THE GEOGRAPHY OF PRODUCTION LINKAGES IN THE IRISH AND SCOTTISH MICROCOMPUTER INDUSTRY: THE ROLE OF INFORMATION EXCHANGE

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Received: March 2005; revised November 2005

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, proximity, linkages, information exchange, multinational enterprises, Ireland and Scotland

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 standardised 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. The capitalist world entered a new era where producers were facing a very different competitive environment characterised by a demand for variety, quality, responsiveness and shorter product life cycles. This required a new style of competition and a new mode of industrial organisation. Some firms have responded to these challenges by adopting what Hudson refers to as, 'new high volume production' (NHVP) approaches (Hudson 1994, 1997a, b). The umbrella-term embraces a range of related models, such as lean production (Womack *et al.* 1990); mass customisation (Pine 1993) and time-based-competition (Stalk & Hout 1990). The spatial implications of one of these approaches, time-based-competition (TBC), have been explicitly addressed by Schoenberger (1997).

The TBC model, like all other NHVP models, stresses that the new challenges will require a new style of competition that will have implications for the firm's entire value chain and,

Tijdschrift voor Economische en Sociale Geografie – 2006, Vol. 97, No. 4 pp. 405–417.

Published by Blackwell Publishing Ltd., 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA

beyond that, for the firm's upstream and downstream relations. Firms now compete primarily on the basis of their ability to compress time. 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 & Hout 1990).

Schoenberger (1997) postulates that the rise of TBC will have repercussions for the geography of production and regional development. She depicts a stylised 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 a 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 here can be reduced to two buyer-supplier proximity drivers: efficient technical information exchange and efficient product flow or logistical efficiency.

The relevance of these ideas was tested in a case study of the microcomputer hardware industry in Ireland and Scotland. Companies in this industry have been portrayed as prime examples of TBC (Hudson 1997b; Schoenberger 1997). 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. The findings concerning the relevance of the second driver, efficient product flow, have been documented elsewhere (van Egeraat & Jacobson 2004). This paper will focus on how considerations related to information exchange have influenced the geography of production linkages in the industry.

As such, the paper contributes to a particular segment of a broader literature dealing with the factors giving rise to the agglomeration or localisation of industry (see Malmberg & Maskell 2002; Phelps & Ozawa 2003). The basic factors have long been identified. Returning to the contributions by Marshall (1898) and Weber (1929), one can distinguish two main reasons for, or advantages of, industry localisation: a local pool of skilled labour and a concentration of specialised suppliers or subsidiary trades. The local pool of skilled labour provides a gain for both workers and individual production units by maximising the job-matching opportunities and thus reducing the search costs (Gordon & McCann 2000; Krugman 1991). As regards the second factor, a localised industry can support more suppliers, which increases the level of specialisation and efficiency of the supply base, which, in turn, presents external economies to its customers (Harrison 1992). Individual suppliers co-locate with their customers because of the costs of transacting across distance (Krugman 1991; Malmberg & Maskell 2002), i.e. the cost of product/flow logistics and the cost of information exchange. As regards information exchange, proximity can facilitate both 'intended' dyadic information exchange between buyers and suppliers as well as 'unintentional' local knowledge spillover (Oerlemans & Meeus 2005). The unintentional form of information exchange in particular can be stimulated by geographical proximity in a more indirect way – by stimulating other dimensions of proximity, notably social and institutional proximity (Boschma 2005). This paper investigates the relevance of the 'intended' information exchange as a driver for buyer-supplier proximity. Indirectly, this paper also contributes to the rising body of literature dealing with 'territorial innovation models', which are partly built on the concept of agglomeration, notably the role of information exchange (Mouleart & Sekia 2003).

Related studies on the industry examined the geography of production networks in the United States and/or the Far East (Angel & Engstrom 1995; Dedrick & Kraemer 2002) – the locations of many of the headquarters and main innovation centres of the microcomputer companies. Our study specifically focuses on the production networks of the subsidiaries of multinational companies located in the European semi-periphery. It is expected that headquarters and subsidiaries have different roles in buyer-supplier technological co-ordination.

The 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 on information exchange presented in this paper pertain to the situation in 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 NHVP concepts on a seven-point Likert-scale. Finally, telephone interviews were conducted with staff at a selection of local supplier firms.

In order to investigate the relation between TBC and the geography of production linkages we first established the extent to which the focal companies matched the textbook picture of TBC. A detailed analysis of the companies' customer relations, distribution systems, product development, manufacturing plants, corporate organisation and supplier relations established that the microcomputer hardware industry can indeed be regarded as a prime example of TBC although some elements were not fully born out (van Egeraat 2002; van Egeraat *et al.* 2002). For space reasons we include here only a select number of issues that are important for the explanation of the geographical configuration of the production linkages.

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 paper 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.

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 at arm's length. Most suppliers were not involved in product development but were provided with a blueprint for production. Other suppliers produced 'catalogue goods', again involving limited supplier-customer co-operation. Supplier-assembler relations were largely regulated through the market. 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, 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 & Hout 1990). These partnership-based product development systems require a great deal of technical information exchange, 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.

According to Schoenberger (1997), the increased requirement of intentional dyadic technical information exchange in the context of TBC will encourage closer buyer-supplier proximity and an increase in local and regional production linkages.[1] Because of the fact that such information is often of a tacit nature, 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). The implicit argument is that, although face-to-face communication does not necessarily require proximity and co-location, proximity does enhance speed and efficiency in face-to-face communication.

In conflict with these ideas, others argue that in many cases geographic proximity is not a crucial issue for the effective dyadic exchange of information and economic co-ordination between firms (Rallet & Torre 2000; Malmberg & Maskell 2002). One of the reasons lies in the fact that, in solving the problem of co-ordination, geographical proximity can be substituted by other forms of proximity, notably organisational proximity, which is based on the collective rules and representations of organisations (Torre & Rallet 2005; Boschma 2006; Cappello & Faggian 2006). In relation to this McCann & Fingleton (1996) found that firms in the Scottish electronics industry 'were 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). In addition, innovations in communication technology have further reduced the need for face-to-face contact in the exchange of both codified information and tacit knowledge even in the context of detailed technical design issues (Mckinnon 1997; Torre & Rallet 2005). The face-to-face contact that is required is often for a short time, and can be fulfilled temporarily by long-distance travel of staff – 'temporary geographical proximity' (Torre & Rallet 2005). Suppliers are able to provide the experience of local engineering and manufacturing support, without actually co-locating facilities (Angel 1994). Apart from short-term travel by research teams this can take the form of seconding engineers for extended periods of time, local agents, small local support units or the stationing of resident planner-engineers at customers' facilities (Pragman 1996).

Arita & McCann's (2000) study of the US semiconductor industry suggests that the need for proximity depends on the intensity of the intentional information exchange – intensity defined as the detail and sensitivity of the information involved. 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' (i.e. 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 intentional technical information exchange is a driver for the reduction in the linkage distance in the 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. Exchange of technical information did not drive co-location of partners involved in lower-order alliances, not even at the scale of the United States in total. Incidentally, their findings pertain to *small* US semiconductor firms only. Information exchange might be an even less spatially restrictive issue for larger multinational firms (McKinnon 1997). 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 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 focal companies imported the vast majority of components and parts from regions outside Ireland and Britain, notably from the Far East and, to a lesser extent, the United States.[2] The only items characterised by significant sourcing in Ireland and/or Scotland were: enclosures (the casing of the computer), motherboards/backpanels (the main printed circuit boards), network cards, non-English-language keyboards, digital/printed media, accessory kits,[3] cables 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. Most of these components were imported from other regions as well. Thus, the majority of motherboards/backpanels, 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.

On average, 10 per cent of the parts and components sourced by the focal companies in Ireland were manufactured in Ireland (ranging from 7% to 12%). The items manufactured in Britain accounted for another four per cent on average (ranging from zero to 9%). As regards the focal companies in Scotland, on average seven per cent of the material inputs was manufactured in Scotland (ranging from 2% to 9%). The items manufactured in the rest of Britain and Ireland accounted for another nine per cent (ranging from 3% to 10%).

TECHNICAL INFORMATION EXCHANGE AND LOCAL LINKAGES OF THE FOCAL COMPANIES

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 choosing 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 of 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 1. 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 were summed and the averages presented in two columns.

Table 1. *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.

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 a very limited or no role.

Thus, the focal companies 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 in conflict with the ideas of Schoenberger (1997), who postulates that in an environment of TBC, the increased need for 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, the next two sections 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, we found that most focal companies had 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 & Robertson (1995) argue that 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. 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.[4] According to Langlois & Robertson (1995) and Angel & Engstrom (1995), the standardisation of the bus from the mid-1980s reduced the need for co-ordinated technology development at the system level.

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 cables. 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 styles.

The design of these components typically involved a substantial amount of technological co-ordination and information exchange. As regards the boards, 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.

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. 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 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 carry out 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.

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. 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 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, the involvement of the focal companies' European operations 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 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 was the same for all markets, apart from 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 England, only two other focal companies had a genuine microcomputer development operation in Europe. IBM had a significant development organisation at its manufacturing site in Scotland, responsible for the development of the 5000 server model and server boards. 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 had a separate group in the European operations, carrying names such as *Customer Special Systems*. 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.

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* included a small team of engineers with expertise in Europe-specific communication hardware as well as regulatory and environmental compliance. 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. One of its 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. 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 United States. 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.

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 United States 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 such as manufacturability of design and process design in general.

The limited R&D function of the European operations was 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 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). 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. Furthermore, using the terminology of Arita & 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 was 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. Much of this information exchange was facilitated by modern communication technologies. 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 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.

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 this 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 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. These items were changed or modified on a regular basis and engineers of European operations had 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.[5]

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 in relation to 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 larger role in the process of technological co-ordination with suppliers, this would probably not have resulted in supplier co-location anyway. As discussed, 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, and this co-ordination involved a substantial exchange of technical information. Still, as documented by Angel & Engstrom (1995), even at the corporate design/production facilities in the United States, efficiency in the exchange of this technical information did not pose a strong driver for supplier co-location, a situation confirmed in our interviews.

Again, part of the explanation lies in the intensity of the information exchange. In terms of the classification of Arita & McCann (2000), many of the partnerships in the microcomputer industry fall into the 'manufacturing' category. 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 relatively low levels of face-to-face contact. Modern communication technology allows for much of the technical information to be exchanged using non-face-to-face modes of communication, such as e-mail or tele-conferencing.

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. For example, during the product 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. To an extent, geographical proximity had been substituted by a combination of 'organisational proximity' (Cappelo & Faggian 2005; Boschma 2006) and 'temporary geographical proximity' (Torre & Rallet 2005). 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 . . . 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).

CONCLUSION

Schoenberger (1997) describes how after the era of Fordist mass production 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 was tested in a case study of the microcomputer hardware industry in Ireland and Scotland.

We showed 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 larger 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 exchange did not constitute a strong driver for buyer-supplier proximity. Although the development process of the microcomputer companies still involves a substantial amount of technological co-ordination with suppliers, even at the corporate R&D facilities much of the technical information exchange is of relatively low intensity, requiring low levels of face-to-face contact. In addition, where more substantial face-to-face communication is required, this can be efficiently organised over long distances through a combination of short-term travel, seconding of engineers and the stationing of resident planner-engineers. To a large extent, geographical proximity has been substituted by 'organisational proximity' (Boschma 2006; Cappelo & Faggian 2006) and 'temporary geographical proximity' (Torre & Rallet 2005). Where Arita & McCann (2000) found that intensive technical information exchange was a driver for (relative) proximity for *small* US semiconductor firms, our research suggests that for large multinational organisations even this more intensive exchange does not appear a spatially restricting issue.

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). Our research suggests that during the 1990s and early 2000s the microcomputer assembly plants in both countries were not really part of a cluster or agglomeration. The main factors behind the concentration of assembly plants were the relatively low wages and fiscal incentives. Not surprisingly, rising wage rates resulted in an exodus of computer assembly from 1998 (van Egeraat & Jacobson 2004). At the same time, some of the focal companies, along with many companies in other sectors, retained or expanded their local R&D and other high value-added functions (Barry & van Egeraat 2006). This development might facilitate the change in the Irish and Scottish industrial strategies, in the direction of a 'technological innovation' route to cluster development, which is hoped to provide 'stickier' industrial clusters. Rather than intentional information exchange and logistical efficiency, the main advantages of such clusters are found in the 'unintentional' local spill-overs (Oerlemans & Meeus 2005) and job-matching opportunities, facilitated by geographical as well as institutional and social proximity (Boschma 2005).

Acknowledgements

This research is supported in part by the Irish Research Council for the Humanities and Social Sciences and Forfas. We would like to thank Dr Nick Phelps and two anonymous referees for their constructive comments.

Notes

1. 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).
2. This paper presents a summary of the geography of the production linkages only. For a more detailed account see Van Egeraat & Jacobson (2005).
3. 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.

4. 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.
5. 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 1.

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