and access to overseas markets for domestic firms.

Also, the Centre for Software Engineering was established in 1991 in Dublin City University Campus. Its services include providing training programs covering diverse software engineering topics, carrying out product, process and technology evaluations for companies, and organising software conferences.

National Development Plan

The government's National Development Plan for 2000-2006 (NDP 2000-2006) was a seven-year nationwide plan to promote Ireland's global competitiveness. This plan consisted of several operational programs with a total budget in excess of EUR 57 billion from public, private and EU funds. The Economic and Social Infrastructure Operational Program (ESIOP) and the Employment and Human Resources Development Operational Program (EHRDOP) were the largest programs, accounting for 80% of the total expenditure.

Government funding for research was also increased significantly as a part of the NDP, even though Ireland's R&D intensity (R&D as percentage of GDP) remained below the OECD average. Some EUR 2.5 billion was allocated to research, technology, innovation and development, a five-fold increase compared to the period 1994-1999 (Enterprise Ireland, 2006). The Irish government has now set a target to increase R&D intensity to 2.5% by 2013 (OECD, 2006c). The Higher Education Authority, through the Program for Research in Third Level Institutions (PRTLI), constitutes the major source for upgrading Ireland's science infrastructure. The PRTL funding has enabled the establishment of 24 major research centres as well as creating some 800 post-graduate research posts (OECD. 2006c).

An independent evaluation of the NDP2000-2006 by the Economic and Social Research Institute (ESRI) found that the NDP has been successful in enhancing the economic and social infrastructure of Ireland with major benefits to regions.

Ireland has recently announced the NDP for 2007-2013 with investment plans of EUR 180 billion (Annex Table 2). There are no software specific programs or strategies as part of the Enterprise, Science and Innovation category. However, the software sector could benefit from sub-programs within that category, in particular, the World Class Research (EUR 3 462 million) and Enterprise STI (EUR 1 292 million) programs. The World Class Research Program covers research in third level institutions and the science foundation. The Enterprise STI Program (managed by Enterprise Ireland and the IDA) covers activities such as transforming R&D activity in enterprise, collaboration between industry and higher educational institutions, and realising the commercial potential of Ireland's research community.

Annex Table 2. NDP 2007-2013 Investment areas (EUR Billion, Current Prices)

Economic Infrastructure: Transport, Energy, Communication and Broadband, Government infrastructure, Environmental services, Local authority development	54.7
Enterprise, Science and Innovation: Science, Technology & Innovation (STI), Enterprise Development, Tourism Development, Agriculture & Food Development, Rural Social & Economic Development, Gaeltacht & Islands Development, Marine and Coastal Communities	20.0
Human Capital: Training & Skills Development, Higher Education, Schools Modernization & Development	25.8
Social Infrastructure: Housing, Health Infrastructure, Justice, Sports, Culture, Heritage & Community Infrastructure	33.6
Social Inclusion: Children Program, Older People, People with Disabilities, Local & Community Development, Working Age	49.6

Source: NDP 2007-2013, www.ndp.ie

4. Spain

Computing services constitute the largest component of the domestic information technology (IT) market in Spain (Annex Table 3), with sales of development and support services, IT consulting services, and operations management increasing rapidly in recent years. These sales are driven by both the business and public sectors, including through the updating of systems infrastructures and the increasing home and business penetration of Internet.

Annex Table 3. Spanish Domestic Market for IT

(EUR millions)

	2003	2004	2005	2006	2007
Hardware	3,178.81	3,196.47	3,340.63	3,498.08	3,750.29
Software	1,274.82	1,360.92	1,481.50	1,600.43	1,765.75
Computing Service	3,898.44	4,131.44	4,502.86	4,974.71	5,557.25
Telemetric Service	587.65	668.25	770.63	848.99	938.81
Other	546.21	567.74	594.52	622.67	583.99

Source: AETIC (2007).

National government initiatives

To improve innovation performance, particularly in the private sector, the Spanish government launched the INGENIO 2010 Program. It complements traditional science and technology policy instruments (in particular, the National R&D and Innovation Plan 2004-2007) by allocating new public funding to strategic initiatives. It aims at aligning Spain with the strategy of the European Union to reach a level of 2% of the GDP invested annually in R&D by 2010. The main strategic objectives of INGENIO 2010 are the following:

- *Increase public and private expenditure in Research & Development & Innovation (R&D&I): Reach a level of 2% of Gross Domestic Expenditure on R&D (GERD) by 2010.*
- *Increase entrepreneurial participation in R&D activities: Reach a 55% share of financing by the private sector in 2010.*
- *Work for the European Research Area, increasing the participation of Spanish enterprises and researchers in the European Framework Program.*
- *Finance key long-term scientific and technological initiatives, developed together by private and public entities; the CENIT Program will support projects co-financed at the 50% level by the private sector, mobilizing EUR 1000 million in the following four years.*
- *Integrate more closely universities and enterprises with the objective of 1300 PhD holders hired each year from 2010 by the private sector through the Program Torres Quevedo.*
- *Recruit and promote researchers, through the Plan I(3) (Plan for Promotion, Incorporation and Reinforcement of the Research activity), provided with EUR 130 million for the following 3 years in support of increased hiring of researchers with an accredited background.*

Three new programs are included in this initiative:

- The CENIT (National Strategic Consortiums for Technological Research) programme is intended to promote public-private partnerships and finance long-term applied research developed in co-operation between firms and public research centres. The four calls for this programme launched since 2006 have funded 61 projects with EUR 752 million, to be complemented with some EUR 868 million committed from the private sector.

- The CONSOLIDER programme seeks to increase the critical mass and excellence in public research centres by concentrating long-term funding on the best research teams.

- The PLAN AVANZA is a strategy for the development of the information society.[54] This five-year program (2006-2010) was created by the Spanish government for development of information and communication technologies with the objective of convergence with the rest of Europe and among all regions in Spain. With an estimated budget of EUR 5.7 billion,[55] the plan is to increase current investment in this field from 4.8% of GDP in 2004 to 7% by 2010 (MITYC, 2007). An Integrated Monitoring and Evaluation System (Sistema Integral de Seguimiento y Evaluacion, SISE) has been setup for the evaluation of the plan, whereby groups of experts are to evaluate various elements on annual basis and make recommendations for their continuation.

R&D supporting programmes

In Spain, the levels of R&D and innovation activities have remained below the EU average. In 2004, R&D expenditure as a percentage of GDP was 1.1%, compared to 1.9% and 2.3% for the EU15 and OECD respectively (OECD 2006d). There are plans however, to boost the R&D budget by 25% annually over the next four years. Spain has also created tax benefits for investment in R&D which includes corporate tax reductions of up to 40% of the Social Security cost of personnel working in R&D.

One of the main challenges in improving the innovation capacity is to encourage R&D activities in the business sector, especially in SMEs which largely dominate this sector. This issue is seen as a priority by Spain's public authorities. In this context, the government approved the National Plan for Scientific Research, Development and Technological Innovation (2004-2007), which is in line with the Sixth EU Framework Program and is partly financed by the EU Structural Funds.

Until early 2008, government programs in support of R&D were managed by different Ministries. At the central government level, the Ministry of Education and Science and the Ministry of Industry, Tourism and Trade were responsible, depending on the area, for the management of research and technological development policies under the Program for the Development of Technological Research (PROFIT), which is part of the National Plan. The PROFIT program is devised to provide soft loans and grants for competitive R&D projects by firms and public research institutes. In 2007, the Ministry of Industry, Tourism and Trade had devoted a total of EUR 114 million in grants for the PROFT program, and some EUR 219 million in loans for projects are to be executed in the period 2007-2008 in ICT-related areas alone. After the March 2008 legislative elections, a new Ministry for Science and Innovation was created; this ministry will be responsible for the coordination and management of most R&D programs funded by

54 The home page for this programme can be found here: http://www.planavanza.es (in Spanish, last accessed 29.09.2008).

55 During the period 2006-2007, EUR 3.9 billion had already been provided (EUR 2.9 billion by the Ministry of Industry, Tourism and Trade and some EUR 1 billion by autonomous communities, local entities and others).

the central government. R&D supporting mechanisms included in National Plan have been launched to focus on several strategic sectors such as: life sciences; agro-food and environment; outer space, mathematics and physics; energy; chemistry, materials and industrial design and production; security and defence; transportation and construction; and information society technology.

There are two main national programs specifically within the IT area: the National Program for Computer Technology and National Program for Information Society Service Technology. The Program for Computer Technology is structured in nine priority areas, including software engineering and software support and development technologies. The main aim is to promote technological research aimed at the development of software technology needed for the Information Society and the development of systems and tools for the production of reliable software.

Spain also participates in international R&D activities. For example, together with Netherlands, Sweden, and Finland, Spain is involved in COSI (Co-development using inner & Open source in Software Intensive products) project to create awareness of the industrial usage of distributed collaborative software and open source. OSIRIS (Open Source Infrastructure for Run-time Integration of Services) is another Open Source project. Many European governments and international software firms are involved in this project in order to find solutions providing high value services to customers by using the open source model. Spain funds these projects through the PROFIT program.

In 2007, Spain approved a new version of National Plan R&D&I (2008-2011), which is structured in four main areas: knowledge and scientific and technological capabilities generation; promotion of R&D co-operation; sectoral technological development and innovation; and strategic actions. The latter includes five different strategic actions: health; biotechnology; energy and climate change; telecommunications and information society; and nanoscience and nanotechnology, new materials and new industrial processes. The R&D program linked to the telecommunications and information society strategic action is named AVANZA I+D.

Regional Initiatives

While the central government of Spain plays a key role in innovation policy and its implementation, regional governments have been playing an increasing role in the decision-making and management of innovation and IT programs. Regional governments have been involved in agreements on the joint financing of the main pillars of the INGENIO 2010 plan and have progressively taken on more spending responsibilities. Many have a R&D&I plan and are investing heavily in R&D. The combination of both national and regional programs has led to a significant increase in R&D investment in the last few years: Madrid (1.98% of regional GDP), Navarre (1.92%), the Basque Country (1.58%) and Catalonia (1.42%), are now spending more than the national average of 1.2% (INE 2008).

As part of this trend, science parks across the country have proliferated in recent years. Between 1997 and 2003, the number of firms and workers in technology parks tripled, while their turnover increased fivefold. In Europe, only Finland and the United Kingdom had more parks than Spain (OECD, 2006c). In the case of the Community of Valencia, for example, their emergence was stimulated by the existence of numerous SMEs working in the same sector. In the Basque region, technology centres appear to have developed to complement universities research capabilities.

Some 13 000 IT related companies are currently operating in Spain, most of them (73%) in Madrid (40.8%) and the Catalonia (32.2%) regions. The trend is towards less concentration, though, as there has been a significant increase in number of companies based elsewhere, especially in Valencia and the Basque region. Other communities experiencing rapid growth include Murcia, Castilla and Léon, Cantabria, Asturias and Galicia.

Software initiatives by the Extremadura Regional Government

The Spanish Region of Extremadura is among the first regions in the world to adopt Open Source software standards in high schools and public offices (IDABC, 2003-2007). Although Extremadura had lagged behind the rest of the country in economic and technological developments, it has moved vigorously to address these gaps. Starting in the mid-1990s, the regional government decided to invest in information technology as a means to overcome its peripheral situation. As one element of the strategy, the regional government anchored the IT systems with a local version of Linux tailored to the needs of the region ("LinEx", short for Linux Extremadura).

The LinEx project is a Linux distribution created to provide all the citizens universal access to regional IT services. It focuses on specific aspects of translation and customization. To avoid technical problems during the initial phase of the project, a Spanish company was hired to take an existing set of Linux software from the web and customize it. LinEx is specifically designed for use in regional administration and schools, but the software is distributed for free on a much larger scale than public bodies.