

***WIRELESS VALLEY, SILICON WADI AND DIGITAL ISLAND –
HELSINKI, TEL AVIV AND DUBLIN AND THE ICT GLOBAL
PRODUCTION NETWORK ABILITY TESTS: THE ROLE OF VALUES
AND TEST TAKING ATTITUDES***

by
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March 2005

ISBN No: 1 85449 695 6

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Wireless Valley, Silicon Wadi and Digital Island - Helsinki, Tel Aviv and Dublin and the ICT Global Production Network

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Revised draft – June 2004

Abstract

Hyper-capitalism in global Information and Communication Technology (ICT) markets during the late 1990s created a new global production network, shaped by multi-national corporations, international capital flows, and a flourishing of high-tech entrepreneurship. Each of the cities considered here benefited substantially from this growth, but their positions as nodes in the ICT global production network differed markedly, as did their ability to appropriate the value they generated. In Dublin, value creation was based largely on inward technology and capital flows, although indigenous Dublin-based software companies did demonstrate their ability to compete internationally. ICT development in Helsinki and Tel Aviv drew more strongly on the local knowledge base, and benefited from changes in national regulatory and political conditions. In Helsinki, public and private R&D investments supported the highly effective globalisation strategy of Nokia to create a strongly localised, vertically-integrated and strongly specialised sector. Value creation in the more diverse Israeli ICT sector was also based primarily on locally developed technology, university R&D and the commercialisation of technology developed initially for military applications. By the end of the 1990s, the resulting ICT node in Tel Aviv was grounded in the local knowledge-base, technologically diverse, strongly entrepreneurial and globally oriented.

Acknowledgements

The Genesis of this paper was a comparison of the Helsinki, Dublin and Tel Aviv ICT sectors conducted as part of the OECD Helsinki Territorial Review. We are grateful for the insights of the members of the Expert Group established to examine the Helsinki ICT sector (Dan Steinbock, Columbia Business School; Fabio Terragni, Northern Milan Development Agency; Joe Cortright, Impresa Consulting; Tim Wojan and Nicola Costa, OECD; Laura Paija, ETLA), and for information provided by interviewees during a study visit to Helsinki in September 2001. Valuable comments on an earlier draft of this paper were provided by participants in the 4th Israeli-British-Irish Regional Science Workshop held in Edinburgh, May 2003, the European Regional Science Association Conference, Finland, August 2003 and the Knowledge Based Economy and Regional Economic Development Conference, St Johns, Newfoundland, October 2003. We are also grateful to three anonymous reviewers and the editor of this journal for their valuable comments. Sins of omission or commission are the authors' alone, however.

Wireless Valley, Silicon Wadi and Digital Island - Helsinki, Tel Aviv and Dublin and the ICT Global Production Network

1. Introduction

During the 1990s, ICT markets grew at unprecedented rates stimulated by international inward investment, global capital flows and a flourishing of high-tech entrepreneurship. Nations' and regions' participation in the ICT boom varied, however, with Finland, Israel and Ireland among the smaller countries to achieve dramatic growth rates. From 1995-2000, Finland achieved an average annual real GDP growth rate of 5.1 per cent per annum, Ireland, grew at 4.4 per cent pa, and Israel achieved a notable 4.0 per cent pa. Over the same period, GDP growth in the EU as a whole averaged 2.6 per cent pa¹. The growth and development of these three 'tiger' economies has, of course, been extensively described elsewhere; on Finland see, for example, Steinbock (2001) and Paija (2000); on Israel see, for example, De Fontenay and Carmel (2001), and Kipnis (2001); and, on Ireland see, for example, O'Riain (1997) and Grimes (2003). Some comparative analyses have also been undertaken, notably Roper and Frenkel (2000) on Israel and Ireland and Koski et al. (who examine the geographical distribution of ICT activity throughout Europe. Our paper extends previous comparative analyses and sets high-tech growth within each area firmly in the context of the global ICT sector. Our key focus is the process of value generation and upgrading in each area which we consider using the notion of the global production network (Henderson et al., 2002; Ernst, 2002; Ernst and Kim, 2002).

Aside from the importance of high-tech growth in the development of the three economies, the comparative development of Ireland, Finland and Israel is all the more interesting because of a number of other shared characteristics. First, each economy is small, forcing firms to develop export markets if they are to maximise the potential for economies of scale in production, and appropriate the full benefits of any innovative activity. Second, each of the three economies is very open with Finland and Ireland full

¹ Sources: OECD Economic Outlook 69, Annex Table 1; Bank of Israel, Table B1.

members of the EU, and Israel benefiting from a free-trade agreement with the EU concluded in the mid-1970s. Third, each country shares a somewhat peripheral location in terms of access to 'core' European markets. Fourth, each country has limited natural resources and future competitiveness and growth therefore depends on their ability to compete in knowledge-intensive markets. Fifth, each of the countries has a very different history of industrial and technology policy which has shaped their involvement in global ICT markets. Some of the main contrasts are illustrated in Table 1, which highlights the dominant role of foreign direct investment (FDI) in Ireland, and the increasing importance of foreign direct investment in Finland over the 1997-99 period.

Sixth, central to the growth of each country was the rapid development of ICT activity in their major cities - Helsinki, Tel Aviv and Dublin. As Koski et al. (2002) notes: 'ICT-related businesses in Europe are concentrated around major urban centres' (p. 11). Cities may offer particular advantages for innovation and the development of knowledge-based industry in terms of the availability of highly skilled labour, high quality business services, and the local availability of technological and financial partners (e.g. Shefer and Frenkel, 1998). Cities may also act as international 'gateways' through which human, financial and informational resources flow into and out of a country (Simmie, 2002), and act as attractors for inward investment. Less tangible benefits may also result from an urban location in the form of externalities from academic research (e.g. Anselin et al., 1997; Anselin et al., 2000), or more generalised knowledge spillovers (Feldman and Audretsch, 1999; Zucker et al., 1998) arising from specialisation (e.g. Griliches, 1992) or sectoral diversity (e.g. Jacobs, 1969). Finally, cities may provide a more supportive environment and institutional framework for high-tech entrepreneurship than other more rural or peripheral areas (e.g. Cooke et al., 2002).

The central focus in the remainder of this paper is how, and why, ICT activity developed in the way it did in Dublin, Helsinki and Tel Aviv during the 1990s. National influences prove to be important but cannot be viewed in isolation from more global trends, in particular, the growth in global high-tech markets during the 1990s and increasing levels of international capital mobility. To reflect both the 'global' and 'local' dimensions of

each city's development, we base our analysis around the notion of a global production network which is outlined in Section 2. Section 3 then provides a brief overview of the ICT global production network of the 1990s and the implicit process of value generation and upgrading. Sections 4, 5 and 6 then focus on each of the three study areas in turn concentrating on the process of value generation and upgrading in each area and the particular role of inward investment, entrepreneurial activity and public policy. Section 7 briefly draws out some common themes and Section 8 concludes.

2. Embeddedness and the Global Production Network

The importance of the centripetal and centrifugal forces which lead to spatial agglomeration and the dispersion of commercial and industrial activity have long been recognised in both the geography and economics literatures. A desire to avoid local competition, the search for lower production costs, and costs of transportation may encourage dispersion; while positive Marshallian externalities, reduced transport costs and informational advantages may encourage spatial agglomeration and clustering (see, for example, the discussion in Koski et al., , pp.145-147). Arguably, however, global moves towards knowledge-based competition, accompanied by the rapid development of connectivity and global logistics, have radically shifted the historical balance between these centrifugal and centripetal forces. On one hand, the increasing importance of knowledge as the basis for competitiveness may have strengthened the centrifugal forces as 'knowledge spillovers tend to be spatially restricted....[this] has triggered a resurgence in the importance of local regions as a key source of comparative advantage' (Audretsch, 1998, p. 26). One reflection of this renewed interest in the region as a unit of analysis has been the growth of the literature on regional innovation systems (e.g. Braczyk et al., 1998), emphasising the capability of firms and other organisations and the degree of association within the regional economy. The focus of this type of literature has, however, been largely on the internal dynamic or composition of the region with much less attention paid to the position of the region in the wider global economy.

On the other hand, improved connectivity and global logistics might encourage the dispersal of commercial and industrial activity, and the geographical separation of

elements of the development and production process. For example, the increasing globalisation of R&D activity may mean that the spatial distribution of the commercial benefits of R&D activity may be very different to that of the R&D activity itself².

Attempts to understand the global distribution of ICT activity – encompassing both these centripetal and centrifugal forces - have drawn both on notions of localised advantages and global corporate and trading networks. Studies have been constrained, however, by the lack of a single framework unifying globalising pressures within the world economy, particularly in high-tech sectors, and the increasing empirical evidence pointing to localised agglomeration advantages in knowledge production and knowledge-based industries. Two recent attempts to overcome these difficulties have been the work by Ernst and others (e.g. Ernst and Ravenhill, 1999; Ernst, 2002; Ernst and Kim, 2002) and Henderson et al. (2002) on the notion of a global production network. Developed largely in parallel, both have attempted to develop ‘a conceptual framework that is capable of grasping the global, regional and local economic and social dimensions of the processes involved in many forms of economic globalisation’. More specifically, the discussion in Henderson et al. (2002), for example, suggests a definition of a GPN as *‘the global network of firms, institutions and other economic agents which shapes, and is shaped by: the fundamental processes of knowledge and wealth creation, enhancement and exploitation; corporate, collective and institutional elements of organisational power; and, spatial and network embeddedness’*. The intention here is clear; on the one hand to recognise the importance of globalising forces, and in particular the influence of multinational companies and international capital markets, while also encompassing the potential for significant local advantages and development trajectories.

Henderson et al. (2002) then identify three ‘conceptual categories’ which they argue characterise any specific Global Production Network: the process of value generation and upgrading; the role (and power) of firms, organisations etc; and, the degree of territorial

² Reddy (1997, p.1821-22), for example, comments that: ‘Today, new needs or trends can arise in any advanced market and the latest technologies may be located in another. Transnational Corporations (TNCs) attempt to gain a competitive advantage by sensing needs in one country, responding with capabilities located in a second, and diffusing the resulting innovation in markets world-wide’.

and network embeddedness. In terms of value generation, a key focus is on the way in which value added is actually generated within the GPN, a process which may be shaped by production and organisational techniques, inter-firm relationships or branding. Equally important perhaps – particularly in the rapidly developing high-tech sectors - is the process by which value added can be increased through, for example, technology transfers within the network, the degree of developmental interaction between network participants, and the capability of local firms to generate positive localised factor or organisational advantages or brand rents. Finally, there is the question of how value is appropriated by different localities. As Henderson et al., 2002, p. 449 remark: ‘It is one thing for value to be created and enhanced in given locations, but it may be quite another for it to be captured for the benefit of those locations. The pertinent issues here partly involve (a) matters of government policy, but they also involve (b) questions of firm ownership and (c) the nature of corporate governance in given national contexts’³. It is this mechanism of value generation and upgrading which forms the main focus of our empirical investigation.

In addition to the process of value generation and upgrading, Henderson et al. (2002) suggest two other factors which characterise a GPN; the distribution of power between companies, institutions and collective organizations including supra-national bodies etc; and, the extent of network and territorial embeddedness of the GPN. ‘GPNs do not only connect firms functionally and territorially but also they connect aspects of the social and spatial arrangements in which those firms are embedded and which influence their strategies and the values, priorities and expectations of managers, workers and communities alike’ (Henderson et al., 2002, p. 451). Two issues are of particular interest here. First, the extent to which inward investment by multinational companies is embedded in the host economy, and thereby provides a conduit for inward (and also perhaps outward) knowledge transfers (e.g. Morris, 1992; Wong, 1992; Young, Hood and

³ For example, in Israel it has been argued that despite high quality basic or scientific research, weaknesses in the capability or willingness of industry to exploit this research have led to a failure to appropriate subsequent value added. For example, Maital et al., 1993, p. 108: ‘Israel has failed to fully convert its scientific achievements into export led growth. In proportion to its GDP, Israel outpaced European countries in patents publications and citations, yet lagged in R&D intensive exports’.

Peters, 1994). Second, the extent to which local entrepreneurial activity has given rise to locally-owned (or at least locally based) enterprises which have developed sufficiently to become part of the GPN (e.g. Cooke et al., 2002).

3. The ICT Global Production Network

Despite considerable internal heterogeneity, a theme which we return to later, significant attention has focused on the anatomy and implications of the growth of global ICT industries during the 1990s. Feng et al. (2001), for example, emphasise: (a) the emergence of a knowledge-based sector producing goods and services with much broader transformational potential than earlier demand-constrained, knowledge-intensive sectors such as pharmaceuticals; (b) falling costs of information and the potential for new distribution channels which may stimulate new competition, creating opportunities for first movers and threatening established corporate players; and, (c) the reproducibility and non-rivalry of digital goods which creates a potentially new growth paradigm of increasing returns. These developments raise the possibility of new business models based on the Internet, and emphasise the importance of human and knowledge capital rather than the historically-important range of physical corporate assets. On the supply-side, this has led to discussion of the spatial distribution of the industry (e.g. Koski et al., 2002), the role of international capital markets (e.g. Baygan and Freudenberg, 2000), and the longer-term consequences of 'turbo-capitalism' (Feng et al., 2001). On the demand-side, ICT growth and diffusion during the 1990s had a profound impact on US productivity and an apparently smaller effect on productivity in Europe (e.g. Daveri, 2002).

Two other features of the ICT global production network of the 1990s are striking: the speed of global market growth, and the dominant position of the US both on the demand and supply sides. Figures from the World Information Technology and Services Alliance (WITSA), for example, suggest that global spending on ICT grew by an average of 8 per cent pa from U.S.\$1.3 trillion in 1993 to U.S.\$2.4 trillion in 2001 (WITSA, 2002). Within this market, around 40 per cent of global ICT spending is linked to telecommunications;

10 per cent to software; 20 per cent to ICT services; 20 per cent to ICT hardware; and, 20 per cent to firms' internal ICT services.

The second key feature of the Information and Communication Technology GPN is the market dominance of the US. OECD figures suggest, for example, that in the late 1990s the US accounted for around a third of global ICT employment. In terms of ICT spending the US was also dominant, accounting for more than 35 per cent of global ICT spend in 2001, a level equivalent to the *combined* spending of the next four countries i.e. Japan, Germany, the UK and France (WITSA, 2002). The US market therefore represented the key international market for technology companies, with Irish and Israeli technology companies often setting up their first international sales office in the US, sometimes as a prelude to an initial public offering (e.g. de Fontenay and Carmel, 2001). Similarly, in 1996, the OECD suggested that the US market accounted for \$212.7bn of the total \$460.3bn OECD market for IT, and \$118.1bn (55.5 per cent) of the \$249.0bn market for packaged software and services (OECD, 1998, Table 19). In terms of capital markets and outward-investment, the US was also dominant over this period. Baygan and Freudenberg (2000), for example, in their analysis of the internationalization of venture capital, note that new private equity funding in the US in 1999 totalled \$108.1bn compared to \$27.1bn in Europe; while venture capital funding totalled \$46.6bn in the US compared to \$12.9bn in Europe. The US was also the largest single source of outward merger and acquisition activity in 1998 with 23.8 per cent of global flows (Kang and Johansson, 2000).

4. Tel Aviv's ICT Node

(a) Origins and National Setting

The development of the Tel Aviv node of the ICT global production network in the 1990s has its roots in longer term measures to promote high-tech growth and ensure national security in Israel, two aspects of Israeli development which are inevitably inter-related. In particular, the continuing security threat to Israel has, over the long-term, discouraged

inward investment and necessitated a largely independent development strategy⁴. In the context of strong external threats, as early as the 1960s, for example, the Israeli government was supporting the development of Science Parks at the universities (e.g. the Kiryat Weizmann Science Park in 1967 at Rehovot; Felsenstein, 1994) and giving R&D grants to individual firms (Teubal, 1993). During the 1970s, the Israeli economy became more open to trade; bi-national R&D funds were established and, albeit relatively unsuccessful, attempts were made to attract inward investment, particularly to more peripheral areas (Shefer and Bar-El, 1993). Despite this, rapid structural change took place in the indigenously-owned sector as the military build-up continued and the related civil electronics and aircraft industries expanded. From 1968-83, for example, high-tech industry in Israel increased its share of output from 6 to 24 per cent and its share of exports from 5 to 28 per cent (Teubal, 1993). Macro-economic crisis in Israel in the early-1980s threatened the growth of indigenous high-tech industry, and perhaps more importantly, reshaped the political complexion of Israel and related social and industrial policy. Previous 'state regulated capitalism' had an implicit 'bias associated with deep antagonism, or even hostility towards small business-owners' and entrepreneurship. With changes in the political scene and a shift towards more free-market economic policies, a gradual change in attitude in favour of the small business sector occurred' (Feitelson, 2001). Geopolitical changes in the 1980s and early-1990s reinforced this effect, providing a more secure external environment and allowing the release from the military establishment of much of the human capital on which Israeli entrepreneurship of more recent years has been based. In particular, the cancellation in 1987 of the Lavi fighter project, the end of the Cold War and the easing of the geo-political situation in the Middle East reduced both export and domestic demand for military hardware and released substantial amounts of highly skilled labour into the Israeli labour market. In addition, post-1989, mass immigration to Israel from the former Soviet Union added nearly a million to the Israeli population and vastly increased the nation's endowment of human capital (Gandel et al., 2004). Simmons (1993), for example, notes that 40 per cent

⁴ The comparison with Ireland where development strategy has based largely on inward investment is illustrative here. This point is discussed in detail in Roper and Frenkel, 2000.

of early immigrants from the former Soviet Union were university graduates compared to 10 per cent of the existing Israeli workforce.

The development of the Israeli ICT sector during the 1990s has been ably described in De Fontenay and Carmel (2001) who note; first that over the 1990-2000 period Israeli exports of manufactured ICT products grew five-fold, while service exports grew by a factor of ten; second, they also note that after the mid-1990s employment in ICT services in Israel exceeded that in ICT manufacturing, and that by 2000, the ICT sector accounted for a third of all Israeli exports but only 6 per cent of national employment. A third facet of the Israeli ICT boom was the concentration of Israeli firms in the 'development' stage of the global electronics value chain, i.e. in niche sectors where competition is knowledge rather than cost-based and production volumes are relatively small. This is a marked contrast to Ireland where the electronics sector is much more concentrated in a specific product group and is more strongly geared to mass rather than niche market (Roper and Frenkel, 2000). An essentially similar contrast could be made between the Irish and Israeli software sectors: the Israeli sector concentrates on developing leading edge applications in imaging, voice response and recognition, artificial intelligence, data communications and network and software security; while the Irish sector - at least the externally-owned element - is focussed on the reproduction, distribution and marketing of software initially developed elsewhere (Crone, 2002; Teubal et al., 2000).

Israeli electronics exports are also diverse with no concentration in any particular product group although telecommunications equipment (44.5 per cent), computer equipment (16.4 per cent) and medical diagnostic equipment (8.1 per cent) were all important export products (Table 3). This diversity – at least within manufactured exports – stands in marked contrast to both Finland and Ireland where more than 60 per cent of electronics exports were telecoms equipment and computer equipment respectively. This difference in the sectoral structure of ICT manufacturing in the three countries suggests the potential for different types of agglomeration economies: in Ireland and Finland, as envisaged by Griliches (1992), for example, such economies might arise from specialisation; whereas

in Israel agglomeration economies may instead reflect sectoral diversity as envisaged by Jacobs (1969).

Israel's success in establishing a market position in knowledge intensive sectors is also evident in its role as a major global development centre for international ICT businesses like Intel, Motorola, IBM, Microsoft, Alcatel and 3Com, all of which have invested in R&D facilities in Israel. Felsenstein (1997) considers this in terms of 'reverse technology transfer' with multi-national companies investing in R&D laboratories in Israel to benefit from the strengths of the Israeli national system of innovation but then manufacturing the products developed elsewhere. More generally, however, it is difficult to get a clear impression of the scale of inward investment to the ICT sector in Israel. Overall, however, the extent of inward investment to Israel remains relatively low, with foreign affiliates accounting for around 9 per cent of GDP, a similar level to Finland, and only a quarter that of Ireland (Table 1)⁵. Again, one possible characterisation of the global market position of the Israeli ICT sector is given in Figure 1 which also represents those in Ireland and Finland described below.

Within Israel, Tel Aviv metropolitan area is the central hub of commercial and high-tech activity as well as the dominant international 'gateway' to Israel for people, capital and trade. The current population of the city is around 350,000 but, perhaps more important is that Tel Aviv is the core of Israel's largest metropolitan area, which covers around 2.65m million people. On the Eastern side, the metropolitan area of Tel Aviv is bounded by the Mediterranean; on the West, urban expansion is limited by the frontier between Israel and the occupied territories. Urban development has therefore largely followed the coastal

⁵ The US was a particularly important source of inward investment for Israel during the 1990s both in terms of the 'knowledge seeking' investment discussed by Felsenstein (1997) and more speculative investment in venture capital activity. By 1998, total US investment in Israel, however, was \$3,067m, around a fifth of US investment in Ireland (\$15,936m) but twice that in Finland (\$1,700m). Source: U.S. Department of Commerce, Bureau of Economic Analysis, available at, for example, www.state.gov/www/issues/economic/trade_reports/1999/finland.html.

strip to the North towards Netanya and to the South towards Rehovot. Over the past decade sub-urbanisation and ex-urbanisation have accelerated and limited gentrification of central areas has also taken place (Feitelson, 2001).

Employment in the Tel Aviv metropolitan area grew steadily during the 1990s reaching around 1.0m, with almost 330,000 people employed in Tel Aviv proper in 1999. The majority of this employment was in financial and business services (28.6 per cent), education and health (20.9 per cent), wholesale and retailing (13.6 per cent) and the other production industries which includes manufacturing (12.4 per cent)⁶. Per capita incomes and growth rates in the Tel Aviv metropolitan area were on average higher than those for Israel as a whole, although unemployment in the Tel Aviv area fluctuated between 7 and 9 per cent through much of the 1990s. In addition, an increasingly wide split in earnings between those employed in the globalised 'new economy' and commercial sectors and those in activities serving largely local markets.

(b) Value Creation and Upgrading

As indicated earlier, creating value added in high-tech industry has long been a concern of the Israeli state, a policy supported nationally with investment and technology grants. Unlike investment grants, however, R&D support has been available to firms in Israel regardless of location, although a locational premium has been paid for firms in less developed areas (Roper and Frenkel, 2000). This has probably favoured high-tech development in Tel Aviv and, together with the other advantages of a metropolitan location, encouraged a concentration of R&D-related activity.

A number of other factors have contributed to the concentration of ICT activity in the Tel Aviv area. First, Israel invests 0.62 per cent of GDP in R&D, compared to 0.54 per cent in Finland and 0.26 per cent in Ireland, and the Tel Aviv region is host to two of Israel's major universities (Tel Aviv University and the Weizmann Institute), and other significant research and educational institutions (e.g. the Soreq Nuclear Research Centre and the agricultural school of Hebrew University of Jerusalem). This contributes to a

⁶ Source: Statistical Abstract of Israel, 2000

knowledge-rich environment for high-tech development and ensures a supply of research trained staff. Second, Tel Aviv is the centre of the Israeli banking, finance and venture capital industries, and has strongly developed links to external financial centres and resources, particularly in the US. Third, Tel Aviv has a concentration of science parks and incubator units supported by the universities, local authorities, private companies and central government. Other industrial areas in Tel Aviv have no direct link to the universities but have also attracted significant high-tech activity. In particular, the Herzliya Industrial Zone to the North of the city (e.g. Digital Equipment, 3Com, Motorola) has been attractive because of the availability of greenfield sites and in more recent years other areas (particularly to the north-east of Tel Aviv) have also attracted high-tech facilities.

Fourth, firms in Tel Aviv probably enjoy 'cluster' based advantages due to a high concentration of other high-tech firms which might act as customers, suppliers, partners or sources of information or skilled manpower. In 2000, for example, the greater Tel Aviv area was said to contain 86 per cent of high-tech firms in Israel (see the discussion in Kipnis, 2001). Fifth, Felsenstein (1997) indicates that in Israel foreign-owned firms - particularly North American-owned businesses - have had a tendency to adopt metropolitan locations (Tel Aviv or Haifa). Notably he concludes that the advantage of such a metropolitan location must be outweighing the incentive benefits of more peripheral locations⁷. Sixth, Kipnis (1998) suggests there may also have been push factors which have encouraged Israeli firms to relocate to Tel Aviv, viz. 'Haifa City, once considered a competitive centre to Tel Aviv, has suffered for the past 30 years from a 'poor business climate' syndrome, and has gradually lost most of its assets. Catalysing this process was a transfer from Haifa to Tel Aviv of almost all of the established national companies' headquarters' (p. 655). Countering these advantages is what Kipnis (2001) has called Tel Aviv's position at a spatial 'dead-end' of the global economy, reflecting the weakness of Tel Aviv's embeddedness within the wider Middle East region.

⁷ Government financial aid has not been clearly directed in the past and still does not aid enough in offsetting peripheral disadvantages, explaining why grant incentives for development towns have not significantly influenced locational decisions of firms' (Shefer and Bar El, 1993, p. 251).

Entrepreneurship has also played an important part in the growth of ICT activity in Tel Aviv. Some notable companies were established by those leaving the Israeli Defence Force (see Cooke et al., 2002; De Fontenay and Carmel, 2001), while others were established as university spin-outs or entrepreneurial start-ups. Checkpoint, Memco and Aladdin, for example, all became world-leaders in their respective markets and numerous other Israeli companies achieved notable success in both capital and product markets. By the peak of the high-tech boom in 2000, De Fontenay and Carmel (2001) suggest Israel had about 4000 high-tech firms and new ones were forming at the rate of 500 start-ups per year. Commercial application of systems originally developed for defence purposes is only part of the story, however. Israel's academic and wider research community - bolstered by immigration from the former Soviet Union - also played an important part in the growth of 'Silicon Wadi'. De Fontenay and Carmel (2001) emphasise algorithmic innovations made at the Weizmann Institute and elsewhere in the development of the Israeli data security industry, while others have focussed on policy initiatives such as the small business advice centres or technology incubator network (e.g. Goldberg and Lavi-Steiner, 1996; Modena and Shefer, 1998; Roper, 1999), and R&D support (e.g. Trajtenberg, 2001).

Another key aspect of the development of high-tech business in Tel Aviv has been ready access to financial and venture capital support for small firms. The dominant position of Tel Aviv in the financial and business services sector in Israel is reflected the larger proportion of employment in this sector (28.6 per cent) than in either Helsinki (19.5 per cent) or Dublin (21.4 per cent) and in the fact that Tel Aviv holds around half of all banking jobs in Israel (16,000 out of 32,000). Tel Aviv and the surrounding areas also played a dominant role in the rapidly expanding Israeli venture capital industry during the 1990s. For example, of the 57 venture capital funds listed on the Israeli government's resource site for science in mid-2001, 85 per cent were located in the Tel Aviv metropolitan area, 13 per cent in Jerusalem and only one in Haifa. A similar concentration is evident in the geographical distribution of venture capital investments in

Israel. In 1999, 78 per cent of all investments were made in Tel Aviv area, 14 per cent in Haifa and the North and 8 per cent in Jerusalem⁸.

2. Dublin's ICT Node

(a) Origins and National Setting

Historically, Ireland does not have a strong industrial tradition like that found in Finland (e.g. Yearly, 1995). Neither has Ireland had the emphasis on applied scientific research which has so strongly characterised the development of the Israeli economy. Instead, since the late 1950s, industrial policy in Ireland has been based on the principle of 'industrialisation by invitation' and the attraction of inward investment. Prior to the mid-1980s, this investment was largely concentrated in computer and computer components. As a result, electronics exports from Ireland remain dominated by computers and computer components which together accounted for 63.5 per cent of all electronics exports (Table 3) and by 1998, meant that 61 per cent of electronics plants in Ireland were US-owned and that these plants accounted for 82 per cent of electronics employment.

As Ireland's dominant population and commercial centre the attraction of Dublin as an industrial location is to some extent self-evident. Early inward investment certainly tended to locate in or near Dublin to take advantage of labour market and logistic advantages. Since the early-1970s, however, attempts to attract high-tech inward investment to Ireland have been accompanied by a policy of dispersal. From 1969-76, the proportion of new high-tech plants being established in Dublin fell from 55 to 20 per cent, with a converse increase in establishments in less developed areas. More recent studies (e.g. Meyler and Strobl, 1997) argue that this trend has been sustained with the extent of external-ownership of manufacturing firms now similar in Dublin and more peripheral areas of Ireland. Moreover, a more sectoral focus adopted since the 1980s has contributed to the development of spatial concentrations of activity outside the Dublin metropolitan area, notably pharmaceuticals in the South West (i.e. Cork) and electronics in the Irish Mid-West and East (Meyler and Strobl, 1997). Despite the success of the

⁸ Source: Israeli High-Tech and Investment Report, Feb 2000 (www.isitech.co.il).

policy of dispersal of high-tech activity a distinct concentration of electronics manufacturing plants in and around Dublin is still evident. In 1998, for example, 27.8 per cent of all manufacturing plants in Ireland were located in the Dublin region which accounted for 43.6 per cent of plants manufacturing office machinery and computers (Nace 30) and 34.3 per cent of plants manufacturing electrical machinery and apparatus (Nace 31).⁹

More recent figures, published by the National Software Directorate in Dublin, suggest that in 1998 the software sector in Ireland employed 21,630 of which 9,250 were working in indigenously-owned companies and 10,650 in externally-owned businesses. A further 1,730 were working in software firms that were originally indigenously-owned but were subsequently acquired by externally-owned firms. By contrast to externally-owned software firms, Irish-owned software firms are typically smaller, more strongly 'product' and export focussed, and selling applications into specialised markets for process industries, financial services and distribution. This difference in activities and market positioning is reflected in figures for the software industry. In 1998, indigenously-owned firms, for example, accounted for 42.8 per cent of employment but only 13.7 per cent of sales and 9.7 per cent of software exports from Ireland.

The growth of the Irish software sector has been particularly important in Dublin where the industry is very strongly concentrated. O'Malley and O'Gorman (2001), suggest that 76 per cent of overseas software companies were located in the Dublin area as early as 1991, and that 67 per cent of indigenous software companies were located in the Dublin region in 1995. O'Malley and O'Gorman (2001), highlight four factors which they regard as having been particularly important in underpinning the growth of the indigenous software sector in Dublin: the availability of skilled graduates; grant support; domestic demand from Transnational Corporations (TNCs); and, the work experience provided by inward investors to future software company founders. Urban regeneration measures, including the re-development of Custom House Docks as an International Financial

⁹ Source: Census of Industrial Production, 1998, Table 20.

Services Centre, and more recently the designation of two further docklands Enterprise Zones supported by the Industrial Development Agency (IDA), have also helped to attract ICT service activities to Dublin.

To summarise, the Dublin node of the ICT global production network may be said to comprise three main elements. First, the Dublin region has a more than proportionate share (around 44 per cent) of high-tech manufacturing plants, located predominantly in the urban periphery. These plants, like much of the Irish electronics sector, are strongly oriented towards the production of computers and computer components. Second, Dublin also hosts a large proportion (perhaps 80 per cent) of software inward investment to Ireland. Primarily these are investments by US companies designed to localise, produce and market existing software products for the European and other markets. Third, Dublin also hosts perhaps the same proportion of a rapidly growing indigenous software sector which by 1999 was almost equivalent in terms of employment to the externally-owned software sector.

(b) Value Creation and Upgrading

Two quite distinct value creation processes are at work within the Dublin element of the ICT global production network. First and dominant in value terms at least, is that firms located in Dublin - and in Ireland more generally - play a key role in a process by which technology developed outside Ireland is embodied in physical hardware and software in large-scale production and support operations. US high-tech firms, in particular, have over the last three decades made substantial investments in Ireland to serve European ICT markets. Local capacities and advantages play relatively little role in either value creation or value upgrading in these plants, which typically depend on inward technology transfer for new product developments etc. Indeed, beyond their labour input the links of many such plants to the indigenous economy are weak, and local value appropriation is limited due to the repatriation of profits. Moreover, in the absence of solid evidence to the contrary, O'Sullivan (2000) expresses considerable skepticism about the extent to which

linkages between indigenous and foreign-owned companies in Ireland are contributing in any significant way towards supporting either a dynamic process of innovation or an upgrading of labour force capabilities.

The second value creation process at work in Dublin is that associated with the indigenously-owned software sector. Although demand for this sector is related to the growth of externally-owned ICT capacity in Ireland as O'Malley and O'Gorman (2001) note, value generation here is locally driven and value upgrading is also largely the result of local innovation and enterprise (Crone, 2002).

The development of these two distinct value creation processes is linked both to the history of inward investment to Ireland and to local social and industrial policy. For example, until the late 1990s - in contrast to both Finland and Israel - levels of public investment in R&D in Ireland were low, suggesting a relatively low level of public commitment to the development of indigenous technological capacity. Even as late as 1997, total R&D investment in Ireland at 1.4 per cent of GDP was only around half of that in Finland and Israel. Business R&D (1.03 per cent) was also low by international standards and was highly concentrated in externally-owned enterprises. Since 1997, however, significant steps have been taken in Ireland to develop indigenous technological capacity. Research funding available to the universities has been increased substantially and other major increases in support for business R&D have also been announced.

More positive - and some would argue crucial to the development of ICT activity in Ireland - has been the expansion in Irish higher education since the 1970s. The development of the Regional Technology Colleges throughout Ireland, and developments in the university network, have benefited other urban centres (e.g. Galway, Limerick), but both further and higher education places remain disproportionately concentrated in Dublin (e.g. Roper et al., 2002). Irish higher education's effect on industrial development, however, has largely been through the provision of a better educated workforce, with the universities themselves having, until very recently, weak industrial and commercial linkages. Kloftsten and Jones-Evans (2000), for example, compare the contribution of

higher education to economic development in Ireland and Sweden, and argue that while there is considerable entrepreneurial experience among academics in Ireland, and that this translates into a high degree of involvement in 'soft' activities such as consultancy and contract research, it has resulted in relatively few technology spin-offs.

Other aspects of the operating environment for high-tech business in Ireland have also proved positive in sustaining the process of value creation, particularly through inward investment. Grants and subsidies for investment, an English language base, free access to EU markets and wage levels which have been until recently moderate by Northern European standards have combined with a 12.5 per cent corporation tax rate applied to both manufacturing and tradable services activities. Another factor worth highlighting, particularly in terms of recent developments in Dublin, have been positive partnership arrangements between government agencies and private sector developers. The evident success of developments in the Designated Areas is one example. Another, more recent, example is the partnership between the Industrial Development Agency and a private sector property company to establish the National Digital Park for e-commerce development at the Citiwest Business Campus. The cumulative impact of these environmental conditions and investment incentives is obvious both in terms of the composition of Irish high-tech industry and in the scale of FDI flows. From 1997-99 FDI into Ireland was equivalent to 47.5 per cent of aggregate investment (i.e. gross domestic capital formation) compared to 26.3 per cent in Finland and only 9.1 per cent in Israel (Table 1).

By contrast, until the late 1990s, support for high-tech entrepreneurship in Ireland was relatively limited, with few significant incubator facilities, and relatively low levels of venture capital availability. Unlike Israel, the general support framework (i.e. grant and subsidy availability) for high-tech start-ups was also similar to that for larger and established businesses. In recent years, however, business incubation facilities have developed, and venture capital availability in Ireland has increased significantly. Through the Seed and Venture Capital Measure of the Operational Programme 1994-99, Enterprise Ireland with support from the European Regional Development Fund have co-

funded a number of venture capital funds and made available (€90 million) targeted at growth oriented SMEs. This funding is strongly concentrated in Dublin, however, which for example was home to 17 of the 18 venture capital funds highlighted by the National Software Directorate. (The exception, Shannon Ventures Ltd, is based on the National Technology Park, Limerick). Irish based venture capital funds totalled around \$120m in 1999, of which \$102m was invested in domestic companies and \$10m was invested outside Ireland. In addition \$380m was invested in Irish companies by venture capital funds located elsewhere. In other words, of a total investment of \$482m in Ireland in 1999, 79 per cent came from outside the country (Baygan and Freudenberg, 2000, Table 5). This level of external dependence is high by European standards with only Denmark having a broadly similar profile.

6. Helsinki's ICT Node

(a) Origins and National Setting

Helsinki is the political capital, financial and trade centre, and largest city in Finland, with a population of 555,000. The Greater Helsinki Region (GHR) has 1.8 million inhabitants out of a national population of 5.2m, and the city region has grown faster than the rest of Finland since 1990 both in terms of population and employment (Tukiainen, 2003, p. 11). In 2000 the Greater Helsinki Region accounted for 48 per cent of all ICT jobs in Finland (59,000) and 37 per cent of all employment.

The dominant position of Helsinki, and more generally the GHR within Finland, is largely historical and developed from Finland's close historical links to its Eastern neighbours. From the mid-1940s to the late 1980s, the development of Finland was closely intertwined with that of the former Soviet Union. From the mid-1950s, Finland adopted a strategy of *investment-driven* growth in traditional forest, and metal and engineering industries with very limited inward investment. In the mid-1980s, Finnish industry and government began to pay increasing attention to the development of high technology, and R&D investment rose from less than 1.5 per cent of GDP in 1985 to more than 2 per cent in 1991.

Following the collapse of the former Soviet Union, Finland experienced a significant recession; GDP declined by 10 per cent between 1991 and 1993, unemployment reached 16.6 per cent in 1994, and the government experienced a substantial budget deficit. This precipitated a significant change in policy with a move towards promoting an *innovation-driven* economy through the development of industrial clusters. This involved first, substantial investments in domestic R&D which reached 3.1 per cent of GDP by 1999, with 44.6 per cent of the Finnish total expenditure concentrated in the Helsinki region. Second, Finland pursued a policy of active participation in EU R&D programmes: by 2000, the volume of European cooperative R&D in Finland was nearly FIM 1 billion (€170 million) annually. Third, strong public institutions have been maintained and developed to support technological development. A key actor has been TEKES, Finland's National Technology Agency, which provides funding and expert services for R&D projects and promotes national and international networking. Fourth, part of the policy transition involved the internationalization of the Finnish capital markets with the abolition of laws restricting foreign ownership. As the restrictions were removed, foreign investment rose rapidly and by 2000, foreign holdings accounted for 74 per cent of the total market capitalization of the Helsinki stock market (Steinbock, 1998, Chapter 10). Fifth, the public authorities adopted a progressive attitude towards all forms of mobile communications (see, for example, Paija, 2000; Steinbock, 2001).

As a result, ICT activity in Helsinki grew at an average annual rate of 20 per cent (manufacturing 32 per cent, services 12 per cent) from 1992-99. By 1999, the value of production amounted to an estimated €21.4bn of which more than 70 per cent was equipment manufacturing and electronic components. A key, if not the crucial, influence on the Helsinki node of the ICT global production network was the emergence of Nokia as the leading global supplier of mobile phones (Nokia's global market share in 2001 was 37 per cent). By 2001, Nokia also had 18 production facilities in 10 countries, was conducting R&D in 15 countries, and had a significant sales presence in 130 countries worldwide. The growth of Nokia was fuelled by rapidly expanding markets but was facilitated by external capital which meant that by 2000, 90 per cent of Nokia stock was

held outside Finland. Nokia's operations remain strongly concentrated in Finland, however. Approximately 60 per cent of the firm's R&D remains in Finland along with some 55 per cent of the firm's entire production volume (Steinbock, 2001). The symbolic importance of Nokia in the growth of the Finnish ICT sector is hard to over-estimate; the firm's quantitative importance is also significant, however, accounting for around 20 per cent of all Finnish R&D spending, around 70 per cent of the total capitalisation of the Helsinki stock exchange, and around half of all ICT employment. In 1999, ICT employment was estimated at around 83,000 in Finland. Nokia itself employed 21,000 in Finland and a further 15,000 were employed in Finnish sub-contractors¹⁰.

A number of strengths of the Helsinki node of the ICT global production network are worth highlighting. In particular, the node is strongly embedded in the wider economy through technological, corporate, organizational and governmental links. Within the corporate sector this is epitomised by strong local supply-chains and a strong dependence on locally-conducted R&D¹¹. This is in marked contrast to both Ireland and Israel both of whose global market position is more concentrated in a specific stage of the ICT value chain than that of Finland where activity is more vertically integrated. The strong position of Nokia in the downstream elements of the value chain also means that a high proportion of the value added resulting from Finnish R&D is captured by other Finnish companies. Van den Berg and Van Winden (2002) also stress, however, the positive role of policy makers in Helsinki in promoting such synergies between indigenous companies in related ICT sub-sectors.

A number of weaknesses of Finland's ICT sector have also been highlighted, however. First, and most obviously, growth has depended significantly on the international success of Nokia. Second, and partly as a result of the dominance of Nokia and mobile telephony, there is a lack of diversity within the Finnish ICT sector, evident in the strong concentration of exports in telecommunications equipment (Table 3). In more human terms too Finland remains the most ethnically homogeneous country in the EU due to its

¹⁰Source: "Nokia jakaa kasvun ja kivun", Helsingin Sanomat, August 1, 1999.

strict, longstanding application of immigration policies and, to a lesser extent, its geographic location, harsh climate, and difficult language. Lack of cultural diversity arguably makes it more difficult to address international markets, restrict personal international networks, and may limit creative diversity within Finnish companies. Other potential difficulties relate to the more general business environment in Finland, particularly high tax rates and the maintenance of Finland's high cost social welfare provisions. More specifically, van den Berg et al. (2001) highlight the weakness of organising capacity at the metropolitan scale in Helsinki, arguing that 'One of the main shortcomings is that there is no integral vision and strategy regarding telecom and new media on a metropolitan level. This hampers the dynamics of the cluster, as synergies and new combinations remain unused' (p. 96).

(b) Value Creation and Upgrading

The development of Finland's ICT sector during the 1990s was largely an urban phenomenon with strong population growth and job increases taking place in only a handful of urban regions, first and foremost in Helsinki (Susiluoto and Loikkanen, 2001). Between 1988 and 1999, for example, the ICT share of total production in Helsinki rose from 17 per cent to 23 per cent (Tukiainen, 2003, p. 23). Within the Helsinki region, however, ICT and related activities are strongly concentrated to the South and West of the metropolitan area, and are almost non-existent in eastern Helsinki, northern Espoo and Vantaa. These concentrations of activity reflect different origins: in Espoo the sector has evolved around Helsinki University of Technology; in Ruoholahti the concentration is a result of city planning policies; while the traditional concentration remains in Helsinki city centre (see also den Berg et al, 2001, pp. 82-85). One consequence is that unemployment rates have tended to be lower in the Greater Helsinki Region than in other parts of Finland and average levels of productivity have been estimated to be up to 50 per cent higher than those in Finland's weakest regions (Susiluoto and Loikkanen, 2001).

¹¹ Although van den Berg et al. (2001) do identify the need for more technology transfer from larger innovative companies to smaller firms in Helsinki and advocate the potential value of such initiatives at a metropolitan scale.

High levels of domestic R&D investment by the business, higher education and public sectors, supported by effective technology transfer institutions (e.g. Tekes, SITRA), have provided the primary basis for value creation in the Finnish ICT sector. In Helsinki, the university sector is particularly important, dominated by Helsinki University of Technology and the University of Art and Design Helsinki, Arabianranta. Also important are the eight polytechnics in the Helsinki region, of which two provide significant ICT training (Helsinki polytechnic Stadia and the EVTEK institute of technology). The impact of the universities and polytechnics on Finnish industry is all the more significant because of a well established tradition of close liaison with industry. Such cooperation has been strongly supported by grant support for collaborative projects from Tekes and the partnership based research activities of the *Technical Research Centre (VTT)*. The largest public research unit in Finland, VTT carries out technical and techno-economic R&D in its own right and in partnership with universities and industry. The organisation has more than 3000 employees of which 2159 work in the Helsinki region (Espoo).

Accompanying these sizable investments in R&D have been attempts to turn Helsinki metropolitan region into a “learning city.” Local initiatives focussing on education, IT skills, promotion of competitiveness, improving entrepreneurship, and opportunities for interaction and cooperation have been supported by national policy intended to develop Finland into an information society through the cultivation of ICT activity, as well as investments in education, research, and product development.

Value appropriation from ICT related R&D in Finland has been shaped largely by Nokia's strategic decisions during the 1990s, and in particular by the decision not to vertically integrate into semiconductors (unlike its direct rivals Motorola, Ericsson). Instead, in addition to developing its R&D networks, Nokia focused on the downstream side of the value chain (e.g. brand, segmentation, design), and developed extensive and long-term supplier relationships with other companies within the Finnish ICT sector. This strategic decision, together with Nokia's dominance, has had important implications for the development of the Finnish ICT sector and local enterprise. On the positive side, outsourcing by Nokia has created growth opportunities and challenges for Finnish firms.

Nokia's sourcing strategy also contributed strongly to the development of ICT activity in the Greater Helsinki Region which provides the base for almost all Nokia suppliers.

On the more negative side, the importance of Nokia as a lead customer has meant that many Finnish firms have developed as subcontractors, possessing little strategic flexibility. Business models have had to be customized to Nokia's requirements, with suppliers forced to focus on cost reduction strategies rather than developing independent market positions (Steinbock, 2001). The increasing requirement during the 1990s for Nokia's suppliers to be able to supply globally has also dominated firms' investment decisions, forcing a dependence on a single major customer relationship. Third, and of broader consequence for the Finnish ICT sector, has been that the domestic *supporting* sector has specialised in meeting the needs of Nokia rather than developing any significant diversity.

High-tech entrepreneurship and start-ups have also yet to achieve prominence in the Finnish ICT sector industry despite substantial development in terms of venture capital and other supports for entrepreneurial activity in Finland. Venture capital support, in particular, expanded rapidly during the 1990s stimulated by the Finnish government's policy of pump-priming venture capital investment since the launch of the Start Fund of Kera Oy in 1990. By the end of 2000, Finland's Venture Capital Association had 35 member organizations of which half a dozen were public venture capital organizations, such as SITRA, and the rest were private venture capital firms, such as Eqvitec Partners, CapMan Capital Management, and Merita Capital. Private venture capital accounted for 91 per cent of funding although the dominant source of funds remained Finnish in origin. In addition to the wider availability of VC funding, a number of other positive influences on entrepreneurship in Finland are worth highlighting. First, as indicated above, Finland has a well developed and commercially focused higher education system and an institutional and financial commitment to supporting commercially oriented research. Second, through TEKES, SITRA and the Employment and Economic Development Centres (TE-centres), Finland provides substantial public support for start-up companies. Third, schemes designed to allow start-ups to draw on the managerial resources of

Finland's larger companies through mentoring/guidance programmes have been developed to increase the probability that high-tech start-ups succeed.

The liberalisation of Finland's capital markets and the relaxation of regulations on external ownership of Finnish companies in the early-1990s also opened the door to greater external involvement in the Finnish economy. The nature of the involvement has been very different, however, to that in Israel and Ireland. In particular, external investment has been primarily attracted by established companies such as Nokia, by other ICT businesses and - to a more limited extent - by the potential rewards of venture capital investments in Finnish ICT start-ups. Very little investment has flowed into Finland with the intention of developing the large-scale production facilities which have characterised inward investment to Ireland. In other words, inward investment to Finland during the 1990s was primarily attracted by Finnish technology and enterprise rather than other factor endowments. Inward technology transfer accompanying the investment was therefore limited, with external investment facilitating the development of the Finnish element of the ICT global production network rather than having any very profound impact on its technological trajectory.

7. Discussion

As we have seen, hyper-capitalism in the ICT global production network during the 1990s created new opportunities for Helsinki, Dublin and Tel Aviv. Their final positions within the ICT global production network are summarised in Table 4, ranking each influence on the local ICT node as either dominant (D), High (H), Medium (M) or Low (L). Knowledge generation in Dublin, for example, was dominated by inward technology transfer while both the Helsinki and Tel Aviv nodes of the ICT global production network drew more strongly on the local knowledge base. In Helsinki, public and private R&D investments supported the highly effective globalisation strategy of Nokia to create a strongly localised, vertically-integrated and strongly specialised node around mobile telephony (Table 4). Value creation in the more diverse Israeli ICT sector was also based primarily on locally developed technology, university R&D and the commercialisation of technology developed initially for military applications.

Partly as a result of these patterns of knowledge creation and diffusion, the primary mechanisms for knowledge exploitation and appropriation also differed between the three cities (Table 4). In Dublin, local appropriation from ICT activity was largely through wage receipts and local service provision as well as local corporation taxes. Profits from the sector were largely remitted to US-based parent companies. Weak local supply chains also meant that generally indigenously-owned Irish manufacturing firms derived little direct benefit from ICT growth, the exception being the entrepreneurial and indigenous Irish software sector, which developed rapidly through the 1990s (e.g. Crone, 2002). By contrast, ICT activity in and around Helsinki, centred on Nokia, was dominated by indigenously-owned firms with strong local supply chains ensuring local value appropriation (Table 4). Entrepreneurship, however, remained relatively unimportant in Finland until the late 1990s, unlike Tel Aviv where an entrepreneurial dynamic – backed by inflows of knowledge seeking capital - was the dominant driver of ICT development during the 1990s (e.g. Cooke et al., 2002).

Beyond the process of value generation and upgrading, Henderson et al. (2002) identify two other elements of a global production network: the balance of power between corporate, collective and institutional actors, and territorial and network embeddedness (Table 4). Of the three cities, corporate power has probably had the most prominent role in ICT development in Helsinki with the dominance of Nokia and its almost symbiotic relationship with the Finnish government. No single company has played such a consistently significant role in either Tel Aviv or Dublin, although companies such as Checkpoint and Iona Technologies have been symbolic of positive developments in each area. Collective power in terms of representative business and labour organisations were a benign influence in each country during the 1990s, with organisations such as the Irish Software Federation and the Finnish Venture Capital Association playing a positive developmental role (Table 4). Perhaps more important in shaping ICT development were institutional and governmental power, particularly in Israel and Finland (Table 4). In both countries, government adopted a proactive stance throughout the 1990s, investing heavily in R&D infrastructure and activity, concentrating resources on higher education R&D,

and focussing on the development of the national innovation system. In Ireland, by contrast, despite the acknowledged importance of technological development (e.g. Government of Ireland, 1996), levels of public investment in R&D remained relatively low by international standards until the late 1990s.

The nature of the value creation and upgrading processes in three cities clearly suggest a distinction in the territorial embeddedness of ICT activity between Tel Aviv and Helsinki on the one hand and Dublin on the other (Table 4). In terms of network embeddedness, however, the distinction between the three cities is defined primarily in terms of their position within the global ICT value chain. Two factors characterise this position: the degree of vertical integration within each cities' ICT sector, and the degree of diversity of ICT activity (Figure 1). In Tel Aviv, for example by 2000, ICT activity was strongly integrated into the early (developmental) stages of the global ICT value chain across a diverse range of industry sub-sectors. In Dublin, activity was less diverse, and also concentrated in the production/distribution segment of the global ICT value chain. In Helsinki, ICT activity was focussed around mobile telephony and its applications with a high degree of vertical integration.

For each of the cities considered here, participation in the ICT boom of the 1990s brought substantial benefits; however, participation was not costless, with each city facing labour shortages, congestion, rising housing costs and increasing income disparities. For example, Felsenstein (1996) notes that even by 1996 large high-tech firms in Tel Aviv were drawing employees from the Haifa, Jerusalem and Beersheva areas up to a 100km away. 'High technology firms are therefore transforming metropolitan labour markets into national labour markets'. Essentially similar issues have meant that road congestion and rapidly rising house prices have also become a barrier to development in Dublin due to urban extension, inadequate public transport infrastructure and inconsistent local and metropolitan planning policies (McGuirk and MacLaren, 2001). Congestion has been less of an issue in Helsinki, but here too housing prices rose rapidly during the 1990s (Tukiainen, 2003). In addition, Vaattovaara and Kortteinen (2003) note that in Helsinki developments in the ICT sector (or more widely 'informational development') have led to

an increasing gap between the demand for skilled and less-educated workers. This, in turn, has contributed to a polarisation of the income distribution, a breakdown in the egalitarian Nordic welfare regime, and the development of a more bimodal socio-economic structure of 'haves' and 'have-nots' that 'seriously challenges the egalitarian ethos of the regime' (Vaattovaara and Kortteinen, 2003, p. 2143).

8. Conclusions

Our focus in this paper has been on the development of ICT activity in Tel Aviv, Dublin and Helsinki through the boom period of the 1990s. What is obvious is that the development path of each city was strongly conditional on its inherited technological and institutional capabilities as well as local and national policy initiatives during the 1990s. In each city, however, the strength of the influence of inherited capabilities and current policy was different. In Tel Aviv, development during the 1990s was perhaps most strongly dependent on past investments in knowledge generation capability in the universities and military establishment, with a liberal policy environment during the 1990s, and an easing of security pressures, encouraging high-tech entrepreneurship. In Helsinki too, prior investments in knowledge generating capacity and a well established social and economic consensus were important in the developments of the 1990s. Equally important, however, were policy liberalisation - particularly in respect of capital markets - and, given its flagship role, the strategic decisions made Nokia. In Dublin, and more generally in Ireland, ICT development during the 1990s probably depended more strongly on the current policy stance, with inherited effects being weaker than in either Helsinki or Tel Aviv. In particular, the importance of inward investment over this period meant that ICT development in Dublin essentially represented a break with the past rather than the process of organic and cumulative development seen in Tel Aviv and Helsinki¹².

¹² It could be argued however that in Ireland the policy stance of the 1990s was itself part of the inherited legacy since the policy of 'industrialisation by invitation' based on attracting inward investment had been in place since the late 1950s.

Local conditions were important but equally important to each city's development, was the availability of internationally mobile capital during the 1990s. For Dublin this came primarily in the form of inward investment complete with related inward technology transfers. For Helsinki, this was primarily rent seeking capital, epitomised by the increase in market value and internationalisation of ownership of Nokia. For Tel Aviv the picture was slightly more complex with externally funded venture capital growth running alongside knowledge seeking inward investment in R&D and development facilities. In each case external capital facilitated the exploitation of each city's specific advantages, and to a greater (Dublin) or lesser (Helsinki) extent changed the cities technological and development trajectory.

In each case therefore, what we observe in terms of ICT development during the 1990s was the result of competing, and sometimes complementary, local, national and global factors. Adopting a purely local focus would have restricted our view of the position (i.e. network embeddedness) of each city's ICT activity within the global value chain. Adopting a purely international perspective would have masked important differences in the process of value generation and upgrading and territorial embeddedness of ICT activity in each area. The global production network, encompassing both local and global forces, overcomes these difficulties and has provided a valuable lens through which to view these local-global interactions and developments. Equally clear, however, is that in this paper we have only begun to scratch the surface of the local-global interactions which have shaped ICT development in each area. A valuable next step would be to examine in much greater detail the pattern and development of local-global linkages in each city, focusing on each local-global dyad and considering actors' ability to contribute to value generation, power and motivation.

Table 1: Foreign Direct Investment and Transnationality Indicators

	Finland	Ireland	Israel
FDI inflows as per cent of gross domestic capital formation 1997-1999	26.3	47.5	9.1
FDI inward stock as per cent of GDP	14.3	45.4	17.9
Value added of foreign affiliates as per cent of GDP	9.5	40.2	8.7
Employment of foreign affiliates as per cent of total employment	10.1	9.8	10.2
Transnationality index	15.0	35.7	11.5

Source: The World Investment Report 2002, United Nations, New York. Annex table A.1.6. p. 275.

Table 2: Scale and Importance of the ICT Sector: 1998

	Employment in ICT (000s)	Share of Empl. In Business Sector (per cent)	Share of Value Added in Business Sector (per cent)	Share of ICT R&D in total business sector (per cent)	Share of ICT in Exports (per cent)	Share of ICT in Imports (per cent)
Finland	88	5.6	8.3	51	16.1	19.6
Ireland	56	4.6		47.7	33.9	32.6
Israel	148	6	12.7	85	14.1	30.1
G7	10449	3.8	7.4	35.3	13.5	12.8
EU 15	4441	3.9	6.4	23.6	11.8	10.1
OECD	12800	3.6	7.4	34.6	13.2	12.5

Sources: OECD (2000), Central Bureau of Statistics, 2002.

Table 3: Composition of Exports of Electronic Products: Finland, Ireland and Israel

SITC.3	Product Group	Finland %	Ireland %	Israel %
751	Office Machines	0.3	0.4	0.0
752	Computer Equipment	8.9	38.4	16.4
759	Office Equip Parts/Accs.	1.5	25.1	6.0
761	Television Receivers	1.8	0.0	0.0
762	Radio Broadcast Receiver	0.1	0.0	2.3
763	Sound/TV Recorders Etc	0.3	0.1	0.4
764	Telecomms Equipment Nes	62.5	14.1	44.5
771	Elect Power Transm Equipment	6.8	1.8	1.2
772	Electric Circuit Equipment	3.8	3.9	7.5
773	Electrical Distribution Equip	3.0	1.5	0.9
774	Medical Etc El Diag Equip	3.0	0.2	8.1
775	Domestic Equipment	2.2	0.9	0.2
776	Valves/Transistors/Etc	3.0	11.1	7.3
778	Electrical Equipment Nes	2.9	2.4	5.1
	Total	100.0	100.0	100.0

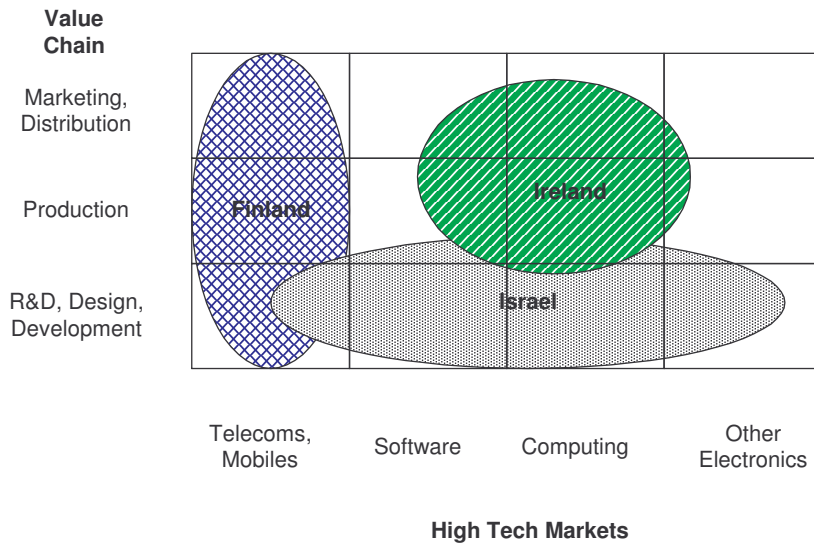
Note: Finland and Israel, 1998; Ireland, 1999.

Source: UN Statistics Division, COMTRADE database.

Table 4: Qualitative Summary of GPN Structures
(D, Dominant; H, High; M, Medium and L, Low)

	Tel Aviv DHML	Dublin DHML	Helsinki DHML
1. Value generation and upgrading			
1.1 Knowledge generation			
Universities	H	L	M
Business R&D	H	L	H
Inward Technology Transfer	L	D	L
Diversity	H	M/L	L
1.2 Knowledge diffusion			
B2B Networks	M	L	H
B2G Networks	H	L	H
Local Supply Chains	L	L	H
1.3 Knowledge exploitation			
Entrepreneurship	H	M	L
Inward Investment	L	D	L
Exiting Indigenous Industry	M	L	D
2. Power			
Corporate	L	M	H
Collective	L	L	L
Institutional	H	M	H
3. Embeddedness			
Territorial	H	M/L	H
Network	H	M	H

Figure 1: Global Positioning of Irish, Finnish and Israeli ICT Sectors



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