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Abstract
The information technology sector in Europe, comprising the production of computer hardware and software, is disproportionately located on the continent's western periphery. The vast bulk of computers sold in Europe in the 1990s were assembled either in Ireland or Scotland, while Ireland also accounted for over 40 percent of all packaged software and 60 percent of all business software sold in Europe. As the sector in both these locations is largely foreign owned, the question arises as to whether EU enlargement might impact on the geography of the sector by diverting information technology FDI from the western to the new eastern periphery. This issue is explored in the present paper by analysis of five individual sub-segments: computer assembly and electronic components, R&D, mass market packaged software and the remainder of the software sector.

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Introduction

The information technology sector in Europe, comprising the production of computer hardware and software, is disproportionately located on the continent's western periphery. The vast bulk of computers sold in Europe in the 1990s were assembled either in Ireland or Scotland, while Ireland also accounted for over 40 percent of all packaged software and 60 percent of all business software sold in Europe. As the sector in both these locations is largely foreign owned, the question arises as to whether EU enlargement might impact on the geography of the sector by diverting information technology FDI from the western to the new eastern periphery.

Four interacting long-term processes determine the location of the sector within the EU. The first is technological change and its impact on industrial organisation.[1] The industry was highly vertically integrated during the mainframe phase, under IBM dominance, with the vast bulk of components produced in-house and in the US. Fragmentation began with the emergence of the integrated circuit which opened up the market for much lower cost minicomputers and allowed a number of new firms to capture market share. Then came IBM's unbundling of software from hardware in 1969 and the introduction of the open architecture of the IBM-compatible PC in the later personal computer era. This saw computer production evolve into a much more low-tech activity, consisting primarily of assembly of components purchased on the open market. Technological leadership in the industry shifted upstream to components producers such as Microsoft and Intel. These developments, as we will see, had important implications for the global geography of the sector.

The market leaders have always been US firms however, and this remains the case today. Thus Dell is dominant in PCs, Microsoft in software, Intel in microchips, Seagate in hard disk drives and IBM right across the board. This influences the geography of the sector also, in that proximity between FDI home and host locations is known to be a statistically significant determinant of FDI inflows, as in the gravity model of Slaughter (2003) for example. Krugman (1997) makes the point that the fact that distance remains of importance today is likely to be due to the impediments it places on speed and ease of communication, meaning that the UK and Ireland – given that they are English speaking and entail relatively short air-travel distances from the US – are likely to remain favoured locations in Europe.[2]

The second process is globalisation, by which we mean the declining importance of distance. As will be shown below however, distance remains of importance in some segments and could possibly even increase in importance in the future, given the taste for customised PCs for example. The third process concerns policy-driven and endogenous changes in the characteristics of national economies, as countries reposition themselves in an attempt to capture larger shares of this dynamic sector. A combination of these various

[1] Histories of the changing IO structure of the sector are provided by Malerba, Torrisi and van Tunzelmann (1991), Bresnahan and Malerba (1999), and Malerba, Nelson, Orsenigo and Winter (2001).

[2] Kraemer and Dedrick (2002) point out that when Dell Computers first moved into Europe, the company was attracted by locations that were similar to the US in terms of language and business culture.

factors is likely to account for the fact that the sector has become less concentrated – or more mobile – within Europe over recent decades, as shown by Midelfart et al. (2000). Indeed it will be clear that this is true not just within Europe but globally as well. The fourth factor – and the specific focus of our attention here – is the current eastwards enlargement of the EU.[3]

To delve further into the geography of the sector requires that we focus more closely on individual sub-segments. The distinction between hardware and software is clearly important. Even within hardware however it is necessary to distinguish between computer assembly operations and the production of components such as semiconductors. Within software also it is necessary to distinguish between mass market packaged software on the one hand and custom and niche software and software services on the other. R&D in both hardware and software, furthermore, must be treated separately from production.

2. The Computer Hardware Sector

A Global Overview

Table 1 displays the shares of world exports of computers (SITC 752) and electronic components (SITC 75997) accounted for by each of the triad locations – Europe (or, more correctly, EMEA: Europe, the Middle East and Africa), Asia and the Americas – in 1985, 1992 and 2000. While Asia grew strongly in both segments, and now comprises around 50 percent of world exports in each, the decline in the shares accounted for by Europe and the Americas was less precipitous in computers.

Table 1: Triad Shares of World Exports

Shares of World Exports						
	Sitc 752			Sitc 75997		
	2000	1992	1985	2000	1992	1985
Europe	0.35	0.33	0.41	0.25	0.33	0.45
Asia	0.50	0.47	0.24	0.52	0.43	0.16
Americas	0.23	0.26	0.34	0.24	0.28	0.38

Source: UN Trade Statistics

This suggests that computers and peripherals are more likely to be produced in each triad market for home triad consumption. This is confirmed in the European case by the fact that intra-EU exports of SITC 752 are almost twice the level of EU imports from the

[3] Because our analysis is confined to the issue of enlargement, we do not consider the implications of some of the technological changes that are thought likely to emerge in the not too distant future. These include the possibility that internet-based services will obviate the need for the kind of software localisation that occurs at present, and that the demand for packaged software may diminish with the increased availability of Application Service Providers. See Bradley (2001) for a discussion of the policy issues that such developments might raise.

other two triad markets. That the electronic components segment is more globalised is suggested by the data in Table 2.

Table 2: Percentage of EU exports bound for each of the triad markets in 2000

	EU	Asia	Americas
SITC 752	77	3	4
SITC 75997	63	10	13

Source: UN Trade Statistics

The worldwide distribution of the computer and components segments in 1999 is displayed in Table 3.[4] This shows that for a small country (with a population of only four million), Ireland is a remarkably large player in the field.

Table 3: Worldwide hardware production, 1999: millions of current USD

Country	**Electronic and data processing equipment**	**Components**
US	91,392	78,831
Japan	60,553	88,516
Korea	10,984	29,926
France	6,737	7,334
Germany	9,678	11,690
Ireland	9,189	4,600
UK	15,000	9,361
China	17,750	14,076
Malaysia	14,474	15,599
Singapore	22,059	14,486
Taiwan	23,079	14,326

The computer hardware sector, in the production data, consists of NACE 3002 (Computers) and NACE 3210 (Electronic Components). In the year 2000, these sub-sectors accounted for 0.6 and 1 percent of EU manufacturing employment. The data in Table 4 report the importance of these sub-sectors in the various EU countries, relative to its overall importance in the EU.[5] Employment in both hardware segments is seen to be particularly important in two peripheral EU economies: Ireland and Scotland.[6]

[4] Only countries with production levels greater than Ireland's in either of the two segments are shown.

[5] Each cell therefore measures, for sector i and country j, $(L_{ij}/L_j)/(L_i/L_{EU})$.

[6] Thus while Scotland in 1997 had only 8 percent of UK manufacturing employment it had 27 percent of the UK's 63,000 jobs in Computers and Office Machinery. As a region of the UK rather than an independent state however, data on Scotland is harder to access than data on Ireland.

Table 4: The relative importance of computer sector employment in EU countries

	Computer Equipment	Electronic components
	Nace 3002	**Nace 321**
Belgium	0.21	0.79
Denmark	0.55	0.65
Germany	0.82	0.90
Spain	0.48	0.44
France	1.48	1.80
Ireland	10.42	3.77
Italy	0.48	0.69
Austria	0.15	1.75
Portugal	0.06	0.71
Finland	0.31	1.07
Sweden	0.46	0.79
United Kingdom	1.79	1.10
Of which: …….Scotland	7.90	3.05
Netherlands	1.54	0.54

Source: Eurostat New Cronos
Note: Data not available for Luxembourg and Greece

Since some production in all industries takes place for the home market, larger states frequently loom larger in production than in trade data, as is apparent in Table 5, which shows the shares of individual countries in world exports of the two segments of the hardware industry.[7]

[7] European countries other than Hungary are only included if they record levels greater than Ireland's in any period.

Table 5: Country Shares in World Computer Hardware Exports

			Shares of world exports			
			SITC 752		SITC 75997	
			2000	1992	2000	1992
Europe	France		0.04	0.05	0.02	0.04
	Germany		0.05	0.07	0.04	0.05
	Ireland		0.05	0.02	0.06	0.05
	Italy		0.01	0.03	0.01	0.03
	Netherlands		0.08	0.04	0.05	0.05
	United Kingdom		0.08	0.09	0.04	0.07
	Hungary		0.01	0.00	0.01	0.00
Asia	Japan		0.08	0.21	0.09	0.16
	Taiwan		0.09	0.07	0.09	0.04
	Hong Kong		0.02	0.02	0.07	0.06
	Korea Rep.		0.05	0.03	0.07	0.02
	China		0.06	0.00	0.04	0.01
	Singapore		0.11	0.13	0.08	0.06
	Thailand		0.01	0.01	0.05	0.03
	Malaysia		0.04	0.00	0.00	0.04
	Philippines		0.03	0.00	0.02	0.00
Americas	USA		0.17	0.23	0.18	0.23
	Canada		0.01	0.02	0.02	0.04
	Mexico		0.04	0.01	0.02	0.01
	Costa Rica		0.00	0.00	0.01	0.00

Source: UN trade statistics.

Within Europe the increase in Ireland's share is seen to have come at the expense of the larger and traditionally more prosperous EU states such as France, Germany, Italy and the UK, as suggested by the analysis of Midelfart et al. (2000). In the other regions, the declining shares of Japan and the US are apparent, as is the very strong presence of Singapore. Other important details from the table will be pointed out as we proceed.

2.1 Computer Assembly and Peripherals

It is clear from our brief discussion above that computer hardware production has evolved in line with the product cycle hypothesis. What was once a relatively high-skill activity has shifted progressively to lower-skill locations. This means that the country characteristics required to attract this kind of activity have changed.

Computer assembly has been and remains regionalised, however, because of the need to tailor products to local market demand. This includes customisation with respect to power supplies, keyboards, software and documentation. This in turn leads to companies being organised along geographic lines into the Americas, Asia and EMEA, as is the case for most of the global IT companies. This need to maintain regional production locations

may become even stronger in the future if the rate of technological depreciation accelerates or build-to-order production methods increase in importance; Dedrick and Kraemer (2002).

In the 1990s assembly for North America remained concentrated in the US, assembly for Europe was concentrated in Ireland and Scotland, and that for Asia was concentrated in Singapore, Taiwan and Japan. In Ireland, Scotland and Singapore the sector is largely under foreign – predominantly US – ownership.[8]

2.1.1 Computer Assembly and Peripherals in Europe

Over the period 1995 to 2000 there was a loss of 34,000 EU jobs in the Computers and Peripherals sector, with Ireland, Scotland and Hungary gaining against the trend. By the end of the period Ireland and Scotland had around 20,000 each in the segment and Hungary had around half the 20,000 CEE jobs in Computers and Peripherals.

Ireland and Scotland together accounted for the vast bulk of personal computers sold in Europe. According to the Irish Industrial Development authority, 33 per cent of PCs sold in Europe in 1999 were manufactured in Ireland, while according to the Scottish Development Agency, Scotland in 1997 produced almost 37 percent of the branded PCs sold in Europe, 68 percent of electronic notebooks, 60 percent of Europe's workstations and 16 percent of computer peripherals; Carding (1997). [9]

Why were Ireland and Scotland so successful in the computer assembly segment? Dedrick and Kraemer (2002) argue that PC assembly firms have no need to cluster, and are indeed, in the US, quite dispersed across the country. They argue that their concentration in countries like Ireland and Scotland had more to do with factors such as infrastructure and government incentives rather than Marshallian factors associated with agglomerations. Both Ireland and Scotland were relatively low labour cost locations within the EU; not as low cost as Greece, Spain or Portugal, but with more abundant supplies of skilled labour than these other economies. Ireland furthermore had the benefit of the lowest effective rate of corporation tax in Europe while Scotland benefited from UK regional grants and other financial and fiscal incentives.[10]

Both countries were already established locations for computer assembly even before the era of the personal computer. Ireland attracted Digital and a number of other

[8] Almost 90 percent of computer hardware employment in Ireland and around 70 percent in Scotland is in foreign-owned firms, with US firms predominant in both countries; Irish Census of Industrial Production (2000) and Scottish Office (1999).

[9] See Van Egeraat and Jacobson (2004) for a detailed history of the Irish and Scottish computer hardware industries.

[10] Hill and Munday (1992) show that Wales, the West Midlands, the North of England and Scotland over the course of the 1980s attracted shares of new FDI well out of proportion to their size, and that infrastructural spending and regional preferential assistance combined were important determinants of new firm location. See McCalman (1988) for details of the fiscal and financial incentives available to electronics firms in the UK at that time.

minicomputer companies as well as a mainframe assembler in the 1970s and these were replaced in the 1980s by a large number of PC assemblers. Scotland was an industrial economy long before Ireland and the roots of its computer industry extend further back to 1959, when IBM began to assemble mainframes there. IBM was followed by other mainframe assemblers in the 1960s, by minicomputer assemblers in the 1970s, and by PC companies in the 1980s.

Van Egeraat and Jacobson (2004) estimate that both the Irish and Scottish computer assembly sectors reached their employment peaks around 1998. Five microcomputer makers and one contract manufacturer employed up to 10,000 workers (out of a total of 16,000 NACE 30 employees) in Ireland, while six of the main global branded microcomputer makers and two local subcontractors were involved in system assembly in Scotland, employing almost 10,000 permanent staff.

Between 1998 and 2002, both Ireland and Scotland sectors experienced serious job-losses and plant closures in computer assembly. Of all the companies present in Ireland in 1998, by 2002 only Dell and Apple continued as assemblers, with the latter's assembly operations having been dramatically downsized. Of the eight microcomputer assemblers in Scotland in 1998, only five continued in 2002 and most had downsized sharply.

The decline came about not just because of the global downturn in the computer market but also because of increased competition from lower-wage economies. Much of the production of computer peripherals shifted to Asia, while a substantial segment of computer assembly moved to Central and Eastern Europe.

Computer assembly has indeed been shifting to lower-cost locations within each of the triad markets. In the North American case the shift has been to Mexico. Dedrick and Kraemer (2002) point out that Mexican computer equipment imports increased by 25 percent a year over the 1990s to a total of $5.2 billion by the decade's end, while exports increased by 38 percent a year, to a total of $11 billion. These numbers are now reasonably close to the numbers recorded for Ireland in 2000; OECD (2002). Within Asia, computer assembly was shifting from Singapore towards lower cost locations such as Thailand, Malaysia and China; Dedrick and Kraemer (2002).

Extrapolation of the global and European trends will see computer assembly for the EMEA market shifting further towards Central and Eastern Europe. As Kraemer and Dedrick (2002) point out, in a paper analysing the Dell business model,

> "Eastern Europe is cheaper than Ireland and more centrally located within Europe and, as a result, many of Dell's contract manufacturers and suppliers are locating there, creating speculation that Dell will follow."

[11] Intel, which came in 1989, assembled PCs and motherboards as well as producing microprocessor wafers.

2.2 Electronic Components

A type of clustering process operates whereby computer assemblers influence the location of components suppliers. This is particularly the case with Dell, whose suppliers are required to maintain inventory close to Dell plants to support Dell's build-to-order production. This leaves them with the choice of shipping goods to supply hubs close to Dell plants or else setting up production locally.[12] Higher-value components do not need to be produced close by as they can be cargoed in by air. Nor do low-value components, for which labour costs are crucial. Kraemer and Dedrick (2002) identify mid-level components as the items whose production is most likely to be influenced by the location of the Dell plant. These kinds of clusters then are likely to be much less stable than R&D clusters.[13]

This clustering process apart, the location of components suppliers appears to be more globalised than that of computer assemblers, and to respect less the boundaries between triad markets. This is clearly the case for Ireland, where most computer exports go to the EU while the bulk of components exports goes to the US, as seen in Table 6

Table 6: Export Destinations of Computers and Electronic Components produced in Ireland, 2000

NACE	% of gross output exported	Exports			
		% going to UK	% to other EU	% to US	% to RoW
30	86	22.5	55.8	8.4	13.3
32 (the bulk of which is 3210)	93	24.9	23.4	42.8	9

Source: Irish Census of Industrial Production 2000

Most of the innovation in computer hardware is now carried out by components suppliers, who tend to have quite high human capital requirements. Although there are many sub-categories within Computers and Peripherals on the one hand and Electronic Components on the other, the implication is that a shift from NACE 30 to NACE 3210 will generally represent a movement up the value chain within the hardware sector.

[12] In the Irish case, while official data show that local sourcing of material inputs for computer assemblers rose from around 5 percent of all material inputs in the early 1980s to 28 percent by 1999, interviews conducted by Van Egeraat and Jacobson (2004) suggest that only 10 percent may actually have been manufactured in Ireland. Much of the rest, they argue, is likely to have been produced elsewhere and purchased from local supply chain managers.

[13] McKendrick (1998) distinguishes between such operational and technological clusters, with technological clusters "stickier" than operational ones.

Within the EU there was a net gain of 100,000 jobs in NACE 3210 between 1993 and 2000, in contrast to the loss of 34,000 jobs in NACE 30 over this period, with 10 of the 13 EU countries for which data are available recording an increase in employment in NACE 3210 relative to NACE 30.[14]

2.3 Climbing the value chain in the computer hardware sector

We have seen that computer assembly has begun to shift to lower-cost locations within each of the triad markets. Unfortunately both the trade and production data are too aggregated to give us a picture of how the hardware industry of the original assembly countries is restructured as assembly operations move out. These processes can be studied however by focussing on the experiences of particular industrial segments and/or particular countries.

Gourevitch et al. (2000) study the hard-disk drive segment of the industry, identifying the steps, from low to high, in the value-added chain. In 1985, more than 80 percent of the entire world's disk drive production occurred in the US. The movement of the US up the value chain is demonstrated by the fact that though less than 5 percent of assembly (at the low end of the chain) continued to take place in the US by 1995, more than 50 percent of employees in the media segment and more than 30 percent of those in semiconductors, both at the higher end of the chain, remained in the US. A large proportion of global employment in higher-end production and test equipment is also located there. Consistent with this, while US firms continued to dominate global production, over 60 percent of the wage bill of these firms was paid to US workers.

Dedrick and Kraemer (2002) argue furthermore that whilst the move offshore reduced hardware employment in the US – by 100,000 between 1985 and 1998 – the associated reduction in the cost of hardware created demand for additional software and services, whose US employment levels increased by around 600,000 over this period.

Of more relevance for present purposes, given its heavy reliance on IT sector FDI (in contrast to Korea and Taiwan, for example, where most of the sector is domestically owned), is the story of Singapore's development. Since 1989 Singapore has been the world's largest producer of disk drives and disk drive parts. As wage levels rose, Seagate – the world's largest manufacturer of HDDs – moved its low-end assembly work elsewhere, replacing it by higher skill activities such as media fabrication, high-end drive assembly and semiconductor wafer fabrication. It also now splits its product and process development between the US and Singapore.

As labour-intensive computer hardware activities relocated over time to lower-wage Asian economies such as Thailand, Malaysia and China, as seen in Table 5 above, Singapore and Taiwan have taken on the role of coordinating production in these sites while continuing to handle the more sophisticated manufacturing processes at home; Dedrick and Kraemer (2002).

[14] By the year 2000 there were almost 50,000 CEE jobs in NACE 3210: about 20,000 each in the Czech Republic and Hungary and around 10,000 in Poland.

The opening up of the Chinese economy can be seen as a similar event in Asia to the accession to the EU of the economies of Central and Eastern Europe. As the Chinese electronics sector grew, the ASEAN electronics sector developed complementarities with the new challenger, integrating China into pre-existing global production networks; Pangestu (2002). Furthermore, inward FDI flows to China just kept pace with the country's GDP growth, leading Wu et al. (2002) to conclude that FDI was not diverted away from ASEAN member states. The latter also benefited substantially from the increased demand emanating from the growing Chinese economy.

There has also been a rapid growth in indigenous electronics firms in Singapore since the late 1980s. Many developed as sub-supply firms to the foreign multinational companies, while others which started out as contract manufacturers later successfully forward integrated into own-brand manufacturing; Wong (1998).

Are there any indications that Ireland and Scotland can follow suit, as the assembly operations formerly located there shift eastwards to the new accession states? The industry remains in a state of flux in both economies since the peak of the high-tech boom in the year 2000. Both economies have seen employment losses in both Computers and Components since then. It is clear however that employment growth in NACE 3210 in Ireland was more rapid than in NACE 30 over the course of the 1990 (with about one-third of current employment in NACE 3210 in Intel). Consistent with this notion of ascending the 'ladder of comparative advantage', wages in the more rapidly growing segment have been higher than in the relatively declining segment in recent years.[15]

In addition, even as computer assembly jobs shift overseas many of the computer firms remain, concentrating on relatively high value-added non-manufacturing functions such as sales and technical support call centres and logistics; Van Egeraat and Jacobson (2004). When Intel consolidated cartridge assembly in its plants in the Philippines and Puerto Rico, it refitted its Irish plant for much higher level wafer production. The performance of Intel's Irish operations in the context of process development also give grounds for optimism. As Durkan (1998) notes,

> "The IFO plant in Ireland contributes 40% of the worldwide Virtual Factory White Papers in the .25 micron technology, and expects to reach the same level in the new .18 micron technology shortly. Furthermore IFO ranks in terms of IMEC paper submissions in the top 2 of Virtual Factory sites, contributing about 10 percent compared with an average of 2 to 3 percent. There have also been other positive developments. The Irish plant developed a safety culture and system that has been adopted across the whole Intel operation worldwide, and Ireland realised ISO9002 certification first. NSAI are the compliance auditors for Intel sites worldwide."

[15] NACE 30 includes computers, disk drives, storage units, keyboards etc. NACE 3210 includes integrated circuits, semiconductors, electronic microassemblies etc. Employment data for 2001 and 2002 for NACE 3210 are not yet available. However, the decline in NACE 32, of which the bulk of employment is in NACE 3210, has been less precipitous than in NACE 30.

The decision in recent years to construct a FAB 24 fabrication facility in Ireland – which will implement the world's most advanced 300 millimetre semiconductor manufacturing technology – as well as a new IT innovation centre, represents a strong vote of confidence in the Irish economy.

It is not clear as yet that Scotland can remain abreast of Ireland in these respects. Scotland has recorded no new IT investments of the scale of Intel's €2.5 billion investment in its new Irish plant. Ireland retains the benefit of a low corporation tax rate while UK regional subsidy levels have had to be progressively scaled back in line with EU state aid restrictions. Fears have also begun to be expressed in Scotland recently that its output of appropriately qualified workers has not have kept pace with Ireland's. Nor are the R&D statistics propitious. While Irish and UK R&D expenditures per employee in computer hardware are on a par with each other, the spend in Scotland is only about one-quarter of the UK average; Scottish Executive (2000).

3. Research and Development

Hardware R&D

While accounting for only around 1 percent of OECD manufacturing employment, Office and Data Processing Equipment consistently accounts for around 7 percent of manufacturing-sector R&D. More than 80 percent of OECD R&D spending in this sector continues to take place in the US and Japan. Unsurprisingly, R&D is therefore far more concentrated geographically than are other measures of activity in this sector.

We illustrate this by comparing Gini coefficients for the concentration of R&D and employment across the 16 OECD countries in Table 7 for which data on both variables are available.[16] The more geographically concentrated a variable is, the closer the Gini index is to unity. The value of the R&D index is 0.83 while that for employment is 0.69.

While R&D spending within a country is positively correlated with a country's level of employment in the sector, the values of the Gini coefficients indicate that it will be far easier to capture employment share than R&D share in the sector.

[16] The locational Gini coefficient yields a measure of industrial concentration between 0 and 1, with a value of zero representing an equal distribution across locations and a value of unity representing complete concentration in a single location. The coefficients we report are absolute rather than relative Gini coefficients, meaning that they are not scaled by a location's share of total R&D spending or total manufacturing employment. On the calculation of these and other measures of concentration see, for example, Devereux, Griffith and Simpson (1999).

Table 7: OECD R&D and Employment statistics for the Office and Data Processing sector, 2000

	Share of OECD R&D	Share of OECD Employ
Australia	0.31	n.a.
Belgium	0.05	0.13
Canada	1.97	1.80
Czech republic	0.00	n.a.
Denmark	0.08	0.27
Finland	0.01	0.13
France	1.38	3.34
Germany	3.14	6.29
Ireland	0.20	2.55
Italy	0.30	2.44
Japan	34.36	33.12
Korea	4.50	9.50
Netherlands	5.62	1.17
Norway	0.05	0.09
Poland	0.03	n.a.
Spain	0.16	1.93
Sweden	0.22	0.42
United Kingdom	0.79	8.06
United States	46.83	28.76
Total OECD R&D	22040.76 million current PPP dollars	

Source: OECD STAN and ANBERD databases; Irish Census of Industrial Production; UK Production and Construction Inquiries.

This conclusion is strengthened by the fact that firms locate their R&D activities disproportionately at their home bases. The vast bulk of computer sector employment in the US and Japan, for example, is in domestic firms, while in the case of the Netherlands around 80 percent of IT-equipment employment is in domestic firms.[17] This compares to figures of well under 35 percent for Italy and the UK and a figure well below that again for Ireland.[18]

Since any expansion of the hardware sector in the accession states is likely to emerge through FDI rather than from domestic industry, this will militate against any strong shift of R&D towards these countries.

[17] Singapore which hosts a good deal of R&D in hard disk drive production, even within US firms, may be an exception. This is likely to arise as a consequence of government strategy.

[18] These numbers are derived from a comparison of the OECD STAN database figures for ODP employment with those for foreign-affiliate IT-equipment employment reported in OECD (2002).

Software R&D

Table 8 provides data on R&D in software and other computer services. Software R&D, with a Gini coefficient of 0.76, is found to be less concentrated geographically than is hardware R&D, for which we found a Gini value of 0.83.[19] It is possible then that enlargement will have a more discernable effect on the geography of software R&D within the EU.

Table 8: R&D spending in software and other computer services

R&D in software and other computer services (2000)[20]	
	Millions of current PPP dollars
total	22278.45
SHARES	
Australia	3.70
Belgium	0.70
Canada	2.51
Czech republic	0.14
Denmark	0.91
Finland	0.54
France	2.37
Germany	3.97
Ireland	0.44
Italy	0.86
Japan	6.07
Korea	2.43
Netherlands	1.17
Norway	0.61
Poland	0.01
Spain	1.39
Sweden	1.50
United Kingdom	4.25
United States	66.43

Source: OECD ANBERD database.

Consider for example the foreign-owned software development sector in Ireland. This accounts for somewhat less than half of foreign-sector software employment but is more high-skill than the remaining segment. One part consists of branches of major computing-services or IT consulting companies (including EDS, IBM, ICL and Accenture). The other is an adjunct to non-software electronics corporations such as

[19] Note that the total R&D spend in software and hardware are quite similar.
[20] 1999 for Denmark, Germany and Ireland and 1997 for Norway.

Motorola and Ericsson, with operations focussed on the production of embedded software and applications for products such as mobile phones; Crone (2002).

The outsourcing of software development work has expanded dramatically over the course of the 1990s, with India, Israel and Hungary all benefiting as well as Ireland. There is the possibility that this segment may be drawn increasingly towards lower wage economies with equally ready supplies of appropriately skilled labour as globalisation and enlargement proceeds. It is likely however that multinational companies in dealing with a high-skill segment such as this will prefer to maintain a portfolio of foreign software development locations, in order to derive the benefits of differing "national systems of innovation"; Cantwell and Piscitello (2002).[21]

4. Computer Software

Table 9 reports the importance of computer software employment in EU countries, again – as in Table 4 above – measured relative to the EU average.[22] Software employment records its highest share of private-sector employment in Sweden, the UK and Ireland.[23] Scotland, though a substantial player in hardware production, plays no such role in software. Instead, the computer services industry in the UK is concentrated in the Greater South East region, the least peripheral and wealthiest region of the economy; Crone (2001).

Table 9: The relative importance of computer software employment in EU countries

Belgium	0.89
Denmark	1.25
Germany	0.61
Spain	0.62
France	1.05
Ireland	1.32
Italy	1.04
Netherlands	1.25
Austria	0.78
Portugal	0.27
Finland	1.25
Sweden	1.95
United Kingdom	1.47

[21] Ireland for example is said to have gained recognition as an important UNIX development centre in Europe; Coe (1997).

[22] Software employment is measured as a share of employment in manufacturing and market services, as countries differ in terms of the relative shares of the latter.

[23] As discussed below, software employment here includes NACE 2233 as well as NACE 72. The Irish National Software Directorate reports 30,000 jobs in Irish software in 2000 (14,000 in domestic firms and 16,000 in foreign firms) compared to the 24,400 reported by Eurostat (18,800 in NACE 72 and 5,600 in NACE 2233). The National Software Directorate numbers would yield a value of 1.62 for Ireland in the table, elevating the country to second place in the chart.

Within software there is an important distinction between mass market packaged products and other software activities – including custom and niche software and business solutions.[24] The EU market is roughly equally divided between the packaged segment and other software activities, with packaged software emerging as the most rapidly growing ICT sub-sector over the last decade; OECD (2002).

Microsoft is by far the largest packaged software firm in the world, followed by IBM with about half of Microsoft's level of packaged software sales; OECD (2002). Domestic firms, on the other hand, are dominant in the non-packaged segment; Mowery (1999).

4.1 Mass Market Packaged Software

We pointed out earlier the extent to which computer production and exporting are triad oriented A similar situation prevails with respect to packaged software exports. Most of the localisation of software for the broader EMEA triad takes place in Ireland. A similar function is performed in Singapore by Microsoft and Lotus for software destined for the Asian market [Coe (1999)], though packaged software is far less important in Asia than in the other triad markets.

According to OECD (2002) Ireland and the US were by far the largest software exporters in the OECD, accounting for shares of 29 and 26 percent respectively. Netherlands and the UK came next at 8 and 7 percent respectively, while Japan came well down the list at only 2 percent. The vast bulk of Irish and US software exports furthermore are of packaged software, with Ireland accounting for around 50 percent of all mass market packaged software sold in Europe.[25]

It is widely accepted that the figures for Irish output are inflated by the transfer-pricing practices of the multinational corporations operating in Ireland. Nevertheless, even in employment terms, the packaged software sector is more important in Ireland than in other EU economies. Eurostat data register employment in this sector (which is classed as NACE 2233 – Reproduction of computer media – and included as part of manufacturing) in only eight EU countries, with employment numbers as shown in Table 10.

[24] Niche software – i.e. software designed for particular business sectors – is sometimes included in the "packaged software" category. We confine our use of the latter term to more general software catering to the global market.

[25] Over two-thirds of Irish software exports go to the EU while one-quarter goes to the rest of the EMEA triad – the Middle East and Africa; Crone (2002).

Table 10: EU Employment in Mass Market Packaged Software

Nace 2233 Reproduction of computer media	
	2000
Spain	663
France	875
Ireland	5591
Italy	342
Netherlands	168
Finland	16
Sweden	194
United Kingdom	3576

Source: Eurostat New Cronos.

Also, the foreign software companies operating in Ireland, which include most of the world's top ten independent software companies, pay very substantial taxes to the exchequer. In 2001, for example, Microsoft, though employing only around 2000 people, paid almost 5 percent of that year's total Irish corporation tax take.[26]

The mass market packaged software sector in Ireland is engaged in the manufacturing, localisation and distribution (MLD) of software packages. This is not a particularly high-skill segment of the software sector. Around 50 percent of employees in these operations are typically engaged in the manufacturing stage, which does not require highly skilled labour, while around 30 percent are involved in localisation. In the case of Microsoft's Irish operations, some 90 percent of staff involved in localisation had third-level qualifications in information technology or linguistics, while 35 percent were nationals of mainland European countries; Coe (1997).

Some of the subsidiaries of packaged software MNCs outsource activities in Ireland, leading to the development of a software-supporting subcontracting sector in activities including localisation and translation, printing, disk manufacturing and logistics.

Even though these activities are not very high tech in nature, the sector has nevertheless moved up the value chain over time. 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 the software programmes 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 to the process. This involves translating the original products into other languages and cultural and technical formats appropriate to the destination markets. Besides translation there is some

[26] Own calculation based on tax details in Sunday Tribune newspaper, June 2, 2002. While Ireland's corporation tax rate is the lowest in the EU furthermore, corporation tax revenues as a proportion of GDP are at the EU average level

programming involved in preparing the text to be translated and then reincorporating it back into the programme. The third phase of the sector's development saw the transfer of the responsibility for distribution, which had previously been handled by local distributors, to the Irish operations themselves. Thus Ireland became an operations hub; Crone (2002), Coe (1997), O Riain (1997).

Crone (2002) and Coe (1999) find that MLD activities account for about half the jobs in the foreign-owned software sector in Ireland. The other half are accounted for by the software development sector, which is substantially more highly skilled. The origins and prospects for the latter will be discussed further below.

What are the factors that are likely to have drawn this particular segment to Ireland, and how will the country fare in the wake of EU enlargement? Several relevant points arise. First, while it is clear that packaged software does not need to be develop and produced close to its customers, the fact that localisation is required, and that this in turn requires a supply of workers with the requisite linguistic knowledge, means that production will remain in Europe. One factor that will continue to operate in Ireland's favour invariably surfaces in interviews with the young continental Europeans upon whom the localisation segment relies; i.e. that Ireland is viewed favourably as a location in which to spend some period of time.[27] In part this is probably due to the fact that it is an English-speaking environment. A further point that will insulate Ireland from competition from the accession states is the fact that because they are lower labour-cost environments they are unlikely to be able to attract the native speakers of French, Italian, Spanish and the other EMEA languages that the localisation process requires.

4.2 Niche Software and Computer Services

The remainder of the software sector makes up NACE 72 (computer services and related activities). This segment includes custom software (which is provided for individual companies), niche software (which is written for specific business sectors) and other software services which are provided both for organisations and for consumers.

In this segment countries like Sweden, Denmark, Finland, the Netherlands and the UK have higher weights than the rest of Europe. These are all countries with high computer penetration rates and other attributes associated with the "information society". Their relatively strong showing in this sector reflects the fact that many computer services are essentially non-tradeable.

Though Ireland achieved phenomenal growth in the software sector throughout the 1990s, this was just sufficient to allow the country attain a middle ranking relative to other EU countries and to the regions of the UK economy in terms of NACE 72. Thus Crone (2001) finds that the importance to Ireland of employment in this sector, though

[27] This is confirmed by the fact that since the mid- to late-1980s Ireland's share of world tourism has risen, while that of Europe in general has fallen.

well above the values pertaining to the UK's peripheral regions (including Scotland), is nevertheless well below that for the most successful region of the UK – the South East.

While UK software and computer services companies, however, are found to obtain only around one-third of their revenues from exports, and French and German companies from 25 to 30 percent, exports accounted for 85 percent of the revenues of Irish indigenous firms in 2002 (up from 41 percent in 1991).[28]

What explains this strong export orientation of the Irish indigenous software sector? The overall EU market for (largely non-tradeable) IT services is about twice the size of the market for (tradeable) software products, according to the European Commission (2003), and Irish indigenous firms have a disproportionately strong weight in the tradeable segment. About half of such firms are engaged in the development and sale of niche products in sectors such as Banking and Finance, Telecommunications and Computer/internet based training.

How then will the computer services and niche software segments fare with increasing globalisation and enlargement?[29] If computer services remain largely non-tradeable, one can predict a substantial increase in computer services employment in the accession states as computer penetration rates converge on the EU average; Table 11. This growth will not threaten existing employment in the incumbent EU states. The export-oriented niche software producers discussed above cannot but gain from the expansion of the EU marketplace that enlargement entails.

[28] These data for the UK, France and Germany come from *Software and Computer Services*, available on the UK Department for Culture, Media and Sport website: www.culture.gov.uk/.../ Computers.pdf. The same document however, on the basis of balance of payments figures, values UK SCS exports in 1998 at only £2.76 billion compared to revenues of £30.3 billion. (On the difficulty of correctly evaluating software exports see OECD, 2002, page 37).

[29] It is worth pointing out that domestic software firms in EU countries are not generally in competition with the high-profile Indian software industry, which is primarily engaged in customised programming for large multinational corporations. In 1999-2000, for example, more than a third of Fortune 500 companies were said to have outsourced their software requirements to India, with North America accounting for over 60 percent of India's software exports.

Table 11: PC penetration rates in Europe: Number of PCs per 100 inhabitants

EU	End 1999	Growth, 1997-1999 (%)	Accession States +	End 2000	Growth, 1998-2000 (%)
Austria	36	29	Bulgaria	4.4	33
Belgium	39	16	Cyprus	28	97
Denmark	61	11	Cz Rep	13	47
Finland	40	17	Estonia	na	Na
France	31	17	Hungary	3.6	43
Germany	36	20	Latvia	11.3	51
UK	49	4	Lithuania	8	44
Greece	11	38	Malta	21	32
Ireland	18	37	Poland	15.5	30
Italy	20	8	Romania	3.2	51
Lux	52	-	Slovakia	13.3	54
Netherlands	35	9	Slovenia	27.3	29
Portugal	22	24			
Spain	15	13			
Sweden	51	36			

Source: Information Society Project Office (2001)

Conclusions

Discussion of the implications of enlargement for the geography of the IT sector in Europe requires analysis at the level of five separate sub-segments: computer hardware and peripherals, electronic components, R&D, mass market packaged software and the remainder of the software sector.

Just as computer assembly operations have shifted within the North American triad from the US to Mexico and within the Asian triad from Singapore to Malaysia, Thailand and China, the shift from Ireland and Scotland to Central and Eastern Europe is likely to continue.

The production of electronic components such as microchips is more highly skilled than computer assembly, and represents a growing share of activity in most EU locations. Ireland has been moving progressively into this segment and has registered a number of important successes in its dealings with Intel over recent years. Most other EU and CEE countries also saw their employment shares in this sector increase over the 1990s, and most analysts expect growth to resume once the consequences of the collapse of the high-tech bubble are played out.

The distribution of R&D activity across Europe and globally is unlikely to be much affected by enlargement. While we countenanced the possibility that some Western European countries could face increased competition for foreign-owned software development activities, it seems more likely that MNCs will continue to maintain a

portfolio of locations in which to carry out these activities in order to reap the benefits of differing national systems of innovation. Public policy will clearly have a role to play however in ensuring that countries remain attractive as locations for these activities.

As long as the localisation of software remains important, Ireland – the EU location in which most of this activity is carried out – seems set to be able to compete strongly, given the attractiveness of its English language environment and other attributes to the young continental Europeans upon which this activity relies. The fact that the country offers much higher wages than the CEE accession states will – perhaps paradoxically – strengthen this conclusion.

Most software services remain largely non-tradeable. This sector will grow in the accession states as computer penetration rates converge on the EU average, but there will be no displacement from the incumbent EU member states. For firms already competing in the tradeable niche software segment, on the other hand, enlargement cannot but be to their benefit because of the impact it has on the size of the market into which they sell.

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