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The Politics of Mobility in Technology-Driven Commodity Chains: Developmental Coalitions in the Irish Software Industry

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National production systems have been fragmented from above and below — by emerging global production networks and regional systems of production. Increasingly, national systems of production do not sit between global and local but are formed out of them (Castells, 1997). Yet the relationship between global and local production networks is a tense one: while regional industrial systems enable more rewarding participation in global networks, participation in those networks simultaneously presents potential problems of the 'hollowing out' of the region and of the 'locking in' of the region at lower levels of the hierarchy of the international division of labour (O'Hearn, 2001). Strategic participation in global networks of production and innovation is crucial to developing strong regional systems. But in order to negotiate access to the upper reaches of the production and innovation hierarchy, a strong regional system is crucial. A dilemma presents itself for regions seeking to grow and develop industrially: how to use global networks to develop the very local systems that will enable regions to bargain their way into a more favourable position within those networks.

The information technology industry in the Republic of Ireland is a useful case for exploring these industrial development dilemmas. Since the 1950s, industrial policy in Ireland has focused on the attraction of foreign investment. After initial growth in the 1960s and 1970s, an economy increasingly based on branch plants and transfer pricing ran into economic problems in the 1980s. Mass unemployment and emigration in the 1980s gave little sign of the economic boom to follow in the 1990s. Driven by foreign investment and governed by new 'social partnership' institutions, the Celtic Tiger years of the 1990s represented a startling turnaround in economic fortunes so that Irish GDP outstripped the EU average by the late 1990s (Ó Riain and O'Connell, 2000).

But if the economic growth of the 1990s is unquestioned, the extent and character of the industrial transformations underpinning it are more controversial. Some see the Celtic Tiger years as bringing industrial upgrading led by foreign firms, while others see the influence of foreign firms as more pernicious, with Ireland in the 1990s largely the beneficiary of enormous entrepot flows of international capital (Barry, 1999; O'Hearn, 2001). However, while there are striking entrepot characteristics to foreign firms in Ireland, significant industrial upgrading has occurred across a wide range of sectors. We see growth almost completely across the board in investment, R&D, employment, professionalization and productivity (Ó Riain, 2004a). Perhaps the central contradiction of Irish industrial development that has fostered the controversies of recent years is that entrepot activity and industrial upgrading occurred within the same sectors and even within the same firms. An intriguing aspect of Irish development is the emergence of local deepening and upgrading from within these non-productive flows of capital.

This article uses these contradictions within the Irish industrial structure to explore the dilemmas of development in a world of global and local networks. Through a case study of the development of the software industry, the most dynamic sector of the Irish economy in the 1990s, the article explores how an industry and region that was 'locked

in' to a dependent relationship of routine production within the global software production network managed to partially move up the production and technology chain to develop more sophisticated operations among foreign firms and an increasingly sophisticated Irish-owned sector.

The analysis suggests that state strategies are central to the ability of firms and territories to integrate into particular niches in global production networks. Relations within production networks tend to become institutionalized and self-reproducing. Firms and territories tend to remain locked in to a particular niche, in the absence of a 'development project' or coalition that mobilizes resources and cooperation to generate a push into a niche further up the network hierarchy. The push for moving up the network comes when a marginalized or vulnerable group within or on the edges of the network makes an alliance with supportive public agencies (Ó Riain, 2004b). Global production networks tend to institutionalize hierarchical relations, but this does not mean that it is impossible for developmental coalitions to mobilize around the connections and resources within those networks to enter new niches further up these hierarchies. In practice, this requires a concerted and ongoing state policy of industrial development and innovation promotion.

Technology-driven commodity chains

Global production networks have come to profoundly shape opportunities for mobility within the contemporary global economy. For some, these networks are conduits of development, where connections to networks of skills, knowledge and innovation bring learning and growth (Reich, 1991). For others, global production networks are fundamentally hierarchical, incorporating new organizations and territories into unequal exchanges that maintain them in a subordinate position, even where growth occurs (O'Hearn, 2001). Each perspective has different implications for strategies of regional development. If global networks bring resources, then integrating into them is unproblematic for regional development. However, if networks are hierarchical then there is a strong probability that resources will be extracted from the region rather than drawn into it.

The concept of 'global commodity chains' (Gereffi, 1994) is a useful one in working through the contradictions between these perspectives — and indeed the contradictions in the real world of production. Commodity chains consist of institutionalized relations between actors in a production network, organizing the distribution of resources and rewards through a more or less hierarchical structure. In this respect, the 'commodity chain' concept is particularly useful as a description of the structure of opportunities and constraints in global production networks. As we will see, it is less useful in explaining relations and mobility within the chains themselves.

Gereffi (1994) distinguishes between producer-driven commodity chains (PDCCs), where a large integrated industrial enterprise (typically a transnational corporation) controls the commodity chain through its control of the critical elements of the manufacturing process, and buyer-driven commodity chains (BDCCs) where 'large retailers, brand-name merchandisers, and trading companies play the pivotal role in setting up decentralized production networks in a variety of exporting countries' (Gereffi, 1994: 221). PDCCs are most common in capital-intensive industries such as automobiles, while BDCCs are most common in labour-intensive industries such as apparel. But this distinction, important as it is, neglects the particular characteristics of production networks where control over technological design, standards and trajectories is the central element of business power.

Figure 1 illustrates the basic structure of a technology-driven commodity chain (TDCC), most common in industries which are research intensive (see UNCTAD, 2002, for analyses of the Intel and Ericsson TDCCs). At the heart of TDCCs are the technology standards and platforms upon which other products are built and with which

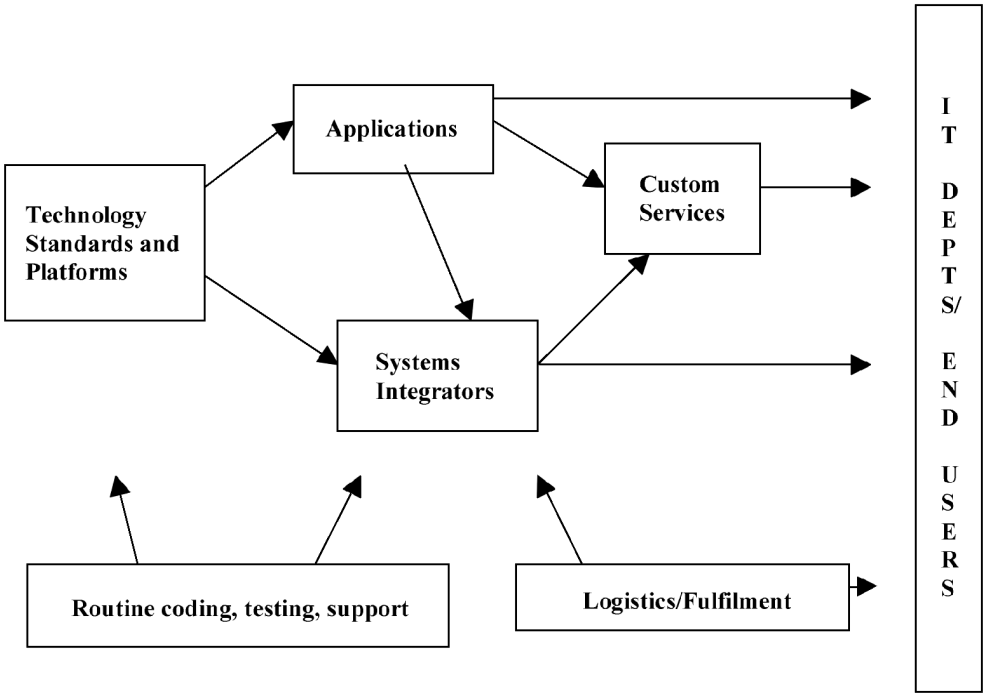

Figure 1 Technology-driven commodity chains

they interact. Next most important are firms which provide applications sold as standardized products where the potential of securing a major part of the value added in the commodity chain is relatively high. System integrators do the work of pulling together systems for customers and integrating a variety of technologies to, presumably, meet a user's needs. Finally, a large variety of custom services providers tailor systems and even write new code but on a much smaller scale. This segment and the work of coding, testing and support throughout the system is the most visible but the least significant part of the TDCCs.

Where economies of scale and production efficiencies are central to producer-driven commodity chains (PDCCs) and control of marketing and distribution to buyer-driven commodity chains (BDCCs), it is control over technical standards which is critical to power in TDCCs (Mowery, 1996: 10): 'Standards setters have the opportunity to lock in customers around their product and will lock customers in for future generations as well' (Dedrick and Kraemer, 1998: 259). 'Lock-in' is reinforced by users who must invest quite substantial amounts of time and money in learning how to use the technologies, applications developers who tailor their products to be compatible with certain operating systems or applications, and because the success of a particular platform increases the potential markets for applications developers. Taken together, these characteristics mean that many ICT markets are characterized by 'increasing returns' to the standards setters, often the first movers who are able to set the terms of the deals made throughout the commodity chain.

Important 'network externalities' emerge 'in which an individual's decision to adopt a given design is influenced positively by the number of other adopters' and typically these 'network externalities have less to do with physical interconnection than with the ability of a dominant design to create a "bandwagon effect" among the independent software developers' (Khazam and Mowery, 1996: 86). Furthermore, as Ernst and O'Connor (1992: 24) argue in their analysis of the global electronics industry in the late 1980s: 'while production-related economies of scale continue to matter, the epicenter of competition has shifted to R&D and other forms of intangible investment and to the

co-ordination of increasingly complex corporate networks … our research shows that competitive success increasingly depends on the capacity to reduce the huge coordination costs of network transactions'. The importance of 'network externalities' in TDCCs was cemented by the shift from proprietary systems, typically self-contained systems operating to a stand-alone company standard, to open systems, which were in principle compatible with a wide variety of other hardware and software components (Steinmuller, 1996; Egan, 1997). This created the basis for an independent software industry which rapidly became a critical part of the computer industry — while hardware costs in computers were five times that of software in 1970, by 1990 they were equal (Ernst and O'Connor, 1992). The industry structure itself therefore moved toward the increasing importance of building alliances and creating technical communities around particular technologies, in the process locking in users and technology developers (Khazam and Mowery, 1996; Egan, 1997; Von Burg, 2001).

Power in TDCCs resides, therefore, in *what* is getting made and mobilizing networks of support for those products rather than in *how* that product is itself produced — emphasizing the place of intellectual property holders in securing the rewards of the network externalities within the system. Technical communities and global technology networks interact to produce the uneven geography of the global information economy. 'Network externalities' in technology development mean that simply emulating dominant models of growth in these industries or mobilizing massive resources is not enough. Competing effectively in these industries requires that both firms and technical communities themselves, although locally embedded, must have close ties to global technology networks of innovation and learning. There remain, however, multiple nodes within these commodity chains where subordinate firms can be integrated, often with dramatically varying developmental results. The question remains how mobility occurs between these niches. To explore this, we turn to the Irish software industry.

Software: the leading sector of the Celtic Tiger

The Irish economy experienced an upgrading of investment, research and development, skills and productivity through the 1990s.[1] Although concentrated in certain sectors and particularly strong among foreign firms, these trends emerged across most sectors and nationalities of ownership of firms (Ó Riain, 2004a). Most striking, however, is the emergence of a potential cluster of sectors in the 'knowledge economy'. These are sectors which are fundamentally based on the processing of information or where, for the most part, indigenous Irish firms spend a greater proportion of their revenues on R&D than the OECD average for their sector (see Forfás, 2000).[2] As well as being the most knowledge-intensive sectors, these sectors are the fastest growing, in terms of employment, output and R&D spending — although still accounting for a minority of industrial employment (Ó Riain, 2004a). Central to this sector is the software industry (see Table 1).

Software is not, however, merely one sector among others but is increasingly the central activity of the knowledge economy. Software accounts for an increasing proportion of the costs of all ICT development (Ernst and O'Connor, 1992; Mowery, 1996) and the boundaries between the 'software industry' and other industries such as computers, telecommunications and business services are increasingly blurred. Software is unusually significant within high technology in Ireland — both the US and Israel have much more diverse ICT sectors. However, the industry potentially knits together an interesting set of relationships among a variety of sectors in Ireland. The indigenous software industry's major sub-sectors include communications software

1 For a more detailed account of industrial upgrading and sectoral differences, see Ó Riain (2004a).

2 Generally, care must be taken with such comparisons across OECD countries as the surveys which form the basis of the figures are often not strictly comparable. However, the patterns are clear enough that we can identify basic patterns within Irish industry.

Table 1 'Knowledge economy' sectors in the Republic of Ireland, 1999 (high growth, R&D intensity above OECD average)

Sector	Output (£m)	Employment 1999	Total employment change 1991–9 (%)	Professional employment change 1991–9 (%)	R&D change 1991–9 (%)	R&D as % of output (OECD) averages)	R&D per employee	R&D per professional employee
Foreign owned firms								
Software*	N/A	33,973	404.0	N/A	681.0	N/A	1,794	N/A
Other internationally traded services*	N/A			N/A	914.0	N/A		N/A
Electronics & electrical equipment	2,967.6	18,706	111.7	137.3	281.6	1.3 (5.6)	5,130	25,808
Instruments	625.6	8,550	65.1	124.9	315.6	1.2 (7.0)	1,406	7,957
Irish-owned firms								
Software*	N/A	16,504	258.0	N/A	841.0	N/A	5,521	N/A
Other internationally traded services*	N/A			N/A	59.0	N/A		N/A
Electronics & electrical equipment	222.8	4,437	84.7	90.6	570.8	6.3 (5.6)	5,593	29,401
Instruments	31.9	719	245.5	199.1	1,030.5	5.9 (7.0)	4,343	15,480

* Export-oriented firms only

Sources: R&D data from Forfás (1999) and special tabulations; employment data for software and international services from Forfás (2000); all other data from special CSO tabulations of Census of Industrial Production data

(with ties to the telecommunications manufacturing sector), banking and finance software (with ties to financial services) and systems software (with ties to the computing sector). In examining the growth of software in Ireland, therefore, we investigate the emergence of a critically important set of capabilities within the economy, as well as an industrial sector in its own right.

The Irish software industry grew rapidly through the 1990s. The industry is divided relatively equally in employment terms between foreign and Irish-owned firms (the disparity in Table 1 is partly due to the omission of Irish-owned firms oriented primarily to the domestic market, although employment in foreign firms has grown more rapidly since 2000). The revenues (and exports) of the foreign-owned firms are much higher than those of the Irish firms. However, the revenue figures for the foreign-owned sector are inflated due to the presence of high visibility packaged software firms (such as Microsoft, Novell, Symantec, etc.) that carry out a great deal of disk duplication, packaging and software localization work in Ireland, mainly for the European market. These companies generate huge sales from their Irish operations but relatively little value is added in the Irish operation as most of the core software development takes place at the US headquarters. This is reflected in the much greater R&D spend per employee among Irish-owned firms.

The industry had seen a decade of rapid growth before the downturn of 2002–3. Among foreign-owned firms employment increased by 128% and revenues by 152% from 1991–97. Irish-owned firms' employment increased by 142% and revenues by 256% in the same period (Ó Riain, 2000). This growth intensified in the late 1990s, with indigenous firms' exports increasing by 92% and sales by 112% between 1997 and 2000 (Brezinitz, 2002) and a boom in foreign investment as Ireland became an increasingly important node for US software companies in Europe.

The Irish-owned (indigenous) industry's export orientation is similar to that of the Indian industry, although the Indian industry's exports have focused more heavily on offshore development and international labour contracting (Parthasarathy, this issue). The Irish industry is similar to the Israeli, and indeed the US, industry in its greater focus on software products and avoidance of large-scale labour contracting. However, it is less sophisticated than either of these industries, with a lower level of productivity (sales per employee) than either the Israeli or the US industry (Brezinitz, 2002).[3]

A comprehensive survey of indigenous software firms carrying out software product development found that in 2001 there were at least 250 such companies, more than half of which were set up after 1999 and more than 70% since 1996 (Hot Origin, 2001). Turnover among these firms grew at 30–40% per annum in the late 1990s. Seven Irish companies were publicly quoted in 2001 — Smartforce (ex-CBT), Iona Technologies, Baltimore Technologies, Trintech, Riverdeep, Parthus and Datalex — and these seven companies accounted for 5,000 of the sector's 11,000 employees and for half of the sector's revenues, with a combined annual turnover of IEP 500 million. Hot Origin claimed that another 30–40 companies were on the brink of reaching this level of success at this high point in the development of the industry.

When a number of these larger companies ran into serious difficulties in 2001 and 2002, the network of small and medium-sized companies beneath them became once more the motor of industry growth. The growth dynamic shifted from these large firms toward the region — and back to private companies who were less exposed to the vagaries of the financial markets. Nonetheless, employment has declined in the industry in 2002 and 2003 as the 'Big Seven' had major layoffs and a number have delisted from NASDAQ, while others have been acquired or merged.

The Irish software industry is characterized by a diversity of modes of integration into the global software industry. While some foreign-owned firms are in Ireland only

3 Brezinitz (2002) argues persuasively that this is because Irish firms support product development with services, promoted by an industrial regime which makes less capital available than in Israel, and that this in turn is shaped by the Irish state's focus on adding employment rather than the Israeli state's emphasis on improving technological capacity.

to take advantage of low tax and transfer pricing opportunities, others have established significant European production and logistics hubs — in a minority of cases supplemented by development centres. Meanwhile, and most surprisingly, a significant indigenous software industry has emerged with higher levels of R&D spending than in the foreign-owned firms. How are we to understand this partial mobility of the industry up through the niches of technology-driven commodity chains? Is it due to earlier forms of participation in TDCCs providing resources that allow for mobility, or have other forces allowed segments of the industry to escape 'lock-in' at the lower levels of TDCCs and pursue a successful strategy of mobility into the higher value-added niches within the chain?

Making the entrepot region

Full integration into the international economy has been the central plank of Irish economic policy since the early 1960s and protectionist measures were almost completely dismantled by the 1970s. When most national economies were still attempting to negotiate with and control foreign capital, the Irish state turned itself to a relatively unconditional pursuit of such investors — creating the first free trade zone in the world in 1958 (at Shannon), providing generous tax incentives and grants, a transnational-friendly environment, a young and cooperative labour force and, in the 1980s, a world-class telecommunications system. An array of financial incentives has been offered for foreign investors and exporters in Ireland over the past 40 years. The physical territory itself was also remade, particularly when the telecommunications system was upgraded in the early 1980s and pricing structured in favour of businesses dealing with international markets and against local business and residential callers.

It is not surprising, therefore, that Honohan *et al*. (1998) could argue that 'the Irish manufacturing sector contains ''invisible entrepôts'' — intangible factors arriving and leaving like cargoes through great transhipment ports'. They identify entrepot sectors as those where labour costs do not exceed 10% of output. These operations take advantage of the tax benefits of an Irish location in order to retain the highest possible share of profits on the proceeds of the intellectual work typically carried out closer to the headquarters (usually in the US) (O'Hearn, 1998). These dynamics are further intensified by the transfer pricing activities of US multinationals in Ireland (Stewart, 1989) and by the character of much high-technology industry where the costs have increasingly shifted towards the design process (primarily retained in the US) and away from the production process (which is more likely to be located in Ireland). Entrepot activities in Ireland are concentrated in the sectors of chemicals, computers, production of cola concentrate — and the reproduction of computer software. Honohan *et al*. (1998) estimate that over one-third of manufacturing output and approximately 10% of manufacturing employment is accounted for by these sectors. Parts of the software industry contribute significantly to the 'black hole' of financial flows through Ireland which generate corporate tax for the national economy but have few other economic benefits.

Despite this hollowing out of the national economy, agencies of the national state were central to attracting foreign direct investment and creating the entrepot region. The Industrial Development Authority (IDA) took on the role of 'hunter and gatherer' of FDI and became unusually powerful within the national state system (Ó Riain, 2004b). The extent of state involvement in restructuring the economy to create an attractive location is evident from the fact that by 1983 the IDA had been associated with the development of nearly one-third of the factory units developed in Dublin since 1960 and was the largest owner of industrial space in the city. Furthermore, the second and third largest owners of Dublin industrial space were a bank and an assurance company which were both owned by the state (MacLaran, 1993: 159).

The project of attracting foreign investment has resulted, therefore, not in the depoliticization of space and territory but in the hyper-politicization of the national

territory as the territory itself becomes an object of political (and particularly state) action. Reshaping the nation into location through incentives, telecommunications and regional and land-use policy has been a major strategy in the pursuit of mobile investment, a strategy which has drawn the state ever more deeply into the management of space (Brenner, 1998).

From entrepot to global hub

However, foreign-owned software firms have added significantly over time to the very basic initial operations which they set up in Ireland. Foreign-owned firms can be divided into two broad categories: firms focusing on the manufacturing, distribution and localization[4] of mass market software packages; and firms providing systems integration and software services or with dedicated software development centres. All of these subsidiaries of foreign firms face struggles in attempting to move up the hierarchy of TDCCs.

Many managers said that getting foreign firms to locate product development in Ireland, or anywhere outside the US, is 'a constant struggle'. 'It's keeping an eye on the crown jewels, they won't let them go. They are afraid of losing control, that's a big issue for them' said one Dublin engineer with extensive experience in a foreign firm. Another manager in a US firm said that while HQ might worry initially about the technical ability in Ireland, over time it becomes an issue of control: 'I don't think it's a skill thing, it's a control thing. It's a distance thing too, they can't see what's going on' (Ó Riain, 1997). Moving beyond the entrepot region was clearly not a straightforward task.

Software localization and the growth of local suppliers

Table 2 outlines the major companies involved in the manufacturing, distribution and localization of mass-market software packages in Ireland throughout the 1990s. Although many of the most prominent software publishers had extensive facilities in Ireland, their operations rarely included significant elements of software development — instead focusing on disk duplication, packaging, fulfilment, localization and porting.

Although these are the least sophisticated foreign-owned software firms, local management have been able to gradually add significantly to their operations in Ireland — starting out with disk duplication operations, typically between 1985 and 1988 for the longest established, and gradually moving into documentation and localization (1988–89). Despite this, most were not able to move significantly beyond localization — although companies such as Lotus, Oracle and Visio flirted with product modification and development.

However, these companies were the foundation of a sub-supplier sector in turnkey services and software manual printing (Jacobson and O'Sullivan, 1994). The printing industry had a pre-installed base in Ireland and was helped by the fact that the foreign firms never printed their own manuals in-house. The Irish-born managers of these foreign firms reputedly told the local printing firms 'we have the business for reprinted software manuals, it's there for you if you can get it'. These companies invested heavily in new technology and the industry grew from $9 to $135 million in 5 years from the

4 'Localization' of software refers to the process of customizing existing software packages for specific national and linguistic markets. The main activity is the translation of the text but it may also involve changing date formats, letter formats and other culture-specific aspects of the software. In US software companies the work of designing the software programme so that it can be customized in this way is called 'internationalization' and is generally carried out in the US. The work of actually customizing the programme for specific markets is called 'localization'. This work is relatively uncomplicated. Porting is the process of making software compatible with new technological platforms and operating systems and involves more genuine software development.

Table 2 Software localization and fulfilment 1992–2001

Company Name	Country of Origin	Location in Ireland	Employment 1992	Employment 1996	Employment 2001	Turnover (£m) 1992	Turnover (£m) 1996	Turnover (£m) 2001
Software publishers								
Microsoft	US	Dublin	300	875	1592	(e)60.0	(e)924.0	(e)3,534
Oracle	US	Dublin			800			1,400
Lotus	US	Dublin	250	400	664	(e)65.0	(e)130.0	(e)425.0
Creative Labs	Singapore	Dublin		240	525		(e)269.0	399.5
Symantec	US	Dublin		199	503		64.0	224.0
Sun Microsystems	US	Dublin			250			65.1
Novell	US	Dublin		70	92		310.0	400.0
Corel	Canada/US	Dublin			16			150.8
Claris	US	Dublin	65	125	0	15.0	(e)50.0	0
Borland	US	Dublin	86	90	0	57.2	45.0	0
Quarterdeck	US	Dublin		50	0		7.0	0
Printing and fulfilment companies								
BG Turnkey/Banta	Ireland/US	Cork	100	150	650	(e)5.0	(e)6.5	150.0
Dakota Group	Ireland	Dublin		322	290		19.0	(e)23.5
Saturn Fulfilment	Canada	Dublin			270			25.8
Microprint	Ireland	Dublin	90	130	100	5.6	9.0	(e)12.5
Stream International	US	Dublin	350	700		(e)18.0	37.2	
Mount Salus Press	Ireland	Dublin	120	127	*	9.0	14.4	*
Printech	Ireland	Dublin	324			19.3		

Localization companies

Berlitz	US	Dublin	220	420	(e)13.0	(e)21.0
Lionbridge	US	Dublin		160		14.0
SDL International	US	Bray		150		25.0
Havas Interactive	France	Dublin		100		47.0
JLS	US	Dublin		80		(e)14.0

* Taken over by Adare Printing Group, which in 2001 had a turnover of £213 million and employed 1,599 people in a broad range of businesses

Sources: 'Top 1,000 Companies' *Business and Finance* (1992; 1996; 2001). Note: Only companies included in the 'Top 1,000' are included in this table. Where data are not present, companies may still be operating but have not reached the turnover threshold for the 'Top 1,000'. This threshold was £1.5m in 1992, £3m in 1996 and £9.8m in 2001. Some companies' revenues will include sources other than software and care should be taken in interpreting these figures. The company name given is that used in 2001, although every effort has been made to assure a consistent series across the *Business and Finance* listings.

late 1980s, based almost totally on the demand of the foreign software firms (IDA, n.d.; Jacobson and O'Sullivan, 1994). Foreign firms were also beginning to rely increasingly on outsourcing as a strategy during the 1980s to take advantage of external economies of scale and the potential for shifting costs onto suppliers. This trend intensified over the period — for example Lotus and Microsoft, which set up in the mid-1980s, did nearly all of their own work in-house, while Oracle (set up in 1990) and Novell (1995) outsourced practically all their work and simply managed these relationships from their Dublin operations.

There were further opportunities for 'turnkey services' companies such as BG Turnkey which was set up by an ex-Apple employee across the road from Apple in Cork. These companies tended to start with very basic operations and expanded to full turnkey operations where they would take responsibility for a whole segment of the production process. As more foreign firms invested in Ireland the supplier base grew — with turnkey services growing from zero to $150 million in five years from the late 1980s (IDA, n.d.). In the localization area, a number of Irish-owned translation bureaus emerged which offered full translation services to foreign firms doing localization in Ireland. Typically, the founders of these firms had themselves worked for foreign localization subsidiaries.

Where the major market for these services, the software publishers, was almost entirely foreign owned, many of the early companies established in these sectors were Irish owned. As Ireland became established as the centre for software localization in Ireland, it attracted many of the major international firms in the software documentation and localization industry. Major firms such as Berlitz and Stream International located in Ireland by acquiring established Irish companies. By the late 1990s, the localization industry was dominated by foreign-owned firms, shifting the ownership of the industry even as Ireland became more clearly established as the territorialized centre of software localization in Europe. The Dublin region had become a 'global region' for software fulfilment and localization (see Ó Riain, 1997 for further detail).

Upgrading software services and development

Nonetheless, localization remains relatively low in the TDCC hierarchy. Systems integration and software development offered an avenue to more rewarding niches in the global information economy. Table 3 gives basic data on the leading foreign-owned firms carrying out such operations in the 1990s.

The firms in this sector generally located in Ireland to gain access to labour which was in short supply in their own country (e.g. EDS, Cambridge Technology) or have been able to build up systems integration businesses around an earlier sales (e.g. IBM) or hardware manufacturing (e.g. Amdahl) operation. In the first case, the critical factor at work was the state's creation of a skilled software labour force — 'the people' were to be moulded into a suitably attractive labour force. Educational reform resulted in increased educational participation at all levels and a reorientation towards technical education at third level, pursued through a range of new educational institutions (Clancy, 1989; Breen *et al*., 1990; Share, 1992; Osborne, 1996: 47). While in 1980 Ireland was behind most developing countries in its provision of engineers and systems analysts/programmers (O'Donnell, 1981), it moved up the ladder relatively rapidly. Between 1991 and 1994 Ireland was among the leading four or five OECD countries in percentage of university level graduates in science-related fields in the labour force, and toward the middle of the OECD distribution in percentages of graduates in mathematics, computer science and in engineering and in overall university graduation rate among the relevant age cohort (OECD, 1992; 1993; 1996). The Irish population had been dramatically reshaped over a 30-year period — although applications to science and engineering degrees dropped enormously after 2002.

This investment in education combined with international software firms' increasing need for a European base to produce growing software development investment. It is noticeable that the firms which have built up development centres or software services

Table 3 Foreign-owned companies with software development operations 1992–2001

Company Name	Country of Origin	Location in Ireland	Employment 1992	Employment 1996	Employment 2001	Turnover (£m) 1992	Turnover (£m) 1996	Turnover (£m) 2001
IBM*	US	Dublin	402	500	4,200	66.7	66.9	156.0
LM Ericsson*	Sweden	Athlone	662	1,010	1,900	52.7	86.1	260.0
Apple*	US	Cork	950	1,500	1,050	525.0	706.5	(e)600.0
Siemens	Germany	Dublin	165	151	688	50.0	48.0	170.0
Compaq/ Digital*	US	Galway	(e)850	400	535	(e)500.0	(e)270.0	330.0
Motorola	US	Cork		122	460		7.6	32.0
EDS	US	Dublin			330			24.8
Bull CARA	France	Dublin			300			73.4
Silicon & Software Systems	Netherlands	Dublin	89	155	300	4.5	8.1	30.0
Alcatel*	France	Bandon, Co. Cork	115	108	199	(e)12.5	24.0	43.0
AMT/Sybex*	UK	Dublin			175			33.5
Amdahl	US/Japan	Dublin	590	167	100	307.0*	115.0*	(e)30.0
Critical Path	US	Dublin			100			(e)11.0
Cambridge Technology Partners	US	Dublin			80			10.0
Memorex Telex*	US	Dublin	60	51	68	9.0	8.0	19.0
Avid Technology*	US	Dublin			65			127.0
Trinity Technology	UK	Dublin			60			24.0
Eicon Networks*	UK	Dublin			50			63.0

* These companies' revenues include significant sources other than software and care should be taken in interpreting these figures

Sources: 'Top 1,000 Companies' *Business and Finance* (1992; 1996; 2001). Note: Only companies included in the 'Top 1,000' are included in this table. Where data are not present, companies may still be operating but have not reached the turnover threshold for the 'Top 1,000'. This threshold was £1.5m in 1992, £3m in 1996 and £9.8m in 2001. The company name given is that used in 2001, although every effort has been made to assure a consistent series across the *Business and Finance* listings.

operations are concentrated in the computer systems and communications areas and are more diverse in their national backgrounds. Most have either built up these operations by strategically adding to an existing hardware operation (e.g. Ericsson, Siemens Nixdorf, Lucent) or entered Ireland largely through social networks and ties that went beyond simply negotiating with the IDA. Siemens Nixdorf and S3 had built up a connection to Ireland through the heavy hiring of Irish graduates in the mid-1980s (*Irish Computer*, November 1986) and in the case of S3 through the presence in the Netherlands of an Irish engineering lecturer who is the current Managing Director of S3. Critical Path took over ISOCOR whose headquarters was in Los Angeles but which maintained most of its development team in Dublin, where it was put together by one of the founders who had worked in Dublin with an earlier telecommunications software company called Retix. Motorola bought another company in the US which happened to have an operation in Cork and the local management were able to maintain and grow this facility, which became well known for its excellent quality standards.

The global hub alliance

The shift from entrepot to global hub has been driven, not by the logic of corporate commodity chains themselves, but by the mobilization of a coalition to move up the commodity chain. Central to this coalition were the (usually Irish-born) managers of foreign subsidiaries, working together with the IDA. While their position within the TDCCs enabled them to access resources, mobility within the commodity chains came as a result of managerial and state strategy rather than as an inevitable part of incorporation into TDCCs.

A significant minority of these Irish subsidiaries have been able to develop quite sophisticated operations through corporate 'intrapreneurialism'. Intrapreneurialism is easier in more diverse parent corporations. Companies such as Microsoft and Lotus concentrate on a relatively small number of strategic software packages — their software development operations are highly concentrated and the opportunities for building up capabilities around complex implementation, systems integration or sales support are limited. However, there are significantly greater opportunities in companies such as Digital, Amdahl, IBM, Siemens Nixdorf and Phillips which sell hardware and software in a variety of 'bundles' or in telecommunications companies such as Ericsson or ATT/ Lucent Technologies which have both hardware and software operations.

Successful 'intrapreneurs' among subsidiary management are able to maintain their own 'embedded autonomy' within the corporation (Evans, 1995). Limited though they are by the parent's European strategy (Coe, 1997), subsidiaries usually have some measure of autonomy as long as they follow the broad corporate strategy and maintain 'your numbers'. The Irish manager of a US firm which had built up its development functions over the years claimed: 'A high proportion of our parent's sales are in Europe; that leads to development, especially where you are dealing with customer facing technologies'. The 'regionalization' of international firms' marketing strategies between North America, Europe and Asia in recent years (Hirst and Thompson, 1992; Gereffi, 1994) has facilitated the expansion of the Irish operations.

Autonomy is only beneficial insofar as the subsidiary can also maintain the critical connections to leading customers and key executives at headquarters. One manager of a US firm had previously worked for a number of years at the company's HQ and had travelled to the US 14 times the year before. He commented on the lack of connections another Irish subsidiary had to its parent in the US: 'They are at risk now. The Irish people should be very close to the guys in the US, they should be mutually adjusting to one another. I get little surprises all the time; they are getting big surprises because they are not close to those guys'. In cases such as Amdahl and Sun, the combination of an energetic local manager with close ties to an executive in the US who is either Irish-born or has Irish ancestry helped to build up the operations of the local subsidiary.

Subsidiaries can create some space to develop their own projects. One manager in a European subsidiary of a Silicon Valley company claimed: 'When we're in Europe we

do things our own way. Local knowledge is a big plus — we had a US guy, he was a disaster, it's hard to manage in another culture. You do things your own way on the ground, you follow the corporate strategy but implement things your own way'. Local managers often see themselves as serving a project of national economic development through promoting the Irish operation and agitating for more sophisticated work for the Irish operation: 'There's a feeling that we're all in this to develop the industry in Ireland, so we help each other out by letting people over from the States visit each others' places and so on' (Irish Manager, US firm). This outlook has been prominent among Irish managers since the 1970s, emerging from the Irish management of Digital in particular.

It was further strengthened by a shift in IDA focus in the 1980s to pressuring and supporting managers in foreign hardware and telecommunications firms to upgrade their operations, often by expanding into software (*Irish Computer*, April 1985). The IDA plays a central role as the 'one stop shop' for foreign-owned firms in Ireland. It has become a significant property owner and acted unofficially to facilitate the foreign firms. One Vice President I interviewed in Silicon Valley pointed to a picture of the Irish facility of his company in an industrial park on the outskirts of Dublin: 'We will need to expand soon and you see that piece of empty land behind our place, we haven't bought it yet but the IDA is holding it for us in case we do need to expand there'.

The state also played a key role in supporting the growth of sub-supplier industries, such as printing and logistics, particularly by providing finance and advice to the entrepreneurs in these newly minted sectors and by coordinating relations among Irish-born managers of foreign firms and these emerging firms. Printing firms, for example, received significant funding from the IDA for the expensive new web print technologies required for software manual printing (Jacobson and O'Sullivan, 1994).

It would seem, then, that the majority of companies which enter the country almost exclusively through negotiations with the state and which are unable to add development functions to their operation contribute much in the way of employment but little to the development of a learning industry and region. There is therefore strong evidence that TDCCs do exert pressures towards 'lock-in' at lower levels of the technology hierarchy. However, a significant minority of companies did contribute to the creation of a learning region as they add strategically to their existing operations or are able to carve out a space within their corporate parent which allows for an upgrading of the functions within the Irish operation. Although constrained by corporate decisions largely out of their control, these subsidiaries have been able to slowly inch their way further up the hierarchy of the TDCCs in which they are embedded, supported in many cases by state agencies.

Indigenous innovation within global networks

However, the emergence of a strong indigenous Irish-owned software sector in the 1990s cannot be explained by this dynamic of state-supported 'intrapreneurialism'. O'Gorman *et al*. find that one-third of the indigenous software entrepreneurs whom they interviewed in 1997 had worked in a foreign firm directly before starting their own company — both in foreign firms in the IT sector and in the IT sections of foreign firms in other sectors (1997: 35). Another third or so had come directly from indigenous software firms while the final third had come from indigenous firms in other sectors, most notably software distribution and computer hardware. Foreign firms provide a significant stimulus to indigenous firms. However, direct spin-offs of indigenous firms from foreign software firms were relatively rare: the dynamic of generating new companies is strongest in the indigenous sector, therefore, and especially within the software industry itself. In the boom years of the late 1990s, start-ups emerged primarily from the leading indigenous software firms (Hot Origin, 2001).

Leaving aside the direct sources of start-ups, two-thirds of indigenous entrepreneurs had worked for a foreign firm in Ireland at some stage of their careers, half had worked abroad in software or a related sector and half had worked in a sector that was now a customer of their firm (O'Gorman *et al*., 1997: 35; for a similar dynamic in the early 1980s see Cogan and Onyenadum, 1981; Onyenadum and Tomlin, 1984a; 1984b). Working on systems integration or custom software development projects has the potential to provide a number of skills which are useful to development more generally. Most basic is the chance to get some experience working on particular platforms or languages — for example, IBM provides experience on AS400 and other IBM platforms, ICL focuses on Unix, Amdahl uses a variety of object-oriented approaches and so on. Such skills mean that employees of these companies are potential candidates for moving into key development roles in other companies. Furthermore, depending on the company, there may be an opportunity for developing project management skills — an area which EDS, for example, claims is a competency of its remote software engineering centre (Coe, 1997; *IT's Monday*, 12 January 1998).

However, while this international and foreign firm experience is important, it cannot explain why these firms were able to grow in the 1990s where similar firms had failed in the late 1980s, especially given that experience in foreign firms was not important to most of the founders of the major indigenous firms of the 1990s. The growth dynamics of the indigenous sector were not generated from within the foreign-owned sector but occurred at a tangent to it.

The earliest indigenous software firms focused either on services (GC McKeown, Core) or made a transition to product development based on connections with large international customers located in Ireland (Kindle, Insight). By 2001, however, a new generation of firms, created under quite different circumstances, was more significant. These firms were rooted in state investments in education and telecommunications as well as being able to draw on state resources to help them mobilize a combination of global and local resources. Table 4 provides employment and revenue information for the leading indigenous companies in the 1990s.[5]

Once again, the dynamics of TDCCs themselves do not generate mobility within the commodity chain. Instead, we must turn again to a socio-political alliance that mobilized to enter a new niche in the TDCC — that of indigenous innovation. A certain amount of political space emerged in the crisis of the 1980s for new institutional projects and state-society alliances. A little recognized but highly significant alliance between science and technology-oriented state agencies, technical professionals and university constituencies emerged which supported the deepening of technical capabilities and collective learning across the Irish economy. This process was underpinned by the state as state agencies, through their participation in this alliance, defined general priorities, provided finance and institutional supports and legitimated this agenda. These state agencies played a central role in upgrading industry and deepening Ireland's production and innovation capabilities in the 1990s, and were themselves rewarded with a greater legitimation of their own position within the state system — although they were never able to overcome the dominance of the IDA-led emphasis on foreign investment. The emergence of this alliance, embedded in both the global and the local and mobilizing resources from each, is the decisive feature which explains the upgrading in Irish technological and organizational capabilities in the 1990s (Ó Riain, 2004b).

Elements of the state had already played a central part in transforming the education system, leading to a reasonable supply of skilled labour. Furthermore, a reserve of emigrant professionals waited for opportunities to return, doing so in large numbers from the mid-1990s. In the years around and after the Telesis report, the state began to pursue a wider range of industrial development strategies. New sectors had been added to the list of target sectors — most important of which were software and financial services. State agencies also acted to support emerging indigenous industry and to

5 Riverdeep is not included in the *Business and Finance* listings, presumably because it is based in large part in the US.

Table 4 Leading indigenous software companies 1992–2001

Company Name	Location in Ireland	Employment			Turnover (£m)		
		1992	1996	2001	1992	1996	2001
Iona Technologies	Dublin			740			82.9
Trintech*	Dublin		55	600		4.9	23.6
Smartforce	Dublin	34	190	500	3.2	13.6	160.5
Baltimore	Dublin			480			29.6
Kindle	Dublin	200	300	465	12.0	23.5	50.7
Datalex	Dublin			450			28.1
Fineos	Dublin			250			10.5
Mentec*	Dublin	170	185	210	15.6	18.6	22.4
MV Technology	Dublin			150			(e)25.0
GC McKeown	Dublin	120	125		4.6	7.3	
Core Computer Consultants	Cork	50	50		5.7	(e)3.5	
Insight	Dublin	68			2.3		

* These companies' revenues include significant sources other than software and care should be taken in interpreting these figures

Sources: "Top 1,000 Companies" *Business and Finance* (1992; 1996; 2001). Note: Only companies included in the 'Top 1000' are included in this table. Where data are not present, companies may still be operating but have not reached the turnover threshold for the 'Top 1000'. This threshold was £1.5m in 1992, £3m in 1996 and £9.8m in 2001. The company name given is that used in 2001, although every effort has been made to assure a consistent series across the *Business and Finance* listings.

upgrade the national system of innovation in three major ways (Ó Riain, 2000; 2004b). By defining the character of industrial strategies, implementing company development through grant aid and creating an associational infrastructure for innovation, the state has been able to contribute handsomely in the 1990s to the development of indigenous industry and the upgrading of the national system of innovation more generally.

Firstly, it acted to define the types of involvement in the international economy which would be supported. The IDA provided valuable investment and other support in particular sub-supply sectors, such as software manual printing (Jacobson and O'Sullivan, 1994) and electronics. More importantly, state agencies emphasized technology-related exporting in their support of indigenous firms. In industries such as software design, the state development agencies focused grant aid almost completely on companies producing software products for export — attempting to steer companies away from the 'easy' profits of labour contracting. The state acted in important ways, therefore, to define the character of Irish industry, without attempting to define the specific strategies to be followed by firms.

However, the state has also made more direct contributions. Its second contribution was to 'making winners'. Private capital was not a major factor in the growth of Irish industry and it is only since 1998 that private investment capital, from both domestic and foreign sources, has become abundant even in leading sectors such as software. The state was therefore the major provider of external capital to indigenous industry. Furthermore, state agencies promoted a general company development programme through their grant giving practices in a variety of areas including marketing, management development, training and R&D. Grant giving became more selective, as recommended by the Culliton Report (1992), and state agencies 'seeded' venture capital funds. The precise form this took was quite flexible depending on the company itself but the state agencies required that such efforts at company development take place (for statistical evidence on the effectiveness of state grant aid see O'Malley *et al*., 1992; Ó Riain, 2004b).

Thirdly, the state played a critical role in the creation of a network of industry and trade associations, universities, innovation and technology centres and other fora and groups which provide an associational infrastructure for information-sharing, cooperation and innovation. While these bodies are outside the state or semi-autonomous from it, in most cases they have been founded through state initiatives and underwritten by state guarantees and funding. Nonetheless, they form a distinct layer of institutional spaces and social networks between the state agencies and the companies in the industry. A diffuse state influence throughout the industry is built into the organizational structure of the institutions. These institutions are typically located within the universities, staffed by academics and industry people, usually have advisory boards containing industry, academic and state representatives, and have extensive ties to industry through consulting, information days and other activities undertaken at least partly for funding purposes. In many ways, these associations and networks perform some of the integrative functions carried out within the corporation in vertically integrated, large firms.

Taking a closer look at the development of the leading indigenous firms points up the increasingly critical role of the state in promoting the embedding of the regional software industry. The state had undertaken large investments in third-level education and telecommunications in order to attract foreign investment. However, these investments had the largely unexpected consequences of contributing to the growth of the indigenous industry. As the 1980s ended, the computer science departments in the universities had been firmly established for a number of years and were beginning to branch out in terms of their research. A number of schemes were put in place to encourage academics to commercialize their research. Since the mid-1980s, firms were emerging in systems software and/or development tools, heavily technology-oriented areas which sell mainly to the software development community itself. This subsector came into its own in the early 1990s as the growing computer science and engineering disciplines within the universities became increasingly established and innovative, assisted by programmes to upgrade research capabilities in the universities.

Trintech was founded in 1987 by two brothers who parlayed a final year undergraduate research project at Trinity College Dublin into a company which initially developed payment software for off-line credit card transactions. Supported by employment and R&D grant aid from the IDA, Trintech grew, and by the late 1990s was a leader in its field of payment software, going public in the US and Germany in 1999. By 1999 Enterprise Ireland had spent 909,000 Irish pounds acquiring equity in Trintech — a significant proportion of which was taken well before the external funding which Trintech received in the mid-1990s. Just before its initial public offering in 1999, Enterprise Ireland held 7.6% of Trintech's shares and had a representative on the company's board. Trintech's path to global success took the road of export success and international alliances, certainly, but was rooted in the education system and in state support — particularly early in its existence.

Iona Technologies and Baltimore Technologies also emerged from the education system but with a greater emphasis on sustained research through European programmes. Both had drawn heavily on EU programmes to support their research efforts — Baltimore as a private company since 1976 and Iona in its existence as a research group at Trinity College in the 1980s before incorporating as a company in 1991. Academics were leading figures in both, with faculty members from the Departments of Maths and Computer Science at Trinity as their first Managing Directors. Baltimore was transformed from a 'research house' on cryptography to an initially successful commercial company focused on internet security when it was purchased by an Irish investment house in 1997. The state continued to play a role in supporting Baltimore, however, with funding for marketing and R&D. Indeed, when Baltimore ran into commercial trouble it appeared in part to be due to financially-driven acquisitions and its overexposure to financial markets.

Iona Technologies was founded by a number of lecturers from the Computer Science department in Trinity College Dublin. A group of researchers in Trinity had been active

in a variety of European Community research projects through the ESPRIT programme from 1984 to 1989, growing until they had a team of 25 staff by 1988. These projects had focused on what was called 'distributed computing', part of the open systems revolution in computing. The Trinity group got a further boost when the National Board for Science and Technology named distributed computing as one of the technologies whose development they wished to support within their software programme. In 1989 the Trinity researchers became members of the newly founded Object Management Group, a body based in the US and dominated by the major computing companies (except Microsoft) who were trying to establish an open systems standard for sharing 'software objects' across different platforms. When this CORBA standard was established in 1990, Iona moved quickly to commercialize its research. With equity and other support provided by IDA Ireland, Iona established a significant presence in the US in 1991, and was able to gain essential external funding from Sun Microsystems. Iona emerged, then, from a technical community rooted in a university, supported by state agencies, but also drawing on European Union and international technology consortia as resources — the local basis of the firm was forged within the global with state support.

In addition to educational investment, the early 1980s saw the upgrading of the telecommunications system, including a commitment to digitize the system and use the latest communications technology available. This decision was taken with a view to providing the infrastructure for participation in the global economy, but limited efforts were also made to build industrial development criteria into the lucrative contracts for the telecommunications system itself. The National Board for Science and Technology (1980) argued that there should be a requirement for the major contractors for the system to locate in Ireland, and Alcatel and Ericsson were required to manufacture their switching hardware in Ireland. Ericsson in particular became a foundation stone of the telecommunications software sector in Ireland, managing to move successfully into the software side of the business through clever corporate 'intrapreneurialism' and also providing a helping hand to others in the industry. Other multinationals such as ATT (now Lucent) and Motorola played significant roles also, although not as heavily involved in the telecommunications system upgrading. Communications software is one of the areas in the Irish software industry where foreign firms made their strongest contribution.

The indigenous communications software industry emerged indirectly out of this era. Jim Mountjoy, who had done a PhD in telecommunications engineering, worked for the Department of Posts and Telegraphs and the National Board for Science and Technology before becoming Managing Director of Baltimore Technologies in 1984. In 1990, Mountjoy went on to found a specialized telecommunications software services company called Euristix, which became a leading firm in the indigenous communications software sector in the 1990s. Another major indigenous firm was Aldiscon, founded by Jay Murray, owner of the company which had the main contract for laying telephone cables for the new telecommunications system in the early 1980s. Seeing that the cable laying business had a limited future, Murray founded Aldiscon in 1988 to create software applications for telecommunications systems. With relatively little technical background himself he hired the leading technical and management staff in from the open market, the majority being Irish people returning from working abroad. These companies provided the foundation for a growing telecommunications industry. Once again, the focus of the state on upgrading for international investment had resulted in unintended beneficial consequences for indigenous industry.

Smartforce had its origins in the early 1980s when a number of computer-based training, or 'courseware' companies were founded. AnCO, the state industrial training board, was very active in using courseware, developing courseware products and running courses which would provide the specific skills needed in the courseware sector. Smartforce, then CBT Systems, received consistent (albeit limited) state financial support through its chequered early history.

Datalex provides a different example of a 1980s firm. Founded in 1985 by people with a background in the airline industry and in IT, Datalex grew steadily by developing

mainframe-based niche applications which could link travel agents and airline computer systems. In 1998 it refocused its business on internet applications for the travel industry, acquiring 10 other companies with backing from a local investment house and from Enterprise Ireland (which had taken half a million Irish pounds in equity by 2000).

Parthus Technologies is involved in the design of IC chips and is the only one of the seven to have significant origins in a multinational subsidiary. When Digital Equipment Corporation laid off 800 workers in its Galway computer hardware operations, the IDA provided support for those laid off and encouraged many of the technical staff to start up their own companies — providing financial and mentoring support as well as a small 'incubator centre' where many ex-Digital staff located their start-ups. One of these was Parthus, then SSD, founded by a one-time Digital engineer. Much of Parthus' early funding came from the state agencies, including support through equity and grants for capital equipment. Fineos too received substantial state support, Enterprise Ireland holding about 10% of its equity in 2001.

By the end of the 1990s, each of these companies had become an important international actor within their industry. Each was involved in a range of international alliances, was listed on one or more international stock exchanges and had undertaken a variety of acquisitions and/or mergers. Each had a range of international marketing and development offices and many are co-headquartered in the US and Ireland. But each also had its origins in a particular local technical culture which in many cases was itself underwritten by the state. Early CBT industry initiatives were supported by the IDA, government training agencies and the export board. Support for research in the universities came largely through the EU, mediated by a small but supportive group of industrial development agency officials. Digital's operations in Galway were heavily supported by state grants and incentives. But the state was also vital to the process through which these firms navigated from these local communities to the status of Irish transnational firm. Having taken significant equity in these firms, Enterprise Ireland realized 25 million IEP on the sale of shareholdings in 1998 and 50 million IEP in 1999. The bulk of this return — which made the state development agencies into a profit-making entity — was realized through investments in Iona, Trintech and Parthus. We find in the case of the seven leading software companies a state-mediated process of building upon embeddedness in local technical communities to create successful transnational firms, which remained embedded in Ireland despite expanding internationally.[6] However, as these firms grew and became more integrated into international financial and equity markets they became more exposed to international markets for governance and, despite their continuing embeddedness in local technical communities, suffered when the dot.com bust hit the industry in 2002.

Conclusion

Both the boosters and the critics of integration into global production networks are correct. As the boosters suggest, these networks do provide potential channels of access to resources for industrial development. However, the critics are correct to point out that access to these resources occurs within an often hierarchical structure within the network that tends to lock industrializing regions into less valuable niches within the network. Both perspectives, however, neglect the role of politics and developmental coalitions in shaping the extent to which industrializing regions can create strategies for mobilizing resources while avoiding complete 'lock in' at lower levels of the hierarchy. The dilemma of participation in global production networks is that participation is

6 This continuing embeddedness in Ireland is secured largely through the dependence of these firms on their 'human capital', or the technical communities in which they are embedded — unlike the manufacturing firms of South Korea, for example, which have rapidly shifted production out of Korea using their large capital reserves. I am indebted to Peter Evans for this point.

necessary to access critical technological resources, but that the structure of the networks themselves makes access to those resources difficult. Public policy and socio-political coalitions for development can mobilize to work around and through these structures, however, so that new niches within the network can be established.

In Irish software, technology-driven commodity chains have provided a structure of opportunity and constraint faced by both Irish managers of subsidiaries of foreign firms and by Irish entrepreneurs. The 'global commodity chain' concept is therefore valuable in helping to map these structures of opportunity and constraint, and this article has extended the concept to suggest that commodity chains can be driven by technology, in addition to those driven by producers and buyers (Gereffi, 1994). However, an analysis of the structure of global commodity chains is less useful in explaining how particular regions are able to pursue different mobility strategies within the commodity chain. In order to explain the intrapreneurialism of some Irish managers of foreign subsidiaries and the entrepreneurialism of Irish-owned software firms, we have had to turn to an analysis of the role of different developmental coalitions formed out of fractions of business and the state (Ó Riain, 2004b). These developmental coalitions, where they emerged, mobilized resources from within TDCCs but were able to reshape those resources into different organizational strategies that ultimately enabled a degree of mobility within the TDCCs themselves. Neoliberal cutbacks in the systems of education and innovation in recent years have begun to undermine the very developmental coalitions that were the basis of the industrial upgrading that did take place in the 1990s (Ó Riain, 2004c). Even in an era of neoliberal marketization, the fate of high technology regions remains as much a socio-political question as it is a socio-economic one.

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