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Information Exchange and the Geography of Production Linkages – The Microcomputer Industry in Ireland and Scotland

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Information Exchange and the Geography of Production Linkages: The Microcomputer Industry in Ireland and Scotland

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Abstract

This paper considers the idea that technical information exchange in the context of Time-Based-Competition encourages buyer-supplier proximity and local production linkages. The relevance of this idea was tested in a study of 11 subsidiaries of multinational microcomputer assemblers operating in Ireland and Scotland. We show that the assembly plants sourced the vast majority of inputs from regions outside Ireland and Britain and where we find regional linkages, proximity was generally not driven by considerations related to information exchange. Part of the explanation lies in the fact that the European operations played a limited role in technological co-ordination with suppliers. Another reason is that much of the technical information exchange in the industry is of a relatively limited intensity requiring low levels of face-to-face contact.

Key words:

Computer industry; Multinational enterprises; Linkages; Information exchange

Introduction

It has been argued that the economic crisis of the mid-1970s was a 'crisis of Fordism' (AMIN, 1994; SCHOENBERGER, 1997). According to this argument, the Fordist industrial paradigm of assembly-line-based mass production of standardized goods (ASHEIM, 1992) and its methods of work organisation had reached their limits in terms of productivity growth. Furthermore, due to its inherent rigidities (SAYER, 1986), the Fordist system was unable to cater for modern markets. According to some, the capitalist world entered a new era, characterized by a new competitive environment that required a new style of competition and a new mode of industrial organisation – Time-Based-Competition (TBC) (SCHEONBERGER, 1997; STALK, 1988; STALK and HOUT, 1990).

In this new era producers are facing a very different competitive environment characterized by a demand for variety, quality and responsiveness and shorter product life cycles. The role of time in competition has changed drastically. Firms now compete primarily on the basis of their ability to compress time in all elements of the value chain and, beyond that, in the firms' relations with upstream and downstream partners. The central focus is on reducing product development times and order-to-delivery cycles. This results in a highly flexible production system that offers a combination of fast response, increased variety, high value and low cost (STALK and HOUT, 1990).

SCHOENBERGER, 1997, postulates that the rise of TBC will have repercussions for the geography of production and regional development. She depicts a stylized scenario of 'concentrated deconcentration' where the multinational firm creates tightly integrated production complexes in each of its primary market regions, including, for example, North America, the European Union, East Asia and Southeast Asia. The regional complexes would include various manufacturing functions as well as some degree of technical and strategic responsibility which would allow the firm to respond to particular needs of the individual regional markets.

She also postulates that TBC will encourage greater proximity between buyers and their suppliers and an increase in local and regional production linkages. The argument can be reduced to two buyer-supplier proximity drivers: efficient technical information exchange and efficient product flow or logistical efficiency. As regards the first driver, in the new environment of TBC the necessity to increase the speed and efficiency in product development requires an active involvement of suppliers in the product and process development process and increased inter-firm functional integration. The development process involves a continuous exchange of technical information. This exchange is facilitated by increased face-to-face interaction which is thought to require buyer-supplier proximity. In relation to the second driver, efficient product flow, one of the central targets of TBC is a reduction of the order-to-delivery cycles or chain cycle times (STALK and HOUT 1990). Towards this end TBC envelopes the Just-In-Time (JIT) production and supply principles which are expected to lead towards close buyer-supplier proximity.

The relevance of these ideas was tested in a case study of the microcomputer hardware industry in Ireland and Scotland. The microcomputer industry is here defined as the industry producing personal computers (including laptops and notebooks), workstations and entry-level servers costing less than $100,000 in 2001. Companies in this industry have been portrayed as prime examples of TBC (HUDSON, 1997; SCHOENBERGER, 1997). The findings concerning the relevance of the second driver, efficient product flow, have been documented elsewhere (VAN EGERAAT and JACOBSON, 2005. Efficient product flow was found to be a relatively insignificant driver for buyer-supplier proximity in the industry. This article will focus on how considerations related to information exchange have influenced the geography of production linkages in the industry.

Related studies on the industry include those by ANGEL and ENGSTROM, 1995, and DEDRICK and KRAEMER, 2002. These studies tend to focus on the geography of production networks in the USA and/or the Far East. Our study specifically focused on the production networks of companies located in the European semi-periphery.

Most data were collected during interviews with general managers, materials managers and logistics managers employed by the 11 branded microcomputer makers located in Ireland (Apple, AST, Dell, Gateway and Intel) and Scotland (Apricot-Mitsubishi, Compaq, Digital, IBM, Packard Bell-NEC and Sun Microsystems) - from here on referred to as 'the focal companies' or 'the focal plants'. Three rounds of semi-structured and structured interviews were conducted in the period 1998-2001. Unless stated otherwise, all data presented in this article pertain to the situation during the period end-1998 to early 1999. (Some of the companies stopped assembling computers in Ireland or Scotland during the research project. However, in all cases, except in the case of Intel, contact with interviewees was retained and data were collected pertaining to the period end-1998 to early 1999.) Additional data were collected via postal questionnaires completed by staff at the focal companies and newspaper research. The postal questionnaire included 63 items measuring the relevance to the focal companies of TBC and other new high volume production concepts (HUDSON, 1994; HUDSON, 1997) on a seven-point Likert-scale. Finally, telephone interviews were conducted with staff at a selection of local supplier firms.

The next section more closely examines the idea that considerations concerning technical information exchange in the context of TBC will drive close buyer-supplier proximity. This is followed by an outline of the geography of the supply chains of the focal companies. It will be shown that the focal companies source the vast majority of material inputs from regions outside Ireland and Britain, notably from the Far East. The subsequent section quantifies the importance of technical information exchange in the focal companies' decision to use local and regional suppliers. It will be shown that considerations related to technical information exchange were generally not an important driver. Working towards an explanation for the conflict between theory and practice, the remainder of this article examines the actual level of technological co-ordination that existed between the focal companies and their suppliers as well as the importance of face-to-face contact. In the conclusion we consider the implications for industrial policy.

TBC, technical information exchange and proximity

The prototypical vertically integrated Mass Production corporation kept most product development and strategic part supply in-house. Relations with suppliers tended to be arm's length. Most suppliers were not involved in product development but were provided with a blueprint for production. Other suppliers produced catalogue goods (HAYTER, 1997), again involving limited supplier-customer co-operation. Supplier-assembler relations were largely regulated through the market. The arm's length relations left the innovative resources of the suppliers largely underdeveloped and unused. This supply model proved increasingly unsuitable for a strategy of rapid and continuous product introduction.

Instead, in TBC, companies aim to more fully exploit the development resources of the supply-base. As the diversity and sophistication of component technologies increase, assemblers increasingly rely on their suppliers for innovation and product and process development. TBC involves a joint approach to product development. In order to facilitate the speed and efficiency of the product and process development process, the development systems of suppliers and customers are strongly integrated and suppliers are involved in product development from an early stage. This allows for the development activities in both companies to take place in parallel, rather than sequentially (STALK and HOUT, 1990). These partnership-based product development systems require a great deal of dyadic information exchange – a constant personal and electronic communication of technical and commercial information about future wants and needs, coming product development projects and continual interaction on quality and product development.

According to SCHOENBERGER, 1997, the rise of TBC will encourage closer buyer-supplier proximity and an increase in local and regional production linkages. The implicit argument is that, in spite of space-shrinking IT developments, some types of information exchange still benefit from large amounts of face-to-face contact. Although face-to-face communication does not necessarily require proximity, proximity does enhance speed and efficiency in communication by reducing the travel time.

The argument does not involve all information exchange. Based on the nature of the information content, one can distinguish three types of information in a supply relation: commercial, administrative and technical (GADDE and HAKANSSON, 1993). As regards the commercial and administrative content, supply relations in TBC involve a constant formal communication of prices, discounts, times, volumes, means of delivery and payment, stock data, current and forecast demand. Although, this exchange involves a strong integration of the partners' purchasing, sales, materials management, logistics and accounts functions (HEPWORTH, 1989), it is generally not mentioned as a driver for customer-supplier proximity.

The literature on the spatial implications of TBC and other partnership-based supply models focuses, nearly exclusively, on the communication of technical information (for example, PIKE, 1998; SCHOENBERGER, 1997; MCKINNON, 1997;

BORDENAVE and LUNG, 1996; REID, 1995; WOMACK *et al*., 1990; LUBBEN, 1988; GLASMEIER and MCCLUSKEY, 1987). The idea is that the customers' increasing reliance on their suppliers for innovation requires a strong integration of engineering and production functions of both partners and an increase in the formal exchange of technical information – both in the early stages of product and process development, involving co-development and simultaneous engineering, and the later stages, involving ongoing technical co-ordination. Because of the fact that such information is often ambiguous and subject to refinement, a large part of the exchange is believed to require face-to-face interaction between engineers (REID, 1995; SCHOENBERGER, 1997).

In conflict with these ideas, some commentators argue that innovations in communication technology have reduced the need for face-to-face contact, even in the context of detailed technical design issues (GERTLER, 1988; HEPWORTH, 1989; MCKINNON, 1997). In addition, suppliers might be able to provide the experience of local engineering and manufacturing support, without actually co-locating facilities (ANGEL, 1994). Apart from the use of electronic communication technology, this can take the form of seconding engineers for extended periods of time, local agents and small local support units or the stationing of resident planner-engineers at customers' facilities (PRAGMAN, 1996). Others suggest that information exchange might be a less spatially restrictive issue for large firms, particularly for MNEs, than it is for small firms (MCKINNON, 1997). In relation to this MCCANN and FINGLETON, 1996, found that firms in the Scottish electronics industry, made-up mainly of subsidiaries of large MNEs, "were already used to co-ordinating long-term supplier-customer relationships which continuously involved the exchange of detailed and complex information on a global basis" (p. 500).

SCHOENBERGER, 1997, acknowledges that it is unrealistic to suppose that all suppliers and customers will commit themselves to the same place. The spatial configuration is the result of conflicting pressures, which will lead to a degree of compromise. This brings up the question of “how close is close”? (p.54) In addition, some parts of the organisation will need to be in closer contact than others and certain tasks need constant collaboration and co-location of facilities while others can be handled by the short-term dispatch of a research team.

ARITA and MCCANN’s, 2000, study of US semiconductor industry suggests that the need for proximity depends on the intensity of the formal information exchange – intensity defined as the detail and sensitivity of the information involved. For their study they devised a classification of the technological content of the partnership, based on the intensity of information exchange involved. At one end, ‘joint R&D and joint-development of new technology’ was expected to promote the most intensive interactions of knowledge exchange, requiring high levels of face-to-face contact between partners. At the other end, the categories ‘manufacturing’ (described as: subcontracting of mass produced activities such as original equipment manufacturing, second sourcing, and fabrication agreements) and ‘investment, business partnership, marketing’ were believed to involve far less intensive information exchange and therefore to require low levels of face-to-face contact. Although not specifically addressed by the authors, the level of face-to-face contact refers to both the frequency of the face-to-face contact and/or the number of engineers involved.

Their findings show that formal technical information exchange is a driver for the reduction in the linkage distance in case of higher-order alliances only. However, even in these alliances, the critical spatial extent over which the information-localisation effect is found to operate is within one day's return journey by air – much less localised than generally assumed. Formal exchange of technical information did not drive co-location of partners involved in lower-order alliances, not even at the scale of the USA in total. Incidentally, their findings pertain to *small* US semiconductor firms only. Again, information exchange might be an even less spatially restrictive issue for larger firms. The following paragraphs will examine the relevance of these ideas in the context of the microcomputer hardware industry in Ireland and Scotland.

Geography of production linkages

The following outline of the sources of the parts and components used by the 11 focal companies is primarily based on detailed information provided during interviews with materials managers conducted in the period 1998 to early 1999. Interviewees provided the names of their suppliers as well as the location of manufacturing. Great care was taken to establish the actual location of end-product manufacturing plants, rather than the location of the suppliers' headquarters, logistics facilities or component plants.

Obviously, the precise detail of the geographical configuration of the supplier networks differed from company to company. However, great commonalties did exist, especially with respect to the regional supply situation. The main 'outlier' was Packard Bell-NEC in Scotland. Mainly due to the recent establishment of the plant, parts and components that other companies typically sourced locally, were still imported by Packard Bell-NEC. However, at the time the interviews were conducted, negotiations with local suppliers were already underway. Apart from this, the main area of difference concerned the location of the motherboard/backpanel suppliers. The geographical origin of parts and components is summarized in Table 1. For more detailed data on individual company level, see VAN EGERAAT *et al*., 1999.

Clearly, the vast majority of components and parts were imported from regions outside Ireland and Britain, notably from the Far East and, to a lesser extent, the USA. The only items characterized by significant sourcing in Ireland and/or Scotland were: enclosures, motherboards/backpanels (mainly from Scotland), network cards (from Ireland only), non-English language keyboards, digital/printed media, accessory kits[i], cables/interconnect and packaging material. England and Wales figured to a small extent in the area of monitors while England played a role in the supply of motherboards as well. However, most of these components were imported from other regions as well. Thus, the majority of motherboards/backpanels[ii], network cards, cables, keyboards and monitors, were manufactured in other regions, notably in the Far East. The only components that were mainly sourced from suppliers in Ireland or Scotland were enclosures, packaging, media, kits and non-English language keyboards.

The local supply networks of the five microcomputer assemblers in Ireland included 47 (mainly foreign owned) companies operating 57 component plants. The local supply networks of the six focal companies in Scotland included 49 (mainly foreign owned) companies operating 51 plants. However, the actual production activities in many plants were very limited or added limited value to the product. Thus, apart from limited digital printing activity, 11 kitting plants were merely packaging media and other language specific parts into a box. Similarly, five keyboard localization plants were merely laser printing (non-English language) keyboards manufactured overseas. Finally, the production activities of the turnkey suppliers involved in rework activities were of a very limited nature.

Ten focal companies provided an estimate of expenditure on locally (Ireland or Scotland) manufactured components as a percentage of total expenditure. Figures were also provided for the share of components sourced in Ireland and Britain together. At the time the interviews were conducted, on average, ten per cent of the parts and components sourced by the focal companies in Ireland were manufactured in Ireland (ranging from seven to twelve per cent). The items manufactured in Britain accounted for another four per cent on average (ranging from zero to nine per cent). As regards the focal companies in Scotland, on average seven per cent of the material inputs was manufactured in Scotland (ranging from two to nine per cent). The items manufactured in the rest of Britain and Ireland accounted for another nine per cent (ranging from three to ten per cent).

The figures on local sourcing presented above are substantially lower than those presented in other studies, based on data collected by the industrial development agencies in Ireland and Scotland. Thus, TUROK, 1997, reports that in 1995 the 16 largest foreign owned electronics companies in Scotland (including all the main computer assemblers) sourced 21 per cent of their total purchases (excluding electronic components, intra-company trading and services) from Scotland. In Ireland local sourcing figures are collected by Forfas as part of the annual Irish Economy Expenditure (IEE) survey. An extract of survey data on four microcomputer assemblers – Apple, Dell, AST and Gateway – provided an average local sourcing figure of 28 per cent for the year 1998 (VAN EGERAAT, 2002).

The discrepancy between the figures based on the surveys carried out by the industrial development agencies and our figures, obtained during company interviews, is partly explained by a less inclusive definition of local sourcing in the company interviews. Thus, the IEE figures include expenditure on items bought from local turnkey supply-chain managers but manufactured in other regions as well as expenditure on complete systems manufactured by contract manufacturers with local operations. Both items were not included in the data collected during the company interviews. A number of focal companies like IBM, Apple and Compaq had outsourced a substantial amount of full system assembly work to global contract electronics manufacturers (CEMs) with local operations. Although this outsourcing involved buyer-supplier links, these links were not vertical production linkages since the focal companies did not carry out any further production work on the systems. In fact, in most cases the systems were shipped directly from the CEM to the customer.

Technical information exchange and local linkages of the focal companies

Thus, the focal companies imported the vast majority of their required components and parts from regions outside Ireland and Britain. To further investigate the role of technical information exchange in shaping the geography of production linkages, the research focused on the suppliers with manufacturing facilities in Ireland and Scotland.

Interviewees in the focal companies were presented with a list of their regional suppliers. First, the question was asked whether the choice for individual local suppliers was influenced by the fact that these suppliers had a regional manufacturing presence. Subsequently, the question was asked to what extent the choice for a particular local supplier had been influenced by two theoretical drivers - efficient technical information exchange and logistical efficiency. Interviewees were asked to score on a scale from one (this driver played no role) to seven (this driver played a very important role). The results are presented in Table 2. Each row indicates a component that was sourced regionally by one or more focal companies. In relation to each component, the scores for individual suppliers at ten focal companies have been added and the averages have been presented in two columns.

The table shows that technical information exchange had a limited influence on buyer-supplier proximity in the microcomputer hardware industry. Where proximity was the result of a deliberate choice to deal with a supplier with a regional manufacturing presence, logistical efficiency was the principal driver. Efficient technical information exchange proved an important driver only in relation to regional suppliers of packaging material. Complete computer systems, enclosures and media kits all received an average score of four, while motherboards/backpanels and printed labels received an average score of three, indicating that the driver played only a modest role. In all other cases, the driver played no role of significance.

In relation to the regional suppliers of microprocessors, memory, hard disk drives, tapes, heat sinks, modems/ network components and microphones, neither driver appears to have played a role of significance. In these cases the link with particular regional suppliers was not the result of a deliberate choice for buyer-supplier proximity. The proximate location of these suppliers, often involved in the manufacture of technology-rich components, is more likely the result of the cost and quality of production factors in the region that were attractive for focal companies as well as for some of their suppliers.

Thus, the focal companies have forged a limited amount of production linkages with local and regional suppliers and where we found regional production linkages, considerations related to technical information exchange were generally not an important driver. These findings are clearly in conflict with the ideas of SCHOENBERGER, 1997, who believes that in an environment of TBC, the increased requirement technological co-ordination and face-to-face interaction in the product development process will encourage greater local and regional production linkages. Working towards an explanation for this conflict, the next two sections first examine the actual level of technological co-ordination that existed between the focal companies and their suppliers.

Technological co-ordination at corporate level

The TBC model contains the idea that assemblers increasingly rely on their suppliers for innovation and product and process development, which requires a great amount of co-ordination between buyers and suppliers. The development systems of suppliers and customers are strongly integrated. In line with this, most focal companies have not only outsourced the majority of component production activities, but also the design of many components.

It has been argued that, in a sense, the process of component outsourcing has progressed one level further. LANGLOIS and ROBERTSON, 1995, argue that the industrial organisation in the microcomputer industry comes near to what they call a modular system. One of the main characteristics of a modular system is that the rules of compatibility of individual components are standardised for the industry and publicly known, rather than laid down by individual lead assemblers. As a result component innovation can proceed in an autonomous fashion. In the microcomputer industry one of those standard interfaces concerns the modular bus architecture[iii]. According to LANGLOIS and ROBERTSON, 1995, and ANGEL and ENGSTROM, 1995, the standardisation of the bus since the mid-1980s reduced the need for co-ordinated technology development at the system level. Component development could proceed in autonomous fashion as long as the suppliers made sure that their components maintained the ability to connect to the standard bus.

Although these ideas were partly supported by our findings, the situation was not as extreme. The focal companies gave evidence of substantial technical co-ordination between corporate design facilities and their suppliers. Apart from the fact that companies like IBM and Intel were still heavily involved in the in-house production of selected component technologies, including hard disk drives, semiconductors, displays and motherboards, nearly all companies were still the co-ordinators of the development of some components, notably motherboards, enclosures and in the case of some focal companies, power supplies and interconnect material. As regards the motherboards, although many companies used OEM-designed solutions for some low-end models, all focal companies retained a strong in-house development function for the design of higher-end motherboard models. In the case of Intel-based systems the design of the motherboards was to some extent controlled. However, most focal companies differentiated these boards in terms of functionality and reliability. Likewise, all companies retained a strong in-house development capability for the design of their own enclosure and bezel styles.

The design of these components typically involved a substantial amount of technological co-ordination and information exchange. As regards the boards, typically the engineers of the focal companies would carry out the electrical and physical design while the subcontractors would be responsible for prototype production. As regards the enclosures, typically the focal companies would be responsible for the industrial design while the subcontractor would be responsible for the production of the tools and dies. The development processes involved a substantial amount of communication between the partners involved, from the stage of conception to final test. “Obviously we have to design to match their [the suppliers’] processes. And they can suggest efficiencies as well. … They can say, if you change this it is going to be easier for our tool-makers" (Interview Director of Development, IBM Scotland, July 1999).

As regards the majority of components where the innovation process was no longer led by the computer assembler, the development process still involved co-ordination integration. In the postal questionnaire the respondents were asked to rate the extent to which their development systems were integrated with those of suppliers that delivered their own component technology on a seven-point Likert-scale. The average score of five indicates a fairly high level of integration.

The interviews showed that the product development teams of all focal companies had a strong interface with the development teams of Intel. Although Intel developed its microprocessors in a largely autonomous process, the company supplied early prototypes to the focal companies, which allowed these companies to do system development work. The systems were heavily tested in both organisations. The focal companies received assistance in the design of their products while Intel was able to resolve potential bugs before its processors went to the market. Another reason for co-ordination concerned the customisation of otherwise industry standard components such as hard disk drives and monitors.

New components could not simply be assembled in an existing computer system. The introduction of every new component involved a certain integration effort and in some cases a great effort. It involved a process of testing, evaluation and certification on the side of the assembler and it could even require motherboard redesign. This process did involve a certain amount of communication between the engineers of the assembler and the suppliers.

Focal companies were also constantly exchanging information on future development projects and technology road maps with all of their (potential) suppliers. On a seven-point Likert-scale the average response to the question on the sharing of information about future development projects was six, suggesting quite substantial information sharing. "It is a continuous process were we meet regularly talking about developments and going forward and looking at industry changes" (Interview Operations and Production Manager, Gateway Computers Ireland, September 1999). Finally, limited technological co-ordination continued to exist during the ramp-up of the computer production process (involving the new component) as well as later, during the entire life-cycle of the component. Thus, some suppliers were heavily involved in the training of technical staff at the focal companies in the run-up to the production of systems involving the new components. During the initial period of production of systems incorporating a new component, the production engineers were typically in contact with engineers of the suppliers and there existed a constant information exchange on issues such as component reliability and quality issues over the entire life-cycle of the component.

Involvement of European operations in technological co-ordination

The above shows that, in line with the TBC model the innovation process involved a substantial amount of co-ordination and information exchange between the focal companies and the component suppliers. However, of particular relevance to the geographical configuration of the supply linkages of the plants in Europe is the involvement of the focal companies' European operations. The interviews showed that their involvement in technological co-ordination was more limited.

This was partly a consequence of the limited R&D activities of the European operations. SCHOENBERGER, 1997, postulates that the rise of TBC will lead to a new spatial configuration of production. In this 'concentrated deconcentration' multinational firms create tightly integrated production complexes in each of their primary market regions. The regional complexes will include various manufacturing functions as well as some degree of technical and strategic responsibility, which allows them to respond to particular needs of the individual regional markets.

In contrast to these ideas, the European operations of the focal companies in the microcomputer industry lacked substantial local-for-local R&D groups – a reflection of the fact that companies were offering basically global products. Rather than developing products unique to each major region, the level of differentiation for specific geographical markets was low in all companies. On a seven point Likert-scale the average response to the question on the extent to which the company as a whole differentiated its products for specific geographical markets was three. Typically, the actual computer – the box in its various possible configurations – was the same for all markets, apart from, in some cases, country specific communication hardware. The differentiation or localisation came with the loading of the language specific software, keyboards, documentation and country specific cables.

The regionally specific product development requirements were therefore relatively small and most focal companies concentrated their microcomputer development facilities in their home country. Apart from UK based Apricot-Mitsubishi, which had its world-wide headquarters and development facilities in Birmingham, England, only two other focal companies had a genuine microcomputer development operation in Europe. IBM had a significant development organisation at its main manufacturing site in Scotland, responsible for the development of the 5000 server model, server boards, as well as several visual products. This R&D function reported directly into IBM's corporate R&D division headquartered in the USA. Likewise, Digital had a small design group of ten engineers in Scotland involved in the design of single-board embedded servers for niche world markets.

Apart from this, most companies, notably Dell, IBM, Compaq, Digital and Packard Bell-NEC, had a separate group in the European operations, carrying names such as *Customer Special Systems* or *Special Bids*. These groups, involving a mixture of development engineers and sales and marketing staff, were involved in the configuration of special systems for large corporate accounts. The activities generally did not involve genuine product development. Typically, the engineers would take a corporate standard product and work with qualified components to take it to another level of configuration for specific customers.

Apricot-Mitsubishi aside, Dell was the only focal company that was in the process of creating a separate group with local-for-local component expertise. This *European Products Group* grew out of the software localisation group (see below). The group included a small team of engineers with expertise in Europe-specific communication hardware as well as regulatory and environmental compliance. As regards communication hardware the group identified European suppliers, brought products through a business justification process and carried out the vendor qualification process.

Nearly all focal companies had what was generally referred to as a localisation group located at the European manufacturing facilities. The precise remit of the localisation group varied from company to company. One of the responsibilities involved the organisation of the development and supply of language-specific components that differentiated the product for the various geographical markets, i.e. mainly firmware, keyboard, power cable and printed/electronic documentation. Typically, this mainly involved the management of local subcontractors that carried out the localisation on behalf of the focal companies. Electronic documentation was typically developed in the English language in the USA. The localisation group sent this US golden master to local translation houses, and subsequently outsourced the reproduction of CDs/printed media and in some cases the kitting of the accessory boxes, to local subcontractors. Another, larger, responsibility of the localisation group involved process development: the continuous creation of software to support the European manufacturing operations.

Finally, Apple and Digital carried out a (limited) amount of fundamental operating system and application software development and testing in Ireland, in Cork and Galway respectively. These development teams were not part of an integrated European production system but carried out activities for the corporate design group in the USA.

The limited amount of local-for-local R&D does not mean that the European operations did not play a role in the corporate product and process development process. The regional manufacturing, development and marketing operations included a substantial number of employees with technical skills and the organisation of the corporate development process typically involved a substantial amount of communication between these employees and the corporate design groups. Staff at the European operations evaluated and discussed parts and system design with the development groups in the USA during formal design and project reviews. Similarly, local programme managers and production engineers were in regular discussion with the prime development sites, mainly to facilitate a smooth introduction of a new product to the European operations but also to discuss issues like manufacturability of design and process design in general.

The limited R&D functions of the European operations were reflected in their involvement in the technological co-ordination with suppliers. In the groups involved in genuine microcomputer development, i.e. the European server development groups of IBM and Digital, and in Dell's *European Products Group*, the level of technological co-ordination was comparable to the level at the corporate design facilities. However, apart from these relatively small development groups, the involvement of the European operations in technological co-ordination with suppliers was limited.

In relation to most components, engineers in European operations did play a role in the corporate development process and were involved in discussions and evaluations of new parts. However, at the design stage, it was typically the engineers of the corporate design facilities that communicated with the development engineers of the suppliers. To support their input in the corporate development process, regional staff kept themselves informed regarding product development plans and general technological advances in the supply base. This generally took place at an informal level, as part of the day-to-day and periodic operational contact with suppliers (see below). "If a supplier came to us and developed a new product, all we could do was to get samples, submit them to the States and get them approved or not" (Interview Materials Manager, AST Research Ireland, Oct. 1999). Furthermore, this integration tended to involve the European sales and marketing groups more than manufacturing engineers at the production facilities. The former were, in all but one case, located in European core cities, notably Paris and London (VAN EGERAAT, 2002).

At most, local engineers were involved in the ramp-up of the suppliers' production facilities, notably production facilities located in Europe. This could involve activities such as managing engineering change orders, the introduction of an existing tool to a regional supplier and process qualification. However, even in these situations, as far as technical issues were concerned, local engineers often played only a supporting role, facilitating and joining meetings between corporate engineers and supplier engineers.

The exceptions included less strategic items, such as packaging, electronic and printed documentation kits, certain cables, screws, fasteners, labels, etc. In these cases the technological co-ordination and information exchange was typically handled entirely by the European operations. Some of these items involved a very limited amount of technological co-ordination but regular changes in packaging, foam and, in some cases, cables involved a substantial engineering interface.

Finally, co-ordination between European operations and suppliers continued in relation to day-to-day operational issues, which could involve technical issues. Thus, supplier-quality engineers in operations were in regular communication with the suppliers for failure analysis and the discussion of general quality issues and staff training. Technical and quality issues figured prominently in discussions with suppliers during the periodic supplier reviews organised by the European operations.

The importance of face-to-face communication

In relation to most components, European operations had a very limited involvement in technological co-ordination and information exchange with suppliers. This fact obviously strongly reduced the relevance of technical information exchange as a driver for a reduction in the linkage distance.

Using the terminology of ARITA and MCCANN, 2000, even in those instances where the European operations were involved in technological co-ordination, the information exchange was generally of relatively low intensity, requiring low levels of face-to-face contact, i.e. the face-to-face contact did not need to be frequent and/or involved a limited number of engineering staff. As a result technical information presented a weak driver for supplier co-location.

As discussed, in relation to most components, the involvement of European operations in technological co-ordination and information exchange mainly concerned ongoing day-to-day operational issues such as failure analysis and the discussion of general quality issues. Much of this information exchange was facilitated by modern communication technologies. Still, the quality engineers of the focal plants were in regular, in some cases daily, face-to-face communication with the main suppliers. However, generally, the exchange could be handled by local supplier representatives such as account managers, sales engineers or field-application engineers and did not necessarily require contact with the engineering teams located at the suppliers' production and design facilities. It was only in the case of major problems that the suppliers' production or design engineers would become involved in the communication. This relatively infrequent contact was not a strong driver for the co-location of fully integrated supplier facilities. Similarly the more formal supplier review meetings, that involved suppliers' production or design engineers, took place on a half-yearly or yearly basis and did not constitute a driver for co-location.

Where engineers of the European operations played a role in the ramping-up of suppliers' production facilities, the communication did involve face-to-face meetings at the suppliers' production facilities. However, engineering change orders took place twice a year at most. This infrequent information exchange constituted a weak driver for buyer-supplier proximity. In addition, as discussed, the meetings with the supplier engineers often included engineers from corporate production/design facilities located in the USA. Thus, any potential communication efficiency gain related to the location of suppliers relative to the European operations could be partly off-set by an efficiency loss due to the distance of the supplier to the focal companies' corporate production/design facilities.

The technological co-ordination and information exchange in relation to less strategic components was typically handled entirely by the European operations. However, in most cases the technical information exchange was of a non-intensive nature, i.e. the detail and sensitivity of the information exchanged were relatively low. The European operations were in very regular face-to-face contact with suppliers of media and kits but most of the communication could be handled by an account manager of the supplier and would concern mainly demand level issues. The exceptions were packaging material and, in a small number of cases, cables. Packaging and some of the cables were changed or modified on a very regular basis and engineers of European operations had very frequent face-to-face meetings with design/production engineers of local suppliers, discussing, *inter alia*, design, tooling and qualification issues. This information exchange did represent a stronger driver for buyer-supplier proximity.[iv]

European operations played only a limited role in technological co-ordination with suppliers and the non-intensive information exchange involved presented only a weak driver for supplier co-location. However, interview data on the corporate design groups of the focal companies, including data on the on-site system development operations of IBM and Digital in Scotland, suggest that even if the European operations had played a bigger role in the corporate process of technological co-ordination with suppliers, this would probably not have resulted in supplier co-location anyway.

As discussed in the previous section, the design of many components involved a substantial amount of technological co-ordination between the corporate design/production facilities of the focal companies and their suppliers. This co-ordination involved a substantial exchange of technical information. Still, as documented by ANGEL and ENGSTROM, 1995, even at the corporate design/production facilities in the USA, efficiency in the exchange of this technical information did not pose a strong driver for supplier co-location, a situation confirmed in our interviews.

The explanation for this is two-fold. First, part of the explanation lies in the intensity of the information exchange. In terms of the classification of ARITA and MCCANN, 2000, many of the partnerships in the microcomputer industry fall in the category ‘manufacturing’. The technical information exchange involved in these ‘lower-order alliances’ is of a relatively low intensity, i.e. the detail and sensitivity of the technical information exchanged is relatively low. Therefore, technological co-ordination requires low levels of face-to-face contact. Secondly, part of the explanation lies in the fact that the focal companies and most of their suppliers are large, global organisations. Arita and MCCANN, 2000, found that intensive formal technical information exchange was a driver for proximity – although, even then, only on the scale of one day's return journey by air. However, their study involved *small* US semiconductor firms only. In support of MCKINNON, 1997, technical information exchange, even the more intensive exchange, appears to be a less spatially restrictive issue for large multinational organisations.

Thus, much of the technical information could be exchanged using non-face-to-face modes of communication, such as electronic mail or tele-conferencing. In relation to this one respondent explained:

> It [proximity of suppliers] is useful but not essential. Most of the stuff is transmitted electronically, the drawings, the requirements, the specifications. … The engineers will visit the supplier only for major process checkpoints, like at the end of the design phase. … Again, I think geography is becoming less and less of an issue. It is much more down to the ability to interchange – how good is the company working electronically and how fast are they responding. … [As to the suppliers with local facilities] Everyday we send them new drawings, new information. They are looking at our tooling development – very close face-to-face information and telephone type communication. The local is interesting, but equally we do business with the Far East, and we are also developing products in the Far East and we talk to them daily on conference calls. But we would not meet them face-to-face regularly. So there is a benefit to have them local, but that does not mean that we will only source locally. (Director of Development, IBM Scotland, July 1999)

In those cases where more substantial face-to-face communication with engineers of the suppliers' design/production facilities was required, this could be efficiently organised through frequent long-distance travel by engineers of both partners or through the short-term out-stationing of design engineers, either at the facilities of the customer or the supplier – it did not require the co-location of integrated supplier operations. During the development phase, the focal companies received frequent visits from engineers of the suppliers' design/manufacturing facilities or, in some cases, had them stationed at the design facilities for a number of weeks. The latter would certainly be the case with the more strategic suppliers, e.g. suppliers of microprocessors. Alternatively, the focal companies assigned design staff to work for a period at the design facilities of suppliers.

Conclusion

SCHOENBERGER, 1997, believes that after the era of Fordist mass production, that lasted until the mid-1970s, the capitalist world entered a new era of TBC. She argues that this transition will lead to a new geography of production, a kind of concentrated deconcentration organised around geographically coherent multinational market regions. One aspect of this model is the idea that the increased focus on reducing the product development times will encourage closer proximity between buyers and their suppliers and an increase in the local and regional production linkages. The relevance of this idea has been tested in a case study of the microcomputer hardware industry in Ireland and Scotland.

It was shown that the microcomputer assemblers imported the vast majority of components and parts from regions outside Ireland and Britain, notably from the Far East. Where regional linkages were found, efficiency in technical information exchange generally constituted an insignificant driver for proximity.

This can be partly explained by the fact that the global business models of the focal companies did not require substantial regionally specific product development and the European operations therefore did not incorporate substantial local-for-local R&D groups. As a result, the involvement of the European operations in technological co-ordination and information exchange was limited. To the extent that they were involved, the exchange was generally of relatively low intensity requiring low levels of face-to-face contact.

Even if European operations had played a bigger role in the corporate process of technological co-ordination with suppliers, this would not have resulted in supplier co-location anyway. Even at the corporate R&D facilities, efficiency in technical information did not constitute a strong driver for buyer-supplier proximity. There are two reasons for this. First, although the product and process development process of the microcomputer companies still involves a substantial amount of technological co-ordination with suppliers, much of this technical information exchange is of a relatively low intensity, requiring low levels of face-to-face contact. Secondly, all focal companies and most of their suppliers were part of large global organisations. In these large organisations, technical information exchange is not as spatially restrictive as it is in small organisations. Much technical information was exchanged using modern communication technologies while the necessary face-to-face communication could be efficiently organised through a combination of long-distance travel by engineers of both partners, secondment of engineers and the use of local supplier representatives.

Related research on the microcomputer industry shows that the second theoretical driver for buyer-supplier proximity in the context of TBC, efficient product/flow logistics, is unlikely to lead to buyer-supplier proximity and an increase in local production linkages either (VAN EGERAAT and JACOBSON, 2005).

What are the lessons for industrial development policy in Ireland and Scotland? Industrial policy and the strategies of the industrial development agencies in Ireland

and Scotland have long included the idea of building integrated vertical production clusters around subsidiaries of MNEs (INDUSTRIAL POLICY REVIEW GROUP, 1992; TUROK 1997). This can be called the "local sourcing route" to cluster development (YOUNG, *et al*., 1994, p. 669). The findings of this research suggest that such a strategy is unlikely to succeed, at least in the context of the microcomputer hardware industry. The growing difference in labor costs between Ireland/Scotland and certain economies in the Far East means that input price advantages associated with sourcing in the Far East will increasingly outstrip the efficiency gains associated with buyer-supplier co-location in Ireland/Scotland. The idea of developing an integrated vertical microcomputer production cluster has been further undermined by the recent shift of microcomputer assembly activity to Eastern Europe and a competition induced shake-out of microcomputer makers, resulting in a serious decline of microcomputer assembly activity in Ireland and Scotland (VAN EGERAAT and JACOBSON, 2004).

The alternative route to cluster development identified by YOUNG, *et al*., 1994, is via "technological innovation". Here, technological cluster development might be stimulated through co-operative R&D projects involving companies, university research labs and government research institutions. This appears to be the more appropriate route for Ireland and Scotland to take. While Ireland and Scotland are rapidly losing their pull on MNEs' high-volume manufacturing operations, the upgraded economies are becoming increasingly attractive to internationally mobile R&D facilities as well as to other high value-added functions. Although most microcomputer companies concentrated their R&D activities in their home countries, there are signs of internationalization, notably in the areas of software development and high-end system development. Recently, IBM and Sun both invested in greenfield R&D facilities in Ireland. Furthermore, companies that recently downsized their local manufacturing operations generally retained or expanded their local R&D functions, as in the case of Apple and Digital/Compaq in Ireland and IBM in Scotland. Although not necessarily integrated in the wider European operations of the microcomputer companies, these R&D functions might well be contributing to technological agglomeration and the generation of broader technological clusters.

Finally, promotion of the development of such technological clusters requires a deep understanding of the actual drivers of technological agglomeration. This requires further research. The insights gained during the present research project lead us to believe that efficiency in formal dyadic technical information exchange will not prove an important driver. The drivers for technological agglomeration are more likely to lie in the job-matching opportunities provided by large pools of labour (GORDON and MCCANN, 2000; KRUGMAN, 1991) located near third-level institutions and in issues related to the local institutional set-up and the wider socio-cultural environment (COOKE and MORGAN, 1998; MALMBERG, 1996).

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Table 1. Summary of geographical sources of material inputs of focal companies

Material input	Main geographical sources of parts and components
Enclosures and racks	For high-volume models and portables: mainly local and to a lesser extent Far East; For less current models and racks: USA and local
Motherboards, backpanels and riser cards	For most focal companies: Mainly Far East and, to a lesser extent, USA; For two focal companies: mainly Scotland and England
Microprocessors	Mainly South-East Asia, small amounts from Ireland; For proprietary technology: USA
Memory	Mainly Korea and Japan and small amounts from USA and Europe
Hard disk drives	Far East, notably Singapore
Floppy drives	Far East
CD-ROM drives; CD-RW drives and DVD drives	Far East
High capacity disc and tape drives	For lower-end technology: mainly Far East; For higher-end technology: USA, Far East, and Europe
Power supply	Low-end: mainly China, Malaysia and Thailand; High-end: USA and, to a lesser extend, Far East, Europe and England
Heatsinks	Mainly Far East, notably Taiwan; to a lesser extent USA and England
Cooling fans	Mainly Far East; to a lesser extent USA; some England and Germany
Batteries and AC-adapter (for portables)	Far East
Modems and network components	Mainly Far East and USA, although four suppliers were manufacturing in Ireland
Graphics, video and sound cards	Mainly Far East, notably South-East Asia; Individual sources in USA, Canada, Mexico and Germany
Cables and interconnect	Mainly the Far East and, to a lesser extent, Ireland and Scotland.
Screws, fasteners and other c-class items	USA and, to a lesser extent, local
Displays	Mainly Far East; Wales and England for few selected models.
Keyboards, mice and joysticks	Manufacturing in Far East, notably China and South-East Asia; Printing of non-English language key-board models local
Printers	Mainly Far East; to a lesser extent USA, Canada, Europe and England
Scanners	No precise data, but not in Ireland or the UK
Digital cameras	Far East
Speakers and microphones	Mainly Far East, notably China
Docking stations	Far East and on-site
Media	Printed manuals: mainly Ireland, and to a lesser extent Scotland; CD replication: Ireland, Scotland, Wales, Germany and USA; Wrapping of digital and printed media: local
Accessory kits	Local
Packaging material	Local
Sub-assembly and rework services	Local
Complete computer systems (contract manufacturing)	Mainly local, England and Taiwan; For portables: mainly Taiwan
Inputs for printed circuit board assembly activity	
Etched boards	Mainly Far East and USA
Microprocessors and memory	See above
Other semiconductors	Mainly Far East; to a lesser extent, USA and Europe; almost no local
Capacitors and resistors	Mainly Far East
Interconnect, jumpers, switches etc.	Mainly Far East and USA

Source: Company interviews 1998-'99.

Table 2. Drivers for choosing a supplier with a regional manufacturing presence

Material input	Average score for logistical efficiency	Average score for technical information exchange.
Packaging material	7	6
Media and kits	7	4
Enclosures and metal and plastic parts	7	4
Complete computer systems (CEM)	6	4
Printed labels	5	3
Keyboard localisation	5	2
Cooling fans	5	1
Motherboards/backpanels/riser cards	5	3
Cables and interconnect	4	2
Display monitors	4	2
Hard disk drives	3	2
Microprocessors	1	1
Memory	1	1
Modems and network components	1	1
Tapes	1	1
Heat sinks	1	1
Microphone	1	1
Printers	No data	No data

Source: Company interviews, 1999.

[i] Items such as media, mice, cables and connectors were typically packaged in a 'country' or 'accessory' kit. Some focal companies had subcontracted the packaging of these kits to local supply-chain managers that were also responsible for the sourcing of the items.

[ii] Only two focal companies sourced the majority of their board requirements from regional suppliers, although a large part of the motherboards used by two other focal companies came from regional suppliers as well.

[iii] A bus is a collection of wires through which data is transmitted from one part of a computer to another. The internal bus connects all the internal computer components to the central processing unit and main memory. The expansion bus enables expansion boards to access the central processing unit and memory.

[iv] This kind of frequent information exchange pertains to a limited number of specialised internal cables only. The importance of the driver in this limited number of cases has found no expression in the average figures on technical information exchange in Table 2.