Journal of the Statistical and Social Inquiry Society of Ireland
Vol. XXXI

THE COMPUTER SECTOR IN IRISH MANUFACTURING: PAST TRIUMPHS, PRESENT STRAINS, FUTURE CHALLENGES

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(read before the Society, 15 November 2001)

Abstract: The health of the computer sector has come to symbolise the modernisation and rapid growth of the Irish economy during the 1990s. Any threats to its sustainability strike at the heart of broader economic and industrial strategy. After a brief statistical overview, this paper examines the wider strategic factors that facilitated the rise of the Irish computer "agglomeration". It describes how domestic policy evolved within a series of coherent frameworks that took account of the nature of the external environment (opportunities and threats) as well as realistic views of domestic capabilities (strengths and weaknesses). Within these frameworks, the decisions of individual policymakers shaped an industrial strategy that took decades to bear fruit and was a key contribution to bringing about convergence to EU standards of living. The paper also explores the likely future of the Irish computer sector, as it attempts to deal with an unfolding recession that started in the United States, the source of almost all high technology inward investment, but threatens to spread to Europe and elsewhere, key destinations of Irish computer-related exports. When the recession passes, the paper suggests that the Irish computer sector is unlikely simply to pick up where it left off in the buoyant latter part of the year 2000, but will undergo fundamental evolution and change in order to meet new global technological and economic challenges.

Keywords: computer sector, industrial strategy, global relocation, market saturation.
JEL Classification: L63, L86, 033.

1. INTRODUCTION

Present concerns about the robustness of the computer sub-sector of Irish manufacturing are caused in part by its large size, supporting, as it does, about 25,000 jobs directly (over 10 per cent of total manufacturing employment) and a similar number of jobs in associated manufacturing and software activities.[1] In addition, from a longer term perspective there is a perception that above all others, it has come to symbolise the modernisation and rapid growth of the economy during the 1990s. Any threat to the computer sub-sector is correctly perceived as a threat that strikes at the heart of industrial and economic strategy in the wider Irish economy.

In the autumn of 2001, hardly a week passes without gloomy news about another electronics plant downsizing its labour force or closing. Reports in the popular media have tended to concentrate on the immediate human costs of such actions, with the accompanying uncertainty about re-employment elsewhere in the economy and collateral disruption to family life. However, in this paper I wish to probe deeper into the background issues involved. It is my contention that there is more going on here than a simple contraction in demand arising as a result of a transient global recession. However important the demand-side factors may be, there are additional supply-side and technological factors that have begun to affect the Irish computer industry adversely, and these underlying strategic concerns need to be better understood.

We start in Section 2 with a description of the structure of the Irish computer sector, making use of data from the Census of Industrial Production for 1998, the latest available year. This data source has the advantage of facilitating the analysis of such issues as the growth of the sector, its relative size, how its characteristics differ from those of the rest of Irish manufacturing, and some of its interactions with the rest of the economy. Many other data sources could be drawn on to shed more detailed light on the computer sector. However, in order to probe deeper into its future prospects, it may be more useful to move beyond examination of data and explore how Irish industrial strategy, from the late 1960s onwards, facilitated the targeting and build-up of a presence in computer and software activity that eventually became large even in a global context.

In Section 3 we examine how small states like Ireland go about designing industrial strategy that takes into account their limited policy autonomy, as they attempt to stimulate indigenous industry and/or or attract foreign industries – such as computers and pharmaceuticals – which have highly desirable attributes. More specifically, in Section 4 we describe three particular policy frameworks that appear to have been influential in Irish industrial strategy and to have guided Irish policymakers since the 1960s, both explicitly and subliminally. In chronological order, these are the product life cycle theory of foreign direct investment (due to Raymond Vernon); the diamond of competitive advantage (due to Michael Porter) and, more recently, the capabilities and innovation perspective (due to Michael Best).[2]

Even with intelligent use, and sometimes inspired anticipation of these three policy frameworks, there was nothing automatic or preordained about the successful systematic build-up of the computer sector in Ireland. A better understanding of the strains that the sector is now experiencing is enhanced by an appreciation of how individual policymakers shaped an industrial strategy that took decades to bear fruit and was a key contribution to bringing about explosive growth, almost full employment, and catch up to average EU levels of income per head. In Section 5 we briefly review this more human side of the story.

Finally, we speculate on the future of the computer sector as it attempts to deal with an unfolding recession that started in the United States, the source of almost all inward investment in the Irish computer sector, but threatens to spread to Europe and elsewhere, the destinations of most Irish high technology exports. When the recession passes, we suggest that the Irish computer sector is unlikely simply to pick up where it left off in the buoyant latter part of the year 2000, but will need to undergo fundamental change in order to meet new technological and economic challenges.

2. KEY CHARACTERISTICS OF THE IRISH COMPUTER SECTOR

In a large economy like the USA, Japan or Germany, one expects to find most manufacturing sectors broadly represented in what one might call the economy's sectoral portfolio. In small open economies such as Ireland however, producers need to specialise in a narrow range of products, sell in highly competitive export markets, and consumers as well as producers import the goods not produced at home.[3] Based on the latest available Census of Industrial Production data for the year 1998, Ireland's manufacturing portfolio is shown in Table 1 (overleaf), where the two digit NACE sectors are ranked in descending order of their share of gross output.

Some key characteristics of the Irish manufacturing portfolio in the year 1998 stand out:

1. Electrical and Optical Equipment (NACE 30-33) is the predominant sector in terms of gross output share (29 per cent), and in terms of employment share (25 per cent). This sector experienced a high average real output growth of about 16 per cent per year over the seven year period 1991-98.

2. Chemicals (including pharmaceuticals) and Man-Made Fibres (NACE 24) has the second largest output share (24 per cent), but a lower employment share (9 per cent), since it is capital intensive and displays high labour productivity. This sector also experienced very high output growth (about 24 per cent per year in real terms over 1991-98).

3. Food Products, Beverages and Tobacco (NACE 15-16) is the third largest sector in terms of output share (21.4 per cent), with a similar employment share (19 per cent). However, average annual real output growth was relatively modest (about 5.5 per cent per year over 1991-98).

4. The only other sector with a double digit output share is Pulp, Paper and Paper Products, Publishing and Printing (NACE 21-22)), with output share of 10.4 per cent and employment share of 9.6 per cent. This is also a high growth sector (14.5 per cent per year for real output over 1991-98).[4]

5. For all the other sectors, output shares are very small, ranging from a high of 2.7 (Basic Metals and Fabricated Metal Products, NACE 27-28) to a low of 1 per cent (Wood and wood products, NACE 20), with real output growth rates considerably lower than the manufacturing average of 14 per cent per year.

In summary, Irish manufacturing is very heavily concentrated into a few sub-sectors. In the latter part of the 1990s, the predominant specialisation is in two high growth, high technology sectors (Electrical and Optical Equipment, NACE 30-33; Chemicals, Chemical Products and Man-made Fibres, NACE 24) and one traditional, fairly capital intensive, slow growth sector (Food Products, Beverages and Tobacco, NACE 15-16). These three sectoral groupings account for 74 per cent of gross output and 53 per cent of employment in total manufacturing. Although the remaining sectoral groupings in manufacturing have a low output share (26 per cent), they are more labour intensive and account for 47 per cent of employment.

Table 1: Sectoral portfolio in Irish manufacturing: 1998

	Gross Output 1998 (£ million)	Gross Output Share 1998 (%)	Gross Output 1991 (£million)	Average Annual Real Growth Rate 1991-98	Employment Numbers 1998	Employment Share 1998 (%)
Electrical & Optical Equipment	13831	28.6	3848	16.3	59830	24.6
Chemicals & Man-made Fibres	11728	24.2	2685	24.1	21432	8.8
Food, Drink & Tobacco	10381	21.4	7807	5.4	46286	19.1
Paper & Printing	5018	10.4	1645	14.5	23237	9.6
Basic Metals & Fabricated Metal Prods	1301	2.7	869	1.7	14920	6.1
Other Machinery & Equip	1196	2.5	732	8	14352	5.9
Other Manufacturing n.e.s.	1207	2.5	771	5.1	12164	5
Other Non-Metallic Mineral Products	917	1.9	582	8.2	9947	4.1
Rubber & Plastics	855	1.8	515	4.1	10516	4.3
Textiles, Clothing & Leather	777	1.6	808	-2.7	15620	6.4
Transport Equipment	749	1.5	4.6	5.3	9286	3.8
Wood & Wood Products	469	1	230	6.7	5092	2.1
TOTAL	**48429**	**100**	**20127**	**13.9**	**242772**	**100**

Source: *Census of Industrial Production* (1991 and 1998).

The main interest in this paper is in the computer industry, broadly defined. This is primarily a sub-sector of the manufacture of Electrical and Optical Equipment – NACE 30-33, and is shown in Table 2.

Table 2: NACE 30-33 – Manufacture of electrical and optical equipment, 1998

NACE code	Description	Gross output 1998 (IR£ million)	Employment Nos 1998
30	Office machinery & computers	8,510	16,049
31	Electrical machinery & apparatus n.e.c.	1,309	14,607
32	Radio, television, communication equip & apparatus	2,505	13,384
33	Medical, precision & optical instruments, watches and clocks	1,506	15,790
30-33	Electrical & optical equip	13,831	59,830

Source: *Census of Industrial Production* (1998).

Using only the CIP data, the closest one can get to isolating the core computer sub-sector, consisting of computer assembly and electronic components, is to combine NACE 3002 (Computers) with NACE 3210 (Electronic Components), and this is shown in Table 3.[5]

Table 3: The core computer and component manufacturing sub-sector

NACE code	Description	Gross output 1998 (IR£ million)	Employment Nos 1998
3002	Computers & other information processing equipment	8,496	15,822
3210	Electronic components	1,603	8,667
Total	Computers and electronic components	10,099	24,489

Source: *Census of Industrial Production* (1998).

Narrowing the focus to NACE 3002 (Computers), it is of interest to compare the characteristics of the core computer manufacturing sub-sector with the Electronic Components sub-sector (NACE 3210) as well as with the wider high technology sector (Electrical and Optical Equipment, NACE 30-33), and the other two

dominant sectors in the Irish manufacturing portfolio (Chemicals and Pharmaceuticals, NACE 24; Food, Drink and Tobacco, NACE 15-16). This is shown in Table 4.

Table 4: Comparative characteristics of computer sub-sector (NACE 3002) – 1998

NACE	Description	GO /LU million	NO /LU million	E /LU nos	W/E thous	W /IW thous	GO/E thous	NO/E thous	WB %NO	NO %GO
3002	Computers	116.4	34.9	217	19.7	17.1	537	161.1	12.3	30
3210	ElComponent	59.4	31.7	321	19.4	14.7	185	98.9	19.6	53.5
30-33	El & Opt	30.5	11.4	132	18.2	14.8	231.2	86.3	21.1	37.3
24	Chem&Phar	48.5	39.2	89	23	20.5	547.5	442.6	5.2	80.9
15-16	FDT	12.8	5.5	57	17	14.7	224.3	96.8	17.4	43.2
15-37	TotManu	10.3	5.6	52	17.6	15.1	199.5	109.2	16	54.7

Source: *Census of Industrial Production* (1998) – notation explained below.

If one measures size in terms of gross output per local unit or plant (**GO/LU** in Table 4), then the average plant size in NACE 3002 (Computers) at £116.4 million is double that of NACE 3210 (Electronic components) and 380 per cent larger than the average plant size in NACE 30-33 (Electrical and optical equipment). If one measures size in terms of numbers engaged per local unit (E/LU), then the average size in the computer sub-sector is only two thirds of the electronic components sub-sector, but is 164 per cent larger than in Electrical and Optical Equipment. However, average size (regardless of how measured) in NACE 30-33 is already much larger than for total manufacturing (by 300 per cent for gross output and by 250 per cent for employment). The computer sub-sector appears to be made up of a few very large plants amongst a number of much smaller plants.

The average wage per employee (**W/E**) in NACE 3002 (at £19,700) is not the highest of all manufacturing sectors.[6] But it is marginally above the average in Electronic Components (at £19,377) and the wider Electrical and Optical sector (at £18,210), and more than £2,000 higher than the average for all manufacturing (at £17,611). Clearly, there is a core of very well qualified and highly paid workers in the computer sector, and these tend to pull up the average. A more significant differential, however, opens up between NACE 3002 and the rest when one narrows the employment category down to industrial workers. Here, the average wage per industrial worker (**W/IW**) is £17,092 in NACE 3002, compared with £14,735 in NACE 3210; £14,795 in NACE 30-33; and £15,053 in all manufacturing. This suggests that the attractiveness of the computer sub-sector (NACE 3002) is that a

group of highly skilled scientific and technical employees can earn very high incomes, but in addition that industrial workers are paid (on average) a differential of almost 15 per cent over other sectors.

Examination of productivity measures also points to the singular nature of NACE 3002 (Computers). Gross output per employee (**GO/E**) is £536,968 in NACE 3002, and is over 230 per cent higher than in the wider high technology NACE 30-33 sector and 275 per cent higher than in all manufacturing. Productivity differentials measured in terms of net output per employee (**NO/E**) are lower (187 per cent and 151 per cent, respectively), since net output as a percentage of gross output (**NO%GO**) is rather low in NACE 3002 (30 per cent, compared to a manufacturing average of 54.7 per cent).

Two other aspects of the computer and high technology sector are noteworthy. First, Table 5 shows employment in NACE 30-33 and all manufacturing, broken down by ownership.[7] Ownership in the broad high technology sector (NACE 30-33) is concentrated predominantly in US hands. The US share is 59 per cent, and when added to the Irish share makes up 78 per cent of the total. In total manufacturing, US owned plants make up 27 per cent of employment.

Table 5: Ownership and employment in manufacturing

Ownership	NACE 30-33	All Manufacturing
USA	35,297	66,018
Irish	11,453	127,529
Other EU	4,911	14,444
Other non-EU	4,477	12,557
Germany	2,627	10,400
United Kingdom	1,065	11,824
Total	59,830	242,772

Source: *Census of Industrial Production* (1998).

Finally, Table 6 shows data on the fraction of material inputs that are imported and the destination of output that is exported.

Table 6: Material inputs and export destinations

NACE Sector	% materials imported	% distribution of output exported			
		UK	Other EU	USA	Elsewhere
30-33	55.9	20.4	45.7	18.2	15.7
30	43.6	20.6	51.3	11.9	16.2
31	77.6	17.8	54.3	20.9	7
32	85.8	24.8	21.9	42.9	10.3
33	73.7	14.2	46.3	10.8	28.7
All M'facturing	46.5	20.7	46	13.5	19.8

Source: *Census of Industrial Production* (1998).

Although the characteristics of the computer element of NACE 30 (i.e. NACE 3002) are not separately identified in the CIP, computers make up most of NACE 30. It is interesting to note that businesses in the NACE 30 sector import a percentage of material inputs that is lower than in NACE 30-33 (by 12.3 percentage points) and lower than the average for total manufacturing (by 2.9 percentage points). At first sight, this appears to offer a crude measure of the fact that a significant element of the component parts of computers are now manufactured in Ireland. However, if one looks at NACE 32, which includes electronic components, one sees that almost 86 percent of inputs are imported. So, although the supply chain of computer assembly (NACE 3002) is located to a considerable extent within Ireland, the supply chains of component manufacturers (NACE 3210) are spread over the globe. Another interesting pattern is that 43 per cent of output of NACE 32 (electronic components) is exported to the USA, but only 12 per cent of NACE 30 (computers and office machinery).

To summarise, the computer sector in Ireland is by no means a homogeneous entity. There are two main categories: computer assembly (NACE 3002) and the manufacture of electronic and computer components (NACE 3210). Within the computer assembly sub-sector, one finds a mixture of technologies and processes, ranging from simple assembly operations to the sophisticated integrated assembly and direct sales operations that are a unique feature of Dell.[8] Within the electronic components sub-sector one finds the manufacture of state-of-the-art micro-chip processors (Intel being the largest and most sophisticated), computer peripherals (disk drives, printers, etc.), and simpler electronic components.

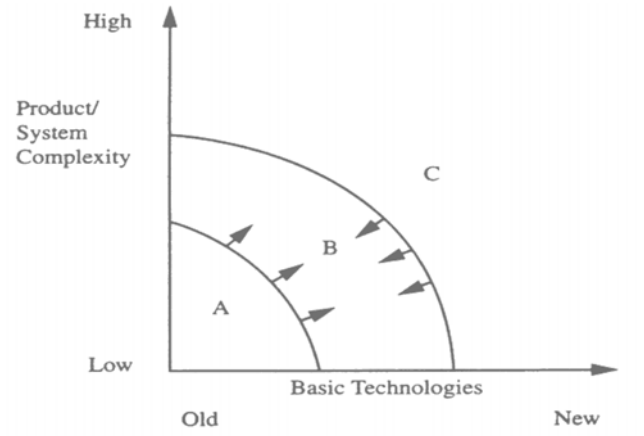
The high technology sector, in particular computers and electronic components, is predominantly foreign owned. Hence, the forces that drive innovation in products and manufacturing processes tend to originate in the USA rather than in Ireland. It is this feature that presents the most serious threat to the survival and progress of the

sector. However, to explore further the policy implications of these issues for the future of the Irish computer sector requires us to step back from data to consider some broader aspects of Irish industrial strategy that brought about the Irish electronics and software agglomeration.

3. BACKGROUND TO IRISH INDUSTRIAL STRATEGY

An important reason why groups of nations tend to adopt similar industrial strategies arises from basic similarities in their size and their stages of development. Ireland belongs to a group of smaller industrialised nations, in particular the smaller EU member states, whose main characteristic is that their domestic markets are too small to permit a competitive strategy based on scale economies and cost reductions other than in highly selective niche sectors. Kotler *et al*. (1997) characterise their strategic dilemma as "the small-country squeeze", illustrated in Figure 1 below:

Figure 1: The small-country squeeze



Source: Kotler *et al*. (1997).

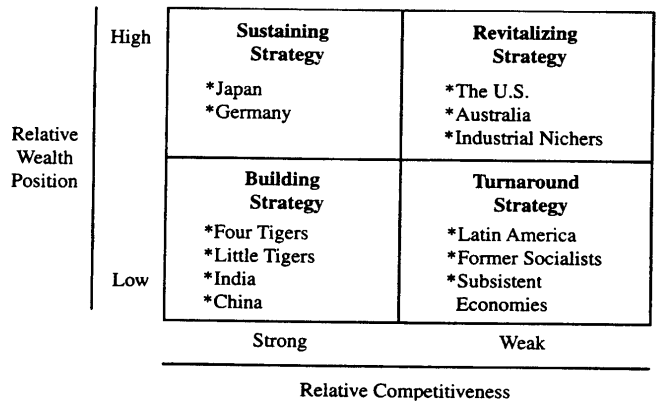
1. They are subject to fierce competition in simple products based on mature technologies from the newly industrialised countries (NICS) of Asia (area A of Figure 1).

2. Their indigenous manufacturing is effectively excluded from markets for complex products, based on new technologies, where the "superpowers" are dominant (area C of Figure 1).[9] Area C is itself increasing as traditional sectors (such as Benetton in textiles and clothing) themselves adopt new technologies.

3. Area B of Figure 1 – the natural domain of smaller industrialised nations – is therefore being squeezed in both directions. Only when their industries are dominated by foreign multinational enterprises are they likely to be capable of sustaining global competition. These sectors in Ireland – computers, software and pharmaceuticals – are almost all foreign owned.

A crucial choice for small nations is whether to encourage specialisation in areas where they already have a comparative advantage (obtained either through low cost production capability arising from scale economies or through experience curve benefits), or to develop strengths in a new area where the potential benefits may be greater. Kotler *et al.* distinguish four types of strategic thrust , and these are shown in Figure 2.

Figure 2: Strategic thrusts of nations



Source: Kotler *et al.* (1997), p. 164.

Policy strategists in Ireland, in view of its very late industrial development choose to build a capability based on new technologies, and so the strategic thrust falls naturally into the "building" box of Figure 2. The "building" strategic thrust is appropriate for nations that have a relatively low level of wealth but possess, or can develop, strong international competitiveness. The strategic goal is to move up the ladder of relative income per head. For a small nation like the Ireland, with wage levels that were initially low relative to the USA and the wealthier European nations, but high relative to those of the less developed regions in Asia, South America and North Africa, the strategy needed the following features:

1. Competitiveness based on high productivity and quality rather than just on low wage costs;

2. Creation of a niche in the global total value chain, assisted by trade liberalisation, improvements in human capital and physical infrastructure, and direct incentives to encourage inward investment;

3. A strategy of continual improvement in quality and towards ever higher value-added activities.

The trends in growth of world trade and investment that came to dominate international business from the 1960s onward are well known. The driving forces included the gradual emergence of a "borderless" world due to trade liberalisation and the emergence of the triad of supranational trading blocs (EU, NAFTA, ASEAN). Global industries emerged, which operate in all parts of the world and create a new international division of labour. With falling transportation and telecommunication costs, national economies were destined to become increasingly interdependent, and:

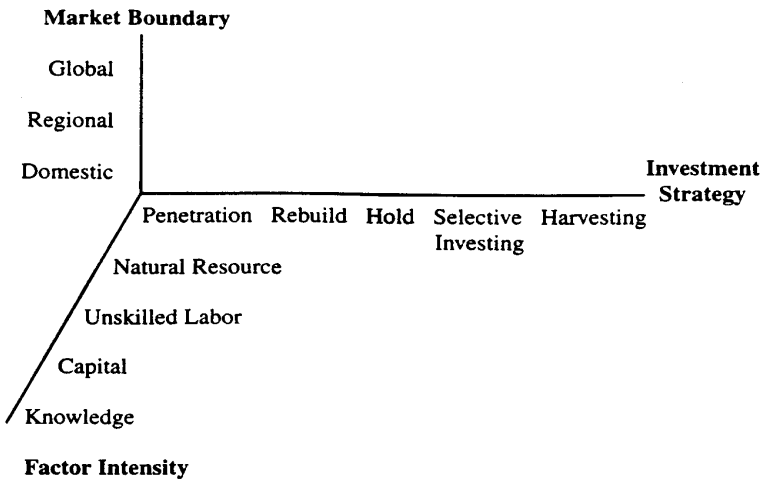
> "*the real economic challenge ... [of the nation] ... is to increase the potential value of what its citizens can add to the global economy, by enhancing their skills and capacities and by improving their means of linking those skills and capacities to the world market*" (Reich, 1993, p.8).

This process of global competition is organised today mainly by multinational firms and not by governments. Production tends to be modularised, with individual modules spread across the globe so as to exploit the comparative advantages of different regions. Hence, individual small nations and regions have less power to influence their destinies than in previous periods of industrialisation, other than by refocusing their economic policies on location factors, especially those which are relatively immobile between regions: the quality of labour, infrastructure and economic governance, and the efficient functioning of labour markets.

For each industry, Kotler *et al.* (1997) suggest drawing up an industry planning map, shown in Figure 3 below. The three axes include an investment strategy (derived from a standard product portfolio analysis), the market boundary (based on the competitive intensity of the industry as well as the nation's ability to compete), and the factor intensity of the industry. In the case of Ireland, the industries inherited from the era of protection (1932-1960) were bounded by domestic consumption, used low-skilled labour, and were doomed for "harvesting" after the economy was opened to foreign direct investment in the early 1960s. The early wave of inward investment in medium-technology industries (electromechanical, food processing), was bounded by regional (mainly EU) consumption, used medium-skilled labour and modest capital, and gave rise to selective investing. Later waves of inward investment were in high-technology industries (computers, micro-processor chips, computer peripherals, software, pharmaceuticals, etc.), using a significant proportion of skilled labour, was capital and knowledge intensive, was destined for

a global market, and penetrated new and related sectors.

Figure 3: A nation's industry planning map



Source: Kotler *et al.* (1997), p. 225.

Irish governments of all parties pursued a vigorous policy of attracting suitable export-oriented industries to invest and produce in the country. In the early stages of the foreign direct investment (FDI) strategy, efforts were made to attract a wide range of industries, often in the mature stage of the product life cycle, but as the competitive position of the country improved, a more selective approach came to be adopted. Today, the support strategies are designed to attract industries that are in the earlier growth stages of their product life cycle, when profitability is high.

At the level of the individual firm or corporation, strategy is usually formulated in a context where government policies are largely exogenous, and firms address the challenges of assessing the business portfolio, identifying strategic goals, and redefining the business domain. The crucial role of management is to formulate a corporate strategy that aligns with the nation's wealth-building strategy. So, this issue is usually examined largely from the point of view of domestic corporations adjusting to national strategy. In Ireland however, causality more often as not runs in the opposite direction. In other words, the Irish Industrial Development Agency – the IDA – was constantly scanning the world for inward investment in high technology sectors. Quite often the domestic environment initially was not sufficiently attractive to persuade cutting edge firms to locate in Ireland. But information on firms needs were fed back to the Irish government authorities by the IDA, and major policy changes could be executed rapidly.[10] The national wealth

creating strategy in Ireland often needs to adapt to the requirements of firms in the global corporate environment, and not the other way around. Hence, the strategic challenges facing small open economies like Ireland are very different from those facing large developed nations like the US, Japan, Germany, France, the UK. Such issues are best treated within policy frameworks, to which we now turn.

4. THREE INFLUENTIAL INDUSTRIAL POLICY FRAMEWORKS

The success of Ireland's industrial strategy was due in large part to the innovative and flexible behaviour of government policy makers as well as to the expertise and dynamism of the state's development agency (the IDA). However, policy makers are usually most effective when they are, so to speak, swimming with the tide of events rather than against it. Irish policy making was, to a considerable extent, pragmatic and opportunistic. But it was characterised by a form of pragmatism that appears to have been singularly in tune with the best thinking on international industrial policy frameworks. In this section, we discuss the characteristics of three such frameworks: Vernon's product life-cycle, Porter's competitiveness diamond, and Best's triad, and explore the role that they played in the development of the computer sector in Ireland.

4.1 Vernon's product life-cycle framework

A powerful concept in business analysis is the product life-cycle (PLC), defined as a process where "*products come into existence, change in character, and eventually disappear or become altered out of all recognition*".[11] Not all products follow a rigid path of birth, growth, maturity and decline. Nevertheless, the product life-cycle in spite of all its vagaries and imperfections served as an anchor for much of the early post WW2 work on industrial strategy.

The seminal paper on the role of the PLC in explaining international investment and trade is Vernon (1966). It is worth remembering that Vernon wrote his paper at a very interesting time in the post-war era. American investment into Europe at that time was so dynamic and threatening that it presented the major European economies with what Jean-Jacques Servan-Schreiber characterised as *The American Challenge* (Servan-Schreiber, 1968). Vernon's main insight was to link the product life-cycle with explanations of international trade and foreign direct investment. Standard trade theory offered little by way of explanation of how US foreign direct investment came to dominate the post-war European economy. Vernon realised that the US home market played a dual role: it was the source of stimulus for the innovating firm as well as the preferred location for the actual development of the innovation. At the early stage of the product life-cycle, producers need great freedom and flexibility to modify, test and improve new processes at a time when the preferred production technology has not yet stabilised. Also, demand for innovative products tends to be relatively insensitive to price, so there is less

pressure to seek lowest cost production locations. Finally, communications between producers, suppliers and final customers must be facilitated, and argues for a home location.

As the product matures, a certain degree of standardisation takes place, and this has locational implications. The need for production flexibility declines and there is now a greater concern for lower costs. Also, demand from abroad increases. However, as long as the marginal production cost plus the transport costs of shipping from the US to the foreign market is lower than the average cost of prospective production in the market of import, *ceteris paribus*, there will be no pressure to invest in foreign production capacity and markets will be served by exports from the US. But as economic and political pressures build up, eventually some production moves abroad, initially into the larger more developed economies like the UK, France, Germany, but soon even to smaller and less developed economies like Ireland. Eventually, as the product fully matures and perhaps enters a declining phase, low cost considerations become paramount, production ceases in the US, declines in other developed economies, and concentrates in low cost developing economies.

Today, of course, the world economy is not dominated to the same extent by the US as it was in the 1950s and 1960s. While products can still be developed initially in home markets (e.g., personal computers in the USA, consumer electronics in Japan), it is more common now for product development and launches to aim at global market coverage from the start, and for elements of the value chain also to be produced abroad from the outset. Nevertheless, the product life-cycle continues to provide very useful insights into the reasons why certain types of foreign direct investment locates in Ireland, as well as why they eventually depart.

Writing in 1979, Vernon provided a reassessment of the role of the PLC in explaining trade and FDI, drawing attention to the fact that advances in technology had led to product life cycles that were much shorter than in the earlier era. In addition, the activity of multinational enterprises (MNE's) was no longer dominated to the same extent by US corporations as it had been in the two decades after WW2. Hence, in terms of demand (the initial market stimulus) and supply (the initial skills needed to design and produce sophisticated products), influences were spread over many more markets. Vernon referred to these factors as "environmental changes" (the decline in the role of the US home market due to convergence of income levels throughout the developed world), and "network spread" (much earlier transfer of technology between a global network of self-standing MNE subsidiaries).

Vernon suggested that multinational enterprises could usefully be classified into two different ideal types. First, "global scanners" innovate and transfer technology instantaneously and costlessly between any parts of the globe, and there is little or no explanatory role for a product cycle hypothesis. But, of course, the acquisition and dissemination of technology is not costless. Second, "global standardisers" consist of firms that develop and produce a line of relatively standardised products

which respond to a homogeneous world demand rather than to the distinctive needs of individual markets. This obviously includes such commodities as oil, chemicals and crude metals, but has also come to include transport equipment, computers and pharmaceuticals. Such firms can save on the costs of segmented market research, and benefit from economies of scale in global production.

With respect to the role of the product cycle, Vernon pointed out that two opposing forces operated for firms who are "global standardisers":

> "*Firms in (the first) category, innovating for a global market, are obliged to play their innovation gambles for relatively heavy stakes. Accordingly, they can be expected to maintain the central core of their innovational activities close to headquarters, where complex face-to-face consultation among key personnel will be possible; in this respect, such firms are likely to perform consistently with the product cycle pattern*" (p.262):

and firms in the second category:

> "*Seeking to exploit scale economies, they are likely to establish various component plants in both advanced industrialized countries and developing countries, and to cross-haul between plants for the assembly of final products. That pattern will be at variance with product cycle expectations*" (p. 263).

The bulk of FDI that has located in Ireland appears to consist predominantly of "global standardisers" (spread across both of the above categories) in the fields of computers, related software, pharmaceuticals and chemicals. Success in attracting these firms to Ireland came primarily from the fact that they were initially targeted by the IDA at a relatively early stage in their (technological) life-cycle, immediately after the new product development stage. For example, as early as 1979 the IDA was among the first such national agencies to lobby the Apple computer company to produce outside their US home base and to come to Ireland (MacSharry and White, 2000, pp. 202-03). The subsequent systematic targeting of the makers of each individual component of computers – keyboards, hard disks, cables, mice, printers – as well as software, meant that the rapid growth of the modern manufacturing sector was heavily concentrated on a narrow range of technologies at early stages of the product life cycle. In this sense, the process represented a classic example of the PLC model of foreign direct investment.[12]

4.2 Porter's diamond of competitiveness framework

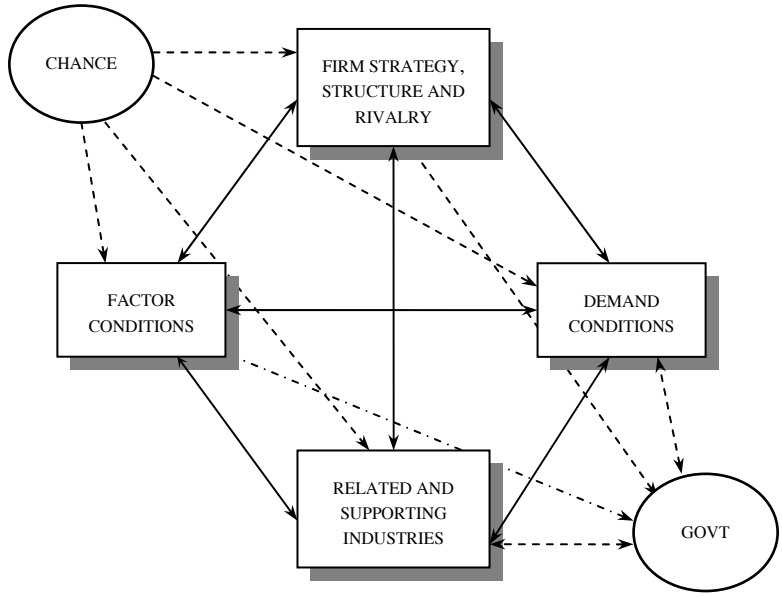
Raymond Vernon had set out to explain why the US was a leader in so many advanced goods. His PLC framework provided a dynamic theory of trade and outward FDI in a context where the US dominated the design of advanced products. This was an influential strategic framework for Irish industrial policy planers.

Michael Porter set out to address a series of wider questions:

> "*Why (do) firms from a particular nation establish leadership in particular new industries? What happens when demand originates simultaneously in different nations? Why is innovation continuous in many national industries and not a once-and-for-all event followed by inevitable standardization of technology as the product cycle theory implies? … How can we explain why some nations' firms are able to sustain advantage in an industry and others are not?*" (Porter, 1990, p.17).

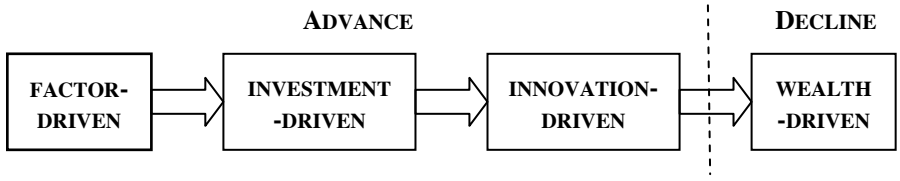
His answers identify four broad attributes (the competitiveness "diamond") that shape the environment in which national firms compete (Figure 4), with an ancillary role played by governments and by chance. *Factor conditions* refer to the availability and quality of the factors of production such as skilled labour, infrastructure, etc. *Demand conditions* refer to the nature of local and external demand for the industry's product or service, where local demand can play a vital role in encouraging product innovation and improvement. *Related and supporting industries* refer to the presence or absence of supplier industries and related industries that are also internationally competitive. *Firm strategy, structure and rivalry* refer to the national conditions governing how companies are created, organised and managed.

Figure 4: Porter's diamond of competitive advantage (Porter, 1990)



Although the diamond itself is not a dynamic system, Porter suggested that there were different stages of competitive development during which different elements of the diamond came into play (Figure 5).

Figure 5: Porter's stages of competitive development (Porter, 1990)



At the early stages, competitive development is driven by factor conditions, and draws on low cost labour and/or abundant natural resources. The next stage is investment driven, and draws from factor conditions, demand conditions as well as firm strategy, structure and rivalry (i.e., from three of the four diamond elements). In the next stage, competitiveness is innovation driven, and draws systematically from the entire diamond.
Using Porter's four-stage development process, one can classify a range of national development strategies as shown in Table 7.

Table 7: Porter's stages of national competitive development

Key driver	Source of Competitive Advantage	Country Examples
Factor conditions	Basic factors of production (e.g. natural resources, lower skilled labour)	South Korea, Singapore and Ireland (before 1980s)
Investment	Capital equipment, transfer of technology	Japan (during 1960s) South Korea (during 1980s) Ireland (after 1980s)
Innovation	All four elements of Porter's "diamond"	Germany, Sweden (post-war) Japan (since 1970s) Italy (since early 1970s) Ireland (post 2000)
Wealth	Erosion of competitive advantage	UK (post-war) USA, Switzerland, Sweden (since 1980s)

Source: Kotler *et al*. (1997), adapted.

Porter's main contribution to explaining the nature of competitive advantage lies in the emphasis he places on the interactions between the four elements of competitiveness and the detailed study of individual successful nations, regions and industries that illustrate these interactions at work. In particular, his approach has strong implications for the design and execution of national industrial policy (Porter, 1990, chapter 12), and provides a useful checklist of what types of policy intervention are likely to improve the individual elements of the diamond as well as their interaction. The analytical work of Michael Porter on competitive advantage has been highly influential in the recent reformulations of Irish industrial strategies.[13] However, as we shall see in Section 5, Irish industrial strategy in the area of attracting high technology sectors in many ways anticipated Porter's later formalisation of his "diamond" framework.

For small countries like Ireland, sectoral clustering, with its accompanying agglomeration effects, are crucial in generating sustained growth. One can define an industrial cluster as a group of industrial segments that share positive vertical and horizontal linkages. Porter's diamond-based framework places great stress on the importance of clusters of related and supporting industries in driving national competitiveness through the spillover benefits of user-producer contacts and information exchange. In some cases – usually in larger developed economies like the USA, Japan and Germany – clusters start up due to historical chance (Arthur, 1994). However, in small open economies like Ireland, cluster formation had to be carefully fostered by policy makers and the promotional agencies. We return to this aspect in Section 5 below.

After more than a decade of impressive growth, a degree of uncertainty has begun to colour industrial strategic thinking in Ireland. Porter's competitive framework – the current business strategy orthodoxy throughout most of the developed and developing world – suggested that a country like Ireland could implement a strategy in a sequence of separate stages: factor driven; investment driven; and innovation driven (Figure 5 above). The first stage lasted almost 25 years in Ireland, from the late 1950s to the mid 1980s, and was "factor" driven, based on policies of low rates of corporation tax, low wages, and subsidised capital formation. The second stage has lasted from the late 1970s to the late 1990s, during which there has been massive public and private investment in plant, infrastructure and human capital, co-funded generously through EU regional aid from 1989 onwards. Policymakers are now seeking to shift to Porter's third (innovation driven) stage. But this has exposed some of the limitations of an industrial strategy that came to be based largely on foreign direct investment.

Of particular interest in the context of small economies such as Ireland is the fact that Porter assigns great significance to indigenous firms and local markets. More ominously, he asserts that:

> "*A development strategy based solely on foreign multinationals may doom a nation to remaining a factor-driven economy*" (Porter, 1990, p. 679)

and that

> "*Except when it is largely passive, widespread foreign investment usually indicates that the process of competitive upgrading in an economy is not entirely healthy because domestic firms in many industries lack the capabilities to defend their market positions against foreign firm … Inbound foreign investment is never the solution to a nation's competitive problems*" (Porter, 1990, p. 671).

Debate on the wisdom and sustainability of the Irish strategy has raged over this important issue. In its crudest interpretation, Porter is simply re-stating the implication of Vernon's early work on the PLC. In other words, if Ireland displays behaviour like the less developed region in Vernon's model of the PLC (see above), it will always remain an underdeveloped country that competes in low cost production of maturing products. But we have seen that Vernon modified his framework considerably, and took account of the fact that the world – viewed narrowly as a productive system – became less rigidly divided into region specific production processes and product technologies. But an even greater degree of integration of policy appears to be needed in a "borderless" world. We now examine one such framework, due to Michael Best.

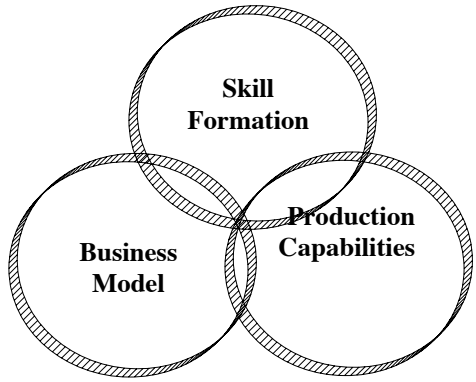
4.3 Best's capability triad

The most recent framework to emerge from a business research perspective is the "capability triad" of Michael Best. What Best offers in his capabilities and innovation perspective – henceforth, the capability triad – is a new and sophisticated strategic framework for the development of industrial policy. The grounds for this synthesis were laid in Best's earlier book on *The New Competition*, which was directed more at the limitations of the conventional neoclassical theory of the firm than at the dominant business taxonomies and frameworks (Best, 1990). In a recent report written for the Northern Ireland Economic Council (Best, 2000), he has applied this framework to Northern Ireland, but of course it is equally relevant to other regions and countries. His latest book, *The New Competitive Advantage* (Best, 2001), uses it to explain the revival of the Massachusetts Route 128 technology complex and the rise of the electronics industry in Malaysia.

Best's capability triad is based on the interaction of three core elements: a business model, production capabilities and skill formation (Figure 6). The *business model* element of the triad describes how entrepreneurial firms grow, based on the creation of new firms through technology diversification, inter-firm networks based on open systems and regional specialisation based on technological capabilities. The *production capabilities* element of the triad integrates ideas from operations

management and operations strategy into a logical system of production system models that drive home the lesson that competitive strategy and productive systems are bound together. The *skill formation* element of the triad, in addition to providing a vital direct input into production, is what serves to enhance the synergistic interaction of the first two elements: the business model and production capabilities.

Figure 6: Best's capability triad



Source: Best (2000).

Perhaps the most daunting aspect of the capability triad is that it treats the scope for public policy as being almost completely and seamlessly blended into the detailed mechanics of change processes that occur within private firms. In this framework, as well as in Porter's diamond, public policy and private entrepreneurial actions do not operate in isolation from each other, but need to become mutually reinforcing. Only in one element of the capability triad – skill formation – is there some scope for a partially separable and transparent role for public policy namely, to ensure that the right mix of education and skills is produced to accommodate the changing demands of the economy as it develops. Even here, the links between public and private activity are crucial.[14]

An obvious question to ask is how the capability triad, if indeed it is a universal process, has operated to produce phenomenal growth in some regions (Route 128, Malaysia and Ireland), but less in others (Northern Ireland). On the one hand, how much is due to domestic policy initiatives, where there may be some degree of freedom and scope for action? On the other hand, how much is due to autonomous localised systems that operate within the private sector (operations systems, entrepreneurial skills, social capital), which are less amenable to direct policy influence? In the case of Ireland, as it addresses the new challenges being faced by the computer sector, an initial fear might be that the capability triad (as well as Porter's "diamond") functions as a "closed" system that explains success or failure, but – rather like meteorology and the weather – does not permit one to have much influence over the outcome. However, any such fear is unfounded, and the logic of

the capability triad provides both structure and content to strategy design.

Strategy has been defined as: "*the evolution of a central idea through continually changing circumstances*" (Welch, 2001, p. 448). The central idea proposed by Best is that industrial strategy should be guided by the capability triad. For example, towards the end of his report on Northern Ireland industrial strategy, Best sets out policy proposals for how such a strategy might be taken forward, and we illustrate these schematically in Figure 7. For the purposes of exposition, three proposals are portrayed as being directed mainly at improving the business model aspect of the triad, three at the capability development element and two at the skill formation element. Of the remaining two proposals, one concerns a general need to link improvements in all elements of the triad; the other concerns a very specific need for synergies between technology management and skill formation.

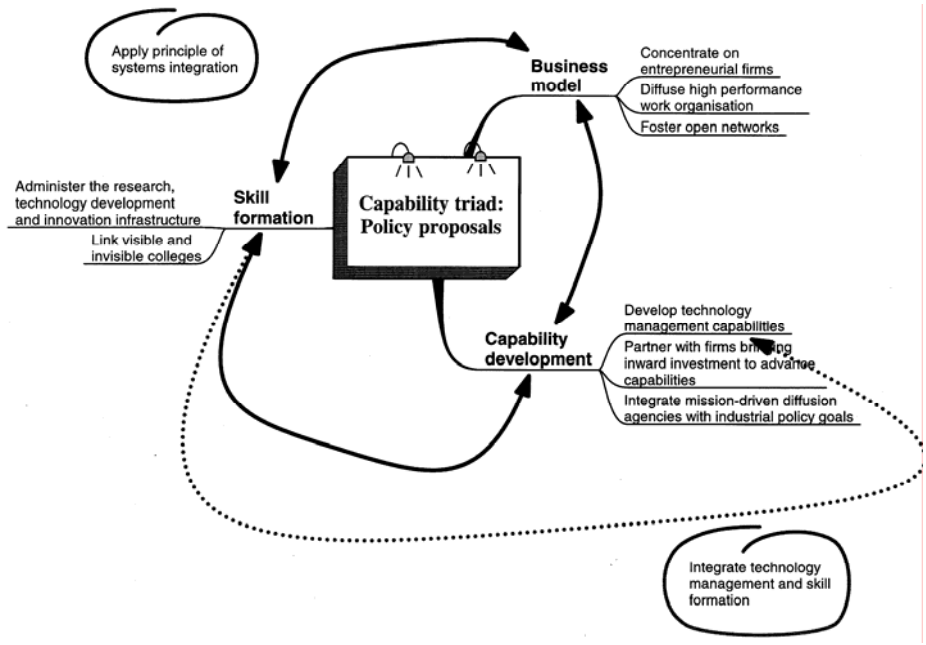
How are policy makers likely to react to Professor Best's ten policy proposals? Some will buy into the organising framework and direct their energies towards the search for what one might call "triad-compatible" practical policy initiatives. But others may react with frustration that the proposals do not resemble the usual detailed shopping list of very specific policy recommendations that often dominate orthodox policy documents. For example, how helpful is it, they may well ask, to be exhorted to "*concentrate on entrepreneurial firms*"? In isolation, such a recommendation is only a pious aspiration. But in the context of the matrix of proposals focused on the three interacting elements of the capability triad, this recommendation opens the floodgates for detailed policy work on how it should be implemented in practice.

How many of the existing Irish firms are truly entrepreneurial, or could become so in the future? Should the Irish development agencies attempt to pick entrepreneurial winners? Conventional economic advice exhorts us to leave this task to market forces. However, Professor Best's detailed review of policy design and implementation in the Massachusetts Route 128 area and in Malaysia provide convincing evidence that there is indeed a crucial strategic organising role for government in order to ensure the creation of conditions that favour the growth of a population of entrepreneurial firms. At the very least, such a role should be used by governments to avoid implementing policies that work *against* the rise of entrepreneurial firms, such as maintaining a system of grants that bails out failing firms or attracts firms into sectors where the preconditions for open networking do not exist. At best, it should encourage policymakers to send clear signals about the characteristics that they wish to foster in a future desirable industrial structure.

Turning to the second recommendation in Figure 7, how should public policy be designed to "*diffuse high performance work organisation*"? To put it bluntly, here the role of government is almost always going to be dominated by the role of the market. As firms move up the production capabilities spectrum, they tend to be rewarded by higher profits and increased market share. But this proposal can be

made into one element of a public policy filter in order to judge the advisability of targeting a firm or a class of firms for policy attention. Also, a policy of "*fostering open networks*" (as in the third recommendation in Figure 7) will address the barriers that Ireland's small firm (SME) economy faces in moving up the production capabilities spectrum towards best industrial operations practice.

Figure 7: Policy proposals linked to the capability triad



Source: Based on Best (2000), pp. 68-76.

In order to advance the debate on industrial policy in Ireland, it may be useful to map the essential elements of any policy analysis and recommendations into Best's capability triad framework.[15] Many benefits would flow from such a mapping. The completeness and closure of the strategy would be easier to check. The nature of the required accommodating fiscal, monetary, social and other policies would become more transparent and provide a logical framework for dialogue and debate within the Irish Social Partnership. A rich database of international industrial experience (from Route 128, Malaysia, the so-called Third Italy) would become easier to access and use as benchmarks to evaluate Ireland's progress. Finally, since the capability triad speaks the language of practical business but draws its organising rigor from economic theory, it will provide a means of synthesising insights from both approaches.

The most important policy implication to emerge from Best's capability triad

framework is that any overall programs of change in the area of industrial policy require the close integration of the change programs in each of the elements of the triad:

> "*Rapid growth involves coordinated organizational changes in each of three domains: the business model, production capabilities, and skill formation.… The three domains are not separable and additive components of growth, but mutually interdependent sub-systems of a single developmental process. … No one of the three elements of the Capability Triad can contribute to growth independently of mutual adjustment processes involving all three elements*" (Best, 2000, p. 2).

In a sense, Best's framework requires a type of "critical mass" of change in each element of the triad before growth can take off. Porter, on the other hand, had suggested that the elements of his diamond could be picked off one by one, leading to a sequential process of growth, as illustrated in Figure 5 above. Although Best's framework requires a degree of sophistication and co-ordination for policy makers that is more demanding than Porter's framework, it appears to be more soundly based on a close integration of insights from economics and business and does not suffer as much from the "big economy" perspective of much of Porter's work.

4.4 Summary on industrial strategy frameworks

One must approach these three policy frameworks with an understanding of their historical origins and their necessary simplifications. Unlike scientific theories, where a single wrong prediction can cause rejection and replacement by a new theory that encompasses old and new observations, these three frameworks simply look at industrial development issues from different perspectives, and place emphasis on different factors. The PLC stresses the primacy of the country that provides the source of FDI, and the dependency of the host countries. This had more universal acceptance in the 1950s and 1960s than it does today, but it continues to apply to small open economies like Ireland, Portugal, Greece, as well as the newly liberalised transition economies of Central and Eastern Europe. The Porter diamond explains the development process in a world that consists of many relatively large and developed economies, and takes up where the PLC leaves off. However, it continues to insist that sustained development is crucially dependent on the domestic market, and cannot be based simply on supply chain linkages to the global economy. Finally, the capability triad of Best selects a very different set of factors that it asserts are the primary causes of development, and further requires simultaneous advances in all three. Each of these three frameworks have operated in Ireland in overlapping ways, with differing degrees of emphasis at different times. They provide useful interpretative frameworks as we re-examine the past and seek guidance for the future.

5. HOW THE COMPUTER SECTOR WAS BROUGHT TO IRELAND

The success of the Celtic Tiger over the past decade has brought forth many explanations of how it came about, and one recent account was co-authored by Padraic White, a former Managing Director of the IDA (MacSharry & White, 2000). Perhaps it is only natural that there should be a touch of suspicion of *post hoc* rationalisation about such accounts, written as they are many years after the key policy decisions were taken. Success has many friends, while failure is an orphan. However, White bases his narrative account of the genesis and evolution of the modern Irish manufacturing sector in part on earlier studies and reports written well before the first major computer company ever decided to locate in Ireland (e.g. McLoughlin, 1972). What is fascinating about such work is the insight that it gives into *ex ante* policy design and execution as distinct from *ex post* policy evaluation.

The story of the IDA is an interesting example of a state development agency that mediated between the narrow firm-based concerns of potential investors and the wider economic and social concerns of national policy makers. The challenge facing the IDA in the 1960s was how to attract just the right type and scale of foreign investment to fit Ireland's needs. Its Planning and Research section (headed then by Ray McLoughlin) generated new ideas and concepts that were tested against the actual experience of the IDA representatives who were in the field trying to convince firms to consider locating in Ireland. The "closed loop" system of industrial planning designed by the IDA in the late 1960s had the following components:

1. Definition of the national economic and social objectives as defined by government policy;
2. Definition of the criteria for selecting target industries, whether in terms of Ireland's location or its capacity to attract inward investment;
3. Identification and targeting of specific foreign companies and detailed assessment of their investment requirements;
4. Assessment of Ireland's ability to meet the development needs of those companies;
5. Monitoring of progress in successfully attracting investment projects.

In more familiar language, White described the IDA policy goal as:

> "*to target with rifle-shot precision individual companies that met specific criteria, then go directly to them and make the case for locating in Ireland*" (MacSharry and White, 2000, p. 231-32).

Using even more colloquial marketing language, White referred to:

> "*these armies of (IDA) cold callers, and the commando-style task forces fanning out across the world, laid the ground for Ireland's dramatic success in getting new industries later in the 1970s*" (*ibid*, p. 231*)*.

Even at a very early stage, the IDA had a sophisticated system of scanning the world business horizon, and identified the electronic and pharmaceutical sectors as having desirable characteristics that particularly suited Ireland's situation. Clothing and textiles was also targeted, and firms like Wrangler, Bluebell, Farah Jeans and Burlington Industries located in Ireland and created welcome jobs (*ibid*, p.274). However, because of tough price competition from low-wage Asian and Southern European economies, along with disruptive changes in fashion, most of them either closed or cut back severely in later years.

The first critical success in attracting a world class computer firm was Digital Equipment Corporation (DEC), a pioneer company in mini-computers that presented the first serious challenge to the global dominance of IBM mainframe computers. DEC's presence heavily influenced many other major multinational computer hardware and software companies to locate in Ireland in the following years.

It was widely realised by the IDA that their unique selling point, giving Ireland a crucial advantage in winning inward investment in the high technology, high profit sectors, was the low rate of tax on corporate profits.[16] This incentive had some striking virtues. Unlike an incentive system that provided high capital grants and risked requiring continuing subventions, the benefits of the tax based incentive was that it only kicked in when firms were up and running, and actually making profits. It also proved to be a crucial benefit to high profit firms, who are invariably located at the earlier stages of the product life cycle and are at the cutting edge of product and process innovation. It was also an incentive that was kept stable over many decades, and the IDA and the Irish government ensured that it could be fully credible over the usual business investment planning cycles of 10 to 15 years or more. Finally, the tax based incentive had the great virtue of being very simple, easy to understand and transparent, which made the marketing task easier.

However, the tax incentive, even combined with fairly generous capital grants, would not have been sufficient by itself to stimulate growth from a zero base in new technology sectors. Prior to 1970 there had been no indigenous electronics sector in Ireland and only a handful of mainly US companies (General Electric, Ecco and Core Memories). The IDA planners realised that the limited supply of electrical engineers and technicians in Ireland would be a major deterrent to selecting the country as a location for industries in this potentially fast growing niche. By the mid-1970s, Irish universities were producing only about 100 electrical engineers and 200 technicians annually, but a massive increase in supply was called for if the sector was to expand.

Having alerted the Irish government to the potential crisis, that could have easily

choked off growth, very quickly the university sector was expanded and given massive increased resources. By as early as 1979, new and expanded courses in electrical engineering were under way, post-graduate conversion courses were provided to encourage science and other graduates to enter the new field, and a system of sub-degree level regional technology institutes was planned and implemented over the next decade. When the poor quality of the telephone network was also identified as another bottleneck that would impede data transmission, a crash programme was put in place, a new state telecommunications agency set up, and a fully digital nationwide system installed and commissioned by the mid-1980s. This programme was also used as a further incentive to attract inward investment in the telecoms area.

Just as DEC was the linchpin of the first phase of inward investment in the computer area, the success in attracting Apple to establish its European manufacturing base in Ireland as early as 1980 was the linchpin of a strategy that targeted the new wave of personal computer (PC) based hardware and software. The IDA approach has been described as follows:

> "*The IDA electronics division used a see-through model of a computer to identify every component in it. Then, systematically, it canvassed the makers of each individual component, such as keyboards, hard disks, cables, computer mice and sub-assemblies. The decade (1980) closed with Ireland successfully inducing two companies the IDA had pursued for over a decade to locate here – Intel's microprocessor plant and Motorola's communications-products plant*" (MacSharry & White, 2000, pp. 288-89).

The high point of the IDA strategy came during the late 1990s, when Ireland became the front-runner for most of the sophisticated foreign investment in electronics, computers and software. A virtuous circle had been created, with electronic components and computer equipment at its core, a spillover into PC-related software development and customisation, and a further spillover into telecommunications-based marketing, customer and technical support services both for existing producers located in Ireland, as well as for the creation of a sophisticated international financial services sector.

Today, computers and electronic components make up a major foreign-owned manufacturing sector. It contributes 30 per cent of total Irish exports and employs about 25,000 people directly. In addition, a large software sector has grown up around the hardware industry, and it employs a further 15,000 people directly and produces 40 per cent of all PC package software sold in Europe. Both the hardware and software sectors have further significant impacts on a wide range of other – often traditional – sectors. For example, the packaging and printing industry, largely locally owned, supplies sophisticated products and services to the hardware and software sectors.[17]

6. PRESENT STRAINS, FUTURE CHALLENGES

At the time of writing – August/September 2001 – the prospect of a major recession in the USA is a cause of some concern to Irish policy makers as well as to those employed in the mainly US-owned computer and electronics companies producing in Ireland. Although this is a vital issue in the short term, there are a series of more serious challenges facing the Irish sector in the longer term. The first challenge consists of the gradual saturation of markets for computer technology in developed countries and the consequential focus on price competition rather that product innovation. A second related challenge concerns the rapid maturing of computer technology in a context where the Irish plants are narrowly concentrated on what has been termed the Wintel subset of a broader technology.[18] The third challenge concerns the imminent enlargement of the EU and the admittance of China into the WTO, with consequences for future relocation of computer plants.

6.1 Saturation of markets

Some of the biggest employers in the largely foreign-owned electronics sector are involved in the production of personal computers and related software. For example, in early 2001 Dell employed over 3,500 people; Gateway over 1,500;[19] Hewlett-Packard about 3,000; IBM, nearly 5,000; Intel, almost 5,000; Microsoft, over 1,500; Compaq, nearly 500. Over the past decade, these firms have enjoyed very high rates of profit, and this has been used by the IDA as a further way of attracting new companies.[20] Consequently, any slowdown in growth in the market for PCs would have a serious impact on employment in the Irish branch plants. Just such a slow down has happened. Table 8 shows the PC penetration growth rate in the EU and suggests that the market (at least in the larger and more advanced countries) may be approaching saturation. Next to Greece, the highest growth rate is for Ireland itself, but the Irish and like markets are so small that their demand will have a negligible impact on overall EU demand.

Where will future expansion take place? Figure 7 suggests that while the EU may be approaching saturation, penetration rates in Central and Eastern Europe is still very low. But these countries have very low standards of living and are unlikely to be dynamic markets for the immediate future. By the time they are full EU members (probably after 2005), technology shifts may well have reduced the role of PC-based computation.

In the software sector, saturation is also an increasing problem. For example, revenue growth for Microsoft, the dominant producer of PC software, is shown in Figure 8. With the exception of high growth in 1996, associated with the launch the previous year of Windows 95, growth rates are declining. It is doubtful if the recently launched Windows XP will revive revenue growth through a rush to

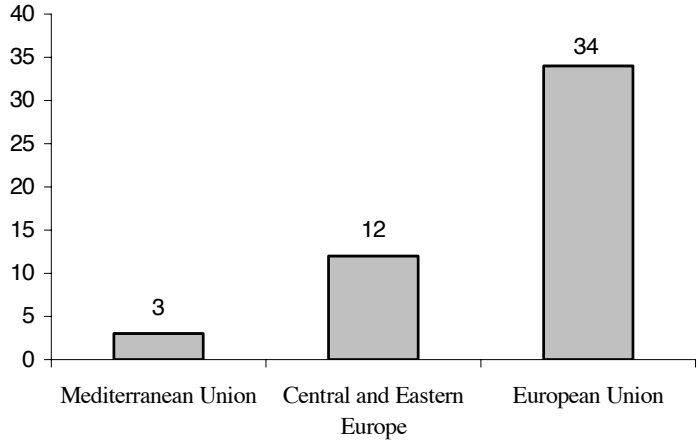
upgrade. And since PC sales are forecast to stagnate until beyond 2002, bundled sales will also be low.

Table 8: PC penetration growth rate in European Union
1997-99 Number of PCs per 100 inhabitants

	End 1997	End 1998	End 1999	Growth 1997-99 (%)
Austria	22	30	36	29
Belgium	29	33	39	16
Denmark	49	54	61	11
Finland	29	32	40	17
France	22	24	31	17
Germany	25	32	36	20
UK	45	47	49	4
Greece	6	7	11	38
Ireland	10	12	18	37
Italy	17	18	20	8
Netherlands	29	32	35	9
Portugal	14	18	22	24
Spain	12	15	15	13
Sweden	28	37	51	36
Average	24	28	34	14

Source: ESIS-ISPO survey (http://www.eu-esis.org/Basic/HomeBasic.htm).

Figure 8: PC penetration by region in Europe – End 1999



Source: ESIS-ISPO survey (http://www.eu-esis.org/Basic/HomeBasic.htm).

Figure 9: Growth of Microsoft Revenues: 1990-2001

Source: The Economist (2001)
Note: Microsoft revenues, percentage increase on year earlier (fiscal years ending June)

6.2 A maturing technology

The challenge of market saturation would not in itself call into question the survival and continued prosperity of the Irish computer sector. More serious is the fact that PC-based technology displays signs of maturity, with falling rates of profit and increased attention to production costs. Vernon's PLC framework suggests that this

will cause pressures for relocation in lower cost centres of production. Here, the behaviour of Dell is likely to provide a useful barometer since Dell sustains its high profitability by means of innovations in operations processes rather than through cutting edge research and development (Dell, 1999). The combination of a low rate of corporation tax, an abundant supply of trained workers, and efficient transport logistics made Ireland an ideal location in the early 1990s.

The open architecture of the PC means that no company can secure an enduring competitive advantage through the basic technology. The most successful PC manufacturers such as Dell have sustained their high profitability through process innovation rather than through product innovation. But their hyper-efficient just-in-time (JIT) inventory systems, as well as direct sales to customers over the internet, can and are being imitated by others. For example, Japanese car manufacturers, who pioneered most of the successful process innovations, were only able to retain a competitive advantage over American and European manufacturers for about a decade and a half. The same is likely to apply to computer manufacturers.

6.3 Global relocation issues

A taste of what might happen to the Irish computer sector inside an enlarged EU can be obtained by examining what is happening to the Malaysian electronics complex due to the imminent entry of China into the World Trade Organisation (WTO) (*Business Week*, 2001, pp.39-56). In a sector that is now displaying signs of the onset of maturity, and spurred on by the need to cut costs in a slowing world economy, companies are intensifying their search for lowest cost manufacturing centres. In a way that mirrors the Irish situation, at least to some extent, Malaysia has created a thriving electronics agglomeration of US, Japanese and Korean-owned plants.

However, the modernisation of the Chinese economy over the past decade has created a formidable rival to the smaller South-East Asian economies, with abundant cheap labour, high levels of human capital in areas of technology and rapidly improving infrastructure. The culmination of this process is the fact that China will shortly join the WTO and will eliminate all quotas and other non-tariff barriers over the coming years. Inward investment in high technology areas is already significant, and China is also accumulating a wide range of supporting industries, thus greatly facilitating its internal supply chain logistics. Just as in Ireland in the 1960s and 1970s, much of the early FDI was in simple assembly operations during the 1990s, but there has been a rapid move to foreign plants of greater technical sophistication.

The impact on the smaller South-East Asian economies has been serious. Only a decade ago, the Association of Southeast Asian Nations took half of the FDI in non-Japan Asia, compared with just 20 per cent for China (*Business Week*, 2001, p. 46). Today, the situation is exactly reversed. In the first nine months of the year 2001, the Malaysian island of Penang has shed about 12,000 jobs in the high technology

sector, or about 10 per cent of its manufacturing workforce. Dozens of foreign companies have either shifted their operations to China, or located expanded capacity in Shanghai, Shenzhen or other Chinese cities.

In the case of Ireland, the threat from China probably relates more immediately to the electronic components sub-sector than to computer assembly and distribution. We saw in Section 2 that the electronic components sub-sector already had a very high import content. In the case of computer assembly, sales and services, Ireland is somewhat more protected, but may be vulnerable to increasingly sophisticated competition from the more advanced economies of Central and Eastern Europe. For example, Hungary is already a site for production and distribution of Dell computers, suggesting that the necessary sophisticated supply chain logistic systems are operating efficiently.

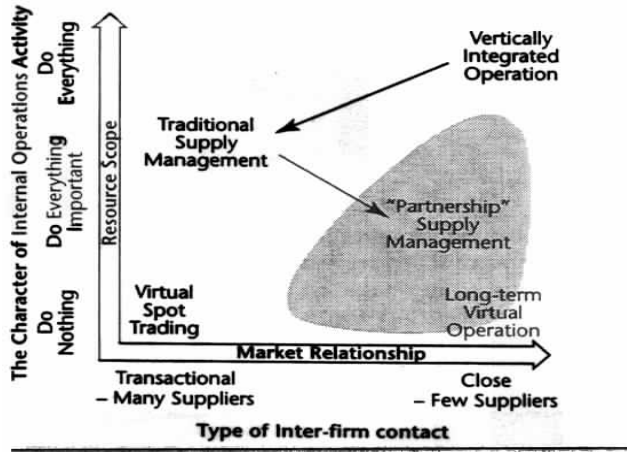
6.4 Future strategies

A hint of how the IDA is moving to deal with this incipient maturity problem was contained in a recent review of industrial promotion strategy (*Enterprise 2010)* prepared by Forfás:

> "*The emerging new business model is leading to a new pattern of international investment, with corporations selecting the best location for each particular activity, rather than necessarily putting integrated projects in a single location*" (*Enterprise 2010*, p. 2).

This type of splitting between firms of activities in the supply chain is well known, and was the basis for the earlier success of Dell in creating a high profit computer firm in an area that looked as if it was reaching maturity in the late 1980s. The issues involved are illustrated in Figure 9. The nature of operations carried out within the firm (its resource scope) can range from "do everything" to "do nothing". The nature of inter-firm contacts (its market relationships) can range from a transactional basis (with many suppliers) to a close basis (with only a few carefully selected suppliers).

Figure 10: Types of supply chain relationships



Source: Warwick Business School, DLMBA, *Operations Strategy,* Lesson 8, Figure 8.6 (p. 12).

What the case of Dell illustrated is that in terms of operations, "everything important" amounted only to final assembly, distribution and marketing. In terms of inter-firm contact, a small number of long-term suppliers were used. Ireland was an obvious location for such a company, particularly in the 1990s, since many of the suppliers (including Intel, the supplier of the vital microprocessors) were already located in Ireland, and the geographical peripherality was not much of a problem because of good transport and communications infrastructure and (in stark contrast to, say, textiles and clothing), the high "added-value" density of the final product.

Until recently, sourcing inputs from other countries would have incurred unacceptably high transactions costs (both in terms of inter-firm communications and border controls for intermediate products). However, the dramatic fall in transport and communications costs, as well as the completion of the Single European Market by 1992, worked strongly in Ireland's favour. Ireland's membership of and enthusiasm for Economic and Monetary Union (the euro) is yet another way in which barriers to its participation in a truly global production system are being minimised and benefits maximised.

Enterprise 2010 appears to envisage a wider application of global outsourcing, with Ireland at the high added-value core of production activities. An obvious problem with this strategy is that while it may be suitable for electronics or certain types of pharmaceuticals, it may not always be suitable for alternative types of manufacturing activity, such a bio-technology. Furthermore, Porter's framework suggests that this approach is fraught with difficulties and would leave Ireland vulnerable to changes in technology. Best's framework suggests that such an

approach will require a very high standard of discipline and excellence in all aspects of the economy. Either way, the suggested new approach of marketing Ireland as a network location in a type of post-industrial age will be a major challenge.

7. CONCLUSIONS

Luck plays a large part in any industrial strategy. The expected external conditions needed to support success do not always conveniently arrive, and their absence may frustrate otherwise admirable policy initiatives. Nor is the true significance of the internal elements of a strategy always fully understood even by its own designers. But luck and chance, however random, can be handled best within well thought out and coherent frameworks that take full account of the nature of the external environment (opportunities and threats) as well as realistic views of domestic capabilities (strengths and weaknesses).

Conceptual frameworks and policy design, implementation and renewal usually evolve parallel to each other. Frameworks are rather like maps that tell you where you are, where you need to go, and the direction that you must take in order to get there. Policy design and implementation deal with the messy business of gathering resources, making pragmatic choices, overcoming obstacles, and bringing the team along with you to your ultimate goal. To confuse these separate but interrelated elements of strategy, or to emphasise one at the expense of the other, will almost certainly lead to problems.

There were many different aspects to the success of Ireland in attracting inward investment in high technology areas. The State's industrial development agency, the IDA, had a certain independence from government and a strategic planning role at the national as well as the firm level. This meant that it was well equipped to deal both with research into the actual needs of individual industries as well as requirements at the national level in terms of basic physical infrastructure, education and training, telecommunications, transport, etc. There was also a realisation that national industrial promotion was a continuously evolving challenge:

> "*The nature of industry keeps changing – there is a continuous process of decline in some sectors (for example, textiles and mechanical engineering) and growth in others (software and e-commerce). So we can assume that a fair share of the industries we have today will decline and decay in coming years. Thus, we need to be continually searching for the emerging star sectors that are competitive in an Ireland of rising costs compared with others in an enlarged European Union*" (MacSharry & White, 2000, p. 313).

Another crucial characteristic of the IDA approach was its pro-activity, described provocatively as follows:

> "*It is IDA policy to gear itself to discharge the total process to the limit of its legislative permit, and while it will not encroach on areas which are clearly the responsibility of other state organizations, it will err on the side of doing rather than not doing where the returns on effort appear to be high*" (McLoughlin, 1972, p. 30)

Today, the technologies of the existing base of mainly personal computers, components and software are rapidly maturing in an increasingly turbulent world of electronic and communications revolution. What the recent downturn in the US economy has done is to expose an incipient lack of competitiveness in a range of computer and electronic component manufacturers who are, perhaps, the least innovative and have the most mature technologies. The recent loss of Gateway, a large-scale computer plant that had been engaged in assembly of standard PCs, as well as that of General Semiconductor, an electronic components plant, were perhaps as inevitable as they were regrettable.

At the risk of oversimplification of what are very complex issues, what an examination of the recent performance in the Irish manufacturing sector shows is that the intelligent combination of economic policy and business strategy can generate huge synergies in terms of rapid national growth and convergence. To achieve these synergies requires a degree of economic policy autonomy and flexibility that can be used, for example, to protect workers who lose their jobs in declining sectors and who require extensive retraining for other occupations.

The experience of the past thirty years illustrated how the IDA played a vital role in mediating between the formulation of national industrial policy (interpreted in the very widest sense as including taxation, infrastructure, education, etc.) and the requirements of selected sectors and firms within these sectors. The sureness of touch that characterised policy-making during the earlier eras of Vernon's PLC and Porter's diamond is less evident today as Ireland faces challenges of a kind that are perhaps more suitably described by Michael Best's capability triad. But this is not to suggest failure of Irish industrial strategy. Rather, it is a measure of the extent to which previous success has projected Ireland into the forefront of economic development where decisions are more complex and harder choices have to be made.

Endnotes

1. Direct employment in the computer sector is measured in terms of NACE code 3002 (computers and other information processing equipment) plus NACE code 3210 (electronic components).
2. See Vernon (1966), Porter (1990), Best (2001).
3. Defined in terms of the ratio of exports and imports to GDP, Ireland has one of the most open economies in the world.
4. It should be noted that an element of the output of the software sector is classified in NACE 21-22, and includes such items as computer manuals and CD-ROMS.
5. NACE 3210 also includes valves and tubes, but these are likely to be insignificant throwbacks to the pre-transistor and pre-microchip age.
6. The highest average wage per person engaged (at £30,900) is in NACE 2414 (Other organic and basic chemicals. The lowest average annual wage (at £7390) is in NACE 2751 (Casting of iron), a trivially small sector. In NACE 1822 (Other outerware), a sector that employs 3178 in 87 local units, the average wage is £9,970).
7. The *Census of Industrial Production* does not identify NACE 3002 or NACE 3210 by ownership.
8. For an full account of the process innovations in Dell, see Dell, 1999.
9. Countries like Finland (Nokia), the Netherlands (Philips) and Switzerland (Nestle) can sustain world class multinational enterprises, but these tend to be exceptions in the context of most small countries.
10. A case of information feedback was the transformation of the Irish university system, where massive resources were put into the education of electronic engineering and chemistry to create a skilled labour force for potential inward investors (MacSharry and White, 2000, pp. 283-285).
11. *New Palgrave Dictionary of Economics* (1987).
12. We consider the IDA sector and product selection process later in Section 5.
13. Porter's approach was used to great advantage by the Industrial Policy Review Group in the Republic of Ireland (Culliton, 1992), and by the Northern Ireland Growth Challenge (NIGC, 1995).
14. For example, a recent ESRI study (Denny *et al.*, 2000) showed that for different types of training intervention, those closely linked to the market were most effective in combating unemployment while in contrast, training of a more general nature did not, on its own, appear to have an enduring beneficial effect.
15. Best's capability triad can also be considered within the wider concept of a *learning region*. An application to the Øresund region of southern Sweden and Denmark is described in Maskell and Törnqvist (1999).
16. Zero on export-related profits initially, but changed eventually to a flat rate of 10 per cent some time after Ireland joined the EEC.
17. Only some of the activities of the software sector fall within the classification of "manufacturing", and are captured in the Census of Industrial Production. Further data are available on the IDA web site: www.ida.ie.

18. Wintel signifies the combination of Microsoft Windows-based software running on Personal Computers that are powered by Intel micro-processor chips.
19. At the time of writing, Gateway 2000 had just announced the closure of its Irish operations with a potential loss of all jobs. This was merely the latest in a series of job losses and downsizing in the computer area as firms struggled to adjust to lower demand.
20. For example, the annual rate of return on US manufacturing in Europe over the period 1991-96 ranged from a low of 8 per cent (in the UK) to a high of 24 per cent. In the Irish case, the US companies are either in computers, software or pharmaceuticals. These data are based on US Department of Commerce figures, and quoted on the IDA web site (in a document called *Achieve European Competitive Advantage in Electronics*).

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DISCUSSION

Mr. Denis Molumby: I would like to propose a vote of thanks to Professor John Bradley for his excellent paper. It raised a number of issues. I would like to comment on a few of these, namely:

- whether the current downturn is "exposing" weaknesses;
- the arguments around our dependence on foreign investment;
- the strengths (rather than weaknesses) of what is already in place;
- the effectiveness of the IDA's strategy.

Professor Bradley maintains that our success demonstrates the effective combination of economic policy and business strategy, but that we now have more complex issues to manage and more difficult decisions to make. I'm not sure that he suggested a clear recipe for dealing with these. Did I detect some lack of confidence in our ability to manage it?

The current downturn has not so much exposed, as drawn attention to, an ongoing feature of the ICT area. Using employment as a measure, an average of over 7 per cent of the base has been lost every year for the past ten years – that is, even in the years before the present downturn. This pattern is an intrinsic part of the high-technology business. If a company cannot move on in terms of its activity, technology and structure, it will move on in terms of its location. This is not a new phenomenon, for major facilities closed in the past (Digital, Seagate etc) and sub-sectors became obsolete (minicomputers in the 1980s and early 1990s, the loss of Wang, Concurrent, Prime etc.).

We lost companies but we gained skills and expertise. The closure of Digital in Galway provided a platform for many subsequent start-ups; the previous facility led to sophisticated technical support and software development, amongst other things. At this stage, our best information from contact with client companies suggests that this year's losses will be slightly higher than average, but only a little more so. Losses may just about be offset by gains.

Professor Bradley seems to imply that not only are we overly dependent on foreign industry, but that this is compounded by too narrow a concentration in our efforts. However, it could be argued that reasonable diversification has taken place. We have focused primarily, but not exclusively, on:

- ICT;
- pharma-healthcare;
- international financial services.

Within ICT, there is an increasing spread of activity and markets served. They are by no means only confined to computers. Telecommunications and data make up, of

course, the biggest chunk, especially high-end manufacture and software development. There are also wireless and optical technology and e-business infrastructure, computers (including all the components) and key software development, networking systems, storage, and server activities. However, one can also find semi-conductors, key integrated circuit design and contract manufacture, complex product engineering, design and manufacture and customer relationship handling, as well as internet-based activity. Services have become a major feature of ICT operations in Ireland.

Over the last ten years at least, we have specifically concentrated on enhancing the spread of activities associated with existing foreign companies. We aim to make them more independent of the parent and more strategically important to the parent, in addition to maximising the return on our investment through further expansion and supply linkages. It is a slow, ongoing process, involving the building of relationships at numerous levels in the company, and the strategy is open to a great deal of disruption. However, we can now point to a number of examples of its successful implementation, including the transformation of Ericsson, the IBM campus, Hewlitt Packard and EMC in Cork.

Naturally, there is no guarantee of success. We made some progress with General Semi, but the ownership changed with unfortunate consequences. Over half of the ICT companies we deal with nonetheless undertake a range of other business functions apart from manufacture, such as product development, technical support, customer support or logistics management. We continue to work both to develop the existing stock and to change the nature of the new entrants. Using a minimum salary criterion, nearly 40 per cent of new investments exceeded the €25,000 target set by the IDA.

The depth of technology and capacity for innovation is, perhaps, also better than Professor Bradley suggests, and is experiencing ongoing growth, both in Irish and overseas companies. Our estimate is that 25 per cent of the foreign companies in ICT now have research and development groups within the Irish operations. Some of these are extremely well developed and, indeed, may be the strategic heart of the multinational itself. Significant Irish companies have been built on the technologies transferred from such activity. With increased research and *Science Foundation Ireland* support, one finds increasing links to colleges and the formation of a more effective cluster. This has not been an easy one to crack – the tax structure is not as friendly to research and development as it is to other activities.

The IDA has a research and development capability programme directed at the existing foreign base. We have eleven projects agreed so far this year, in addition to more than thirty others which receive research, technology and innovation assistance. They are significant in both nature and spread and include some quite valuable research projects. We weren't really following Porter's or Vernon's model specifically. We were trying to balance the requirement for long-term development

with the political and social requirement for job creation, against the backdrop of the quality of the infrastructure we had to work with at any point in time. Increasingly, however, we also had a vision of a total industry. We were constantly looking at the trends, at emerging business sectors and business models. Obviously, we wanted to get not just the presence of the brand name, but the most sophisticated and integrated operations we could.

A key element then, as it still is today, was feedback from the marketplace and our clients, and the fast response of the "system" to the need for changes. Professor Bradley touched on this above. This could encompass anything from the education of technicians, software courses and language courses to, more recently, telecommunications, tax and regulatory changes and science and research initiatives. Today we see not just that there is a changing global business model, but that Irish expectations are different too. Technology and globalisation are leading to changes in the structure of businesses, so that each activity is located wherever makes most business sense. Increasingly, the traditional value chain is being replaced by a "virtual company", with many functions outsourced. Emphasis is placed on managing the supply chain, responding to the market and developing applications.

We continue to seek out the best available foreign direct investment, suitable to our national needs; we attract it to locate here, work to expand it, develop it, and deepen its roots, activities and value. In addition, however, the aim is to become in time, in areas not yet clearly identified, the equivalent of Silicon Valley for ICT, the Nordic countries for mobile communications, or Hollywood for films. We want Ireland to become the best, or among the best, in the world for specific niches, and effectively set the agenda, so that for business in these activities Ireland will be an essential place to be. In capturing more of the front-end innovation, the objective is to generate a dynamic which is widely identified with the success of the cluster or activity and attracts other serious players in the area.

The situation is more complex, as Professor Bradley says. However, we have more to work with than he seems to suggest. The ICT sector, we believe, is even more important than he acknowledges, but has much of the key elements already in place. It may, indeed, be more or less developed by now. It is certainly present in some form.

It should not be forgotten that success is not solely based on FDI anyway. In tandem, *Enterprise Ireland* have their programmes for indigenous business, and with significant success. Indigenous software companies employ as many as those from overseas do, and arguably have more development content today, while many new Irish companies in the sector have made their mark globally.

Our ability to pull together wider elements to develop the functioning cluster has also progressed. Skills, infrastructure and regulatory mechanisms are functioning well, and draw on the experiences of the past twenty years. Client feedback, to

which Professor Bradley refers, is positive. Skill level, flexibility, the "can do" attitude of Irish management and labour, and our ability to react quickly to changing conditions and evolving needs are consistently highlighted as being major competitive advantages. The challenge is to retain this.

We are now more confident of our ability to generate indigenous companies successful on a global scale. However FDI will continue to give us a direct link to leading edge technology and markets, higher value replacement activities for expiring activities, and a kick start for regional development. If we face a challenge, it does not arise from uncertainty as to what we should do. Rather, the challenge is to remain committed to vital investments under the National Development Plan, especially in telecommunications, power and access. Such measures are essential to our continued success.

Dr. Frank Barry: Professor Bradley's paper is thoughtful and interesting. To me though, the insights come from the author himself rather than from the theoretical frameworks he adopts.

What is the aim of Business Studies as a research field? It would appear to be about developing an empirical understanding of firms' strategies. There are many interesting economic topics that would benefit from such an understanding. For example:

- We know that average leading EU firms with a facility in Ireland have facilities in the same industry in 5 other EU countries (not counting the home base).[1] Why? Why does this differ by nationality (with UK MNCs producing in less locations than others) and by sector (with cars, chemicals and electrical engineering coming in with the highest number of locations, and other transport vehicles, textiles and wood products coming in lowest)? Is the same activity carried out in each facility, or do they tend to locate particular activities in Ireland?

- Given the very strong incentive offered by low corporation tax rates, why does the IDA occasionally fail in the battle to attract particular firms?

- How *embedded* in Ireland are foreign firms, and how do we measure embeddedness?

The present paper however seeks, wrongly to my mind, to replace an economic perspective with a business studies one. There is nothing to be said against the cross-fertilisation of ideas of course; in dealing with issues which are the proper subject matter of economics, however, I feel that business studies offers a less rigorous perspective, both methodologically and empirically, than the field it is replacing in this analysis. This is the argument I want to develop here.

First comes the issue of whether we are dealing here with the positive theory of "what is", or the normative theory of "what should be". Vernon's product cycle hypothesis is positive, while Porter and Best seem more concerned with the question of what policymakers should do.

Economics approaches policy (at least when dealing with efficiency as opposed to equity considerations) by asking first what the *market failures* are that justify intervention. The business studies methodology does not do this, and hence runs the risk of being based on apparent "common sense" arguments. Krugman and Obstfeld's textbook on International Economics lists a number of incorrect such arguments for industrial targeting, including for example the emphasis on industries with high value added per worker and strong linkages.

Vernon does not get into these issues. Before one jumps to policy conclusions that appear to be based on his analysis, then, it is important to bear in mind the warning from Krugman and Obstfeld that advantaging one sector disadvantages others, and a rather difficult *net* accounting is required before this can be justified.

As to Porter, the author criticises his "large-economy perspective" for failing to recognise that FDI can be an important stimulus to economic development. The conditions under which it can so act as a stimulus are carefully explored in the economics literature; e.g. Markusen and Venables (1999) focus on the creation of linkages when production is characterised by increasing returns, Gao (1999) shows how FDI helps peripheral countries surmount the problems that arise if increasing-returns sectors agglomerate in richer core countries, while Rodriguez-Clare (1996) explores the possibility of negative consequences arising, though these conditions are unlikely to characterise the Irish situation for the kinds of reasons outlined in Barry (1996) and Barry, Gorg and Strobl (2001).[2]

I am a little surprised that Porter emerges with only the mildest of criticism. One of Porter's difficulties with FDI is that "*domestic firms may lack the capabilities to defend their market positions against foreign firms*". This is not the kind of FDI that has been attracted to Ireland. Here FDI has appeared to trigger development within certain areas of indigenous industry. Many others in Porter's own field have suggested that changes are required if his model is to apply to peripheral economies. Dunning (1992) for example suggests ways in which foreign-owned MNEs can be fitted into the analysis, while Cartwright (1993) argues for a greater accounting of the importance of trading partners in determining an economy's competitive advantage.[3] I know that this latter position would accord with the author's own views as expressed in other publications. In any case, it is not pointed out in the paper that Porter's views appear to be in direct contrast to those the author ascribes earlier to Kotler *et al.* (1997).[4]

Best's view appears to be that good firms are not sufficient to generate good (economically advanced) regions. Action is also required at the meso (industry) and general macro levels. This is surely true, as we can see from looking at the confluence of factors that led to the economic boom in Ireland. Thus on the micro side we had the fact that the long domestic recession meant that only the most innovative outward-oriented firms remained in the pool by the late 1980s; on the meso side we had the liberalisation of air access routes, the commercialisation of the telecommunications sector and the increased rigour with which government expenditures came to be scrutinised, while on the macro side we had the trade-off of tax cuts for industrial peace, the Single Market, the Structural Funds and so on. Perhaps Best is saying more than this, though there is also the possibility that he is saying less. His capability triad (though the author talks about public policy being seamlessly blended into the equation) seems overly focused on the narrow realm of business (as befits a business analyst, perhaps, but this is surely an overly narrow perspective from which to study an entire economy). I certainly do not think we can exclude the need for correct macro policies, which makes me feel the paper is over-enthusiastic in asking (p. 21) "*how the capability triad, if indeed it is a universal process, has operated to produce phenomenal growth in some regions*" including Ireland.

In terms of issues concerning the computer sector specifically, the new field of empirical economic geography appears to me to offer some very stimulating ideas. Midelfart-Knarvik *et al.* (2000) divide industries into groups that (a) were concentrated in a small group of rich countries in the 1970s and remain so concentrated today, (b) those that were so concentrated but have now become dispersed, and (c) those that were dispersed across Europe in the 1970s but have become concentrated (in the poorer peripheral economies) over time.[5]

Each groups shares certain identifiable characteristics. Those that have remained concentrated in the EU core tend to be relatively high-technology sectors and to be characterised by high increasing returns. This group includes Motor Vehicles and Aircraft production. Formerly concentrated industries that have become more dispersed have lower levels of increasing returns, less intra-industry linkages, a less significant final demand bias, but quite high levels of skill intensity. We will discuss these further in a moment. The initially dispersed industries that have become more concentrated in the periphery are low-technology sectors with low levels of increasing returns and low degrees of skill intensity, such as Textiles and Clothing.

Table 1 charts developments over time in each of these sectors, in terms of their share of total manufacturing sector employment in Ireland.

Table 1: Shares of Irish Manufacturing Employment in Certain Groups of Sectors.[6]

Ireland	1973-76	1993-96
CC	9.53	14.17
CD	11.06	20.91
DC	19.31	11.64

The most dramatic adjustment of all is clearly in the middle group of industries, which includes computers, professional instruments, machinery and equipment, and beverages and tobacco. This suggests that there was more than just industrial targeting at play in allowing us expand in these sectors. These (along with the DC group) were the sectors that had become mobile across Europe. Try as we might, it would have been much more difficult had we targeted the Aircraft or Motor Vehicles sectors.

The low rate of corporation tax is undoubtedly significant in determining not just how much FDI comes to Ireland but also the sectors into which it comes. Why do we find ourselves more specialised than heretofore in these high-technology sectors? One possibility is that the elasticity of FDI with respect to corporation tax rates has increased, as Altshuler et al.(2001) argue.[7] Another is that we have only recently achieved critical mass in terms of other factors which are crucial to these industries, particularly appropriately skilled labour. This is not at all to downplay the role of the IDA, just to question whether the general outline of our industrial structure is due completely to their decisions on which sectors to target. Undoubtedly they were crucial in advertising Ireland's advantages, in convincing potential investors that apparent difficulties could be overcome, and perhaps most importantly in going after "flagship projects", which appear to be important in generating agglomerations.

This perspective is partly corroborated by Midelfart-Knarvik *et al*. (2000) who note (i) that research and development intensive industries are increasingly responsive to countries' endowments of scientific personnel and (ii) that the educational level of the population remains of great importance for the location of skill-intensive industries.

I agree with the author that in ten years time our specialisation may well not be in computers. I would be more sanguine than Professor Bradley is about this, *if we can maintain our position in the corporation tax stakes*. If we can, the country will undoubtedly continue to be able to attract FDI in certain high profit sectors. One must admit that it is looking increasingly unlikely to be the case however.

A fourth finding reported by Midelfart-Knarvik *et al.*(2000) draws attention to further dangers on the horizon. This is that geographically central or "core" EU locations seem to be becoming increasingly attractive to industries higher up the value chain.

Endnotes

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2. Markusen, J. and A. Venables, 1999. "Foreign Direct Investment as a Catalyst for Industrial Development", *European Economic Review*, Vol. 43, pp. 335-356; Gao, T., 1999. "Economic Geography and Vertical Multinational Production", *Journal of International Economics*, Vol. 48, pp. 301-320; Rodriguez-Clare, A., 1996. "Multinationals, Linkages and Economic Development", *American Economic Review*, Vol. 86, pp. 852-873; Barry, F., 1996. "Peripherality in Economic Geography and Modern Growth Theory: Evidence from Ireland's Adjustment to Free Trade", *World Economy*, Vol. 19 (3), pp. 345-365; Barry, F., H. Gorg and E. Strobl, 2001. "FDI and Wages in Domestic Firms", unpublished ms, UCD.
3. Dunning, J., 1992. "The Competitive Advantage of Countries and the Activities of TNCs", *Transnational Corporations*, Vol. 1, pp. 135-168; Cartwright, W., 1993. "Multiple Linked Diamonds and the International Competitiveness of Export-Dependent Industries: The New Zealand Experience", *Management International Review*, Vol. 33, pp. 55-70.
4. Kotler's framework purports to be about small economies. It seems more appropriate to think about it as having to do with late industrialisers. In addition to the small countries mentioned in the author's footnote 9, Pavelin's database on leading EU firms (i.e. firms among the top 5 in terms of EU production in each 3-digit NACE industry) shows several from Denmark, Sweden, Belgium and even one Portuguese firm. Only Greece and Ireland do not appear.
5. Midelfart-Knarvik, K.H., H. Overman, S. Redding and A. Venables, 2000. "The Location of European Industry", European Commission Economic Paper 142, (DG Economic and Financial Affairs); forthcoming in *European Economy*.
6. Source: Barry, F., S. Barrios and E. Strobl, 2001. "FDI and the Economic Geography of the EU Periphery", work in progress, UCD.
7. Altshuler, R., H. Grubert and T. Newlon, 2001. "Has US Investment Abroad become More Sensitive to Tax Rates?" in J. Hines Jnr., (ed.) *International Taxation and Multinational Activity*, Chicago: University of Chicago Press.

Dr. Roy Johnston: I feel I should place on record something of the pre-history of the Irish computer industry, based on my experience with Aer Lingus in the 1960s and the university-industry interface in TCD in the 1970s. The IBM real-time reservations project took shape in the 1960s and was IBM's pilot project for addressing the European market. There were many Irish software engineers in the IBM team, who had served their time in the US and taken the opportunity to return; Fred Kennedy, Paddy Doyle, Tom McGovern, Dick Cahill and others. This was the "leading edge" technology at the time, and by far the largest Irish based computer investment (there had been prior computer investments in the Sugar Company and in the ESB, but the Aer Lingus was "real-time" and innovative). The "project champion" within Aer Lingus was Finbar Donovan, who had a background in applied mathematics research; he recruited to the Aer Lingus team not only software people but also people with an applied scientific R&D background, such as myself. After a false start, which we demonstrated unworkable, it was in the end implemented successfully in or about 1968 with third generation equipment. (We in Aer Lingus were the first to apply queue theory to the prediction of the performance of real-time systems in a stochastic environment; we were also the first airline to apply the computer to the analysis of the economic performance of a specific aircraft on a route system serving a market, prior to the decision to invest in it).

Some of the IBM team subsequently left to start Irish based software enterprises, examples being System Dynamics and Captec. Others who had been with Aer Lingus did the same, over a longer period of time, an example from the 1980s being Irish Medical Systems. These firms continue to cultivate various niche applications markets, using state-of-the-art technology. This process of enterprise generation is perhaps worthy of analysis, as also is that associated with the university-industry interface, where for example in the mid-1970s, under the influence of the opportunity presented by DEC and the mini-computer, the firm Mentec spun off from the TCD engineering research community, on the initiative of Mike Pierce. The technological, organisational and human factors influencing this type of high-technology enterprise generation I suggest are worthy of study, as a means of further understanding the processes described so well by Professor Bradley.