CHAPTER 14

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

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Introduction

According to some, the economic crisis of the mid 1970s marked the transition from the traditional Fordist mode of industrial organization to one of Time-Based-Competition (Schoenberger, 1997; Stalk, 1988; Stalk and Hout, 1990). As an industrial paradigm, the 'old', ideal-type, Fordism was a system of 'assembly-line-based mass production' of standardized goods (Asheim, 1992). Production took place in large vertically integrated plants owned and centrally controlled by large, often multinational, corporations. Rising productivity was based on mechanization, the pursuit of internal economies of scale, a detailed division of tasks and work intensification (Amin, 1994). Long production runs and dedicated machinery were intended to minimize downtime. Driven by similar considerations, suppliers produced and delivered standardized components in large, infrequent, batches. Price competitiveness was the single most important criterion in supplier-selection (Sayer, 1986). Finally, as regards the geography of production, the narrow focus on price, production costs and labor cost minimization meant that the Fordist system was often characterized by an extreme spatial division of labor and spaced-out supply chains. Peripheral regions were incorporated in a dependent way through branch-plant investment that contributed little to regional development.

The Fordist methods of work organization had reached their limits in terms of productivity growth by the 1970s. Furthermore, due to its inherent rigidities, the Fordist system was unable to cater for modern markets, characterized by a demand for variety, quality and responsiveness and by shorter product life cycles. For these reasons, among others, the economic crisis of the mid-1970s has been interpreted as a 'crisis of Fordism' (Amin, 1994; Schoenberger, 1997). One idea is that a resolution of this crisis, if possible at all, requires a return to a more flexible, craft-based mode of production[1].

Others point at many firms that are successfully competing in the new market environment with new flexible forms of high volume production that are blurring the distinction between craft and mass production

[1] See, for example, Piore and Sabel (1984) on 'flexible specialization' and Storper and Scott (1989) on 'flexible accumulation'.

(Jessop, 1992; Tomaney, 1994). These firms are not producing standardized end-products but instead have succeeded in combining mass production with product variety and customization. All new high volume production firms, in one way or another, "combine the benefits of economies of scope and greater flexibility in responding to consumer demand, which are characteristic of small batch production, with those of economies of scale, characteristic of mass production" (Hudson, 1997b, p. 303). These ideas are captured in a number of production concepts, including Lean Production (Womack, Jones and Roos, 1990), Mass Customisation (Pine, 1993), Dynamic Flexibility (Coriat, 1991, Veltz, 1991), Diversified Quality Production (Jessop, 1992) and Time-Based-Competition (Stalk and Hout, 1990; Schoenberger, 1997).

The Time-Based-Competition (TBC) model emphasizes the fact that the new competitive environment and the requirements of modern markets have drastically changed the role of time in competition. According to the proponents of the model, 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, in theory, 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 lead towards a greater proximity between buyers and their suppliers and an increase in local and regional production linkages. The argument basically involves two buyer-supplier proximity drivers: efficient technical information exchange and efficient product flow or logistical efficiency. As regards 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. It involves both microcomputer assemblers and the manufacturers of components and parts. Companies in this industry have been portrayed as prime examples of TBC and JIT supply (Hudson, 1997; *International Business Week*, 3 November 1983 and 14 May 1984; Sayer, 1986). The microcomputer sector is a good example of an industry facing highly volatile markets and irregular and unpredictable demand - characteristics that will prove to be central to the analysis later in this paper. The findings concerning the relevance of the first driver, efficient technical information exchange, have been documented elsewhere (van Egeraat, 2002; van Egeraat, Jacobson, and Phelps, 2002). This article will focus on how the logistical considerations have influenced the geography of production linkages in the industry. Related studies on the industry (e.g. Angel and Engstrom, 1995; Dedrick and Kraemer, 2002) 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. Furthermore, Angel and Engstrom analyzed the role of technical information exchange and paid no attention to logistical considerations.

This article focuses strongly on the relevance of the efficiency argument for buyer-supplier proximity. Less attention is paid to other aspects of buyer-supplier relationships, notably a shift from producer-driven to buyer-driven commodity chains (Gereffi, 2001) or from supplier to client markets and the associated shift of relative power among chain members. Whether governance mechanisms in the microcomputer hardware industry are really shifting towards buyer-driven chains is a matter for debate (see, for example, Chen, 2002). Nevertheless, power-relations in general could have a confounding effect on the analysis of logistical arrangements and their influence will therefore receive attention as well.

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 1998 to early 1999. Additional data were collected via postal questionnaires completed by staff at the focal companies and newspaper research. Finally, telephone interviews were conducted with staff at a selection of local supplier firms.

The next section will more closely examine the logic underlying the idea that logistical considerations 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 microcomputer companies in Ireland and Scotland. 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 next section provides an insight into the way the focal companies structured their inbound logistics pipelines. This provides the basis for the subsequent analysis of data on inventory levels, shipment frequencies and modes of transport. We focus on the question whether the focal companies are still operating sub-optimal inbound logistics system organized on traditional Fordist, Mass Production, principles, or whether, in line with TBC, the focal companies have optimal (or at least less sub-optimal)[2] inbound logistics systems that take full account of the modern comprehensive logistics management principles underlying TBC. If the latter is the case, then we will have to conclude that these principles do not necessarily lead to buyer-supplier proximity. In the conclusion we consider the implications of this for industrial policy.

Comprehensive logistics management principles

One of the central components of Time Based Competition is JIT supply. Textbook 'true JIT' (Morris, 1989; Morris, 1992), 'full JIT' (Mair, 1992), or 'pure JIT' (Fawcett and Birou, 1992) is a logistics system characterized by very low buffer inventories, near synchronous production and delivery of inputs on a daily basis[3] directly to the assembly line. The term sequential JIT has been used for situations where suppliers manufacture and deliver components in the same order as they are used at the assembly lines of their customers (Larsson, 2000). Such systems are believed to lead to close buyer-supplier proximity (Estall, 1985; Kenney and Florida, 1992; Mair, 1992; Mair, Florida, and Kenney, 1988; Sayer, 1986; Schoenberger, 1997). True JIT is often presented as the optimal supply system. However, true JIT supply should really be interpreted as an extreme outcome in a spectrum of possible optimal outcomes based on modern comprehensive logistics management principles. The explanation requires a closer look at the comprehensive logistics management principles underlying JIT supply.

Logistics management systems have always involved calculating the minimum required component inventory levels and related individual order quantities. In the old system, the individual order quantities, or lot sizes, were typically based on a traditional economic order quantity (EOQ) formulation (Christopher, 1992; McCann, 1998). The EOQ model is based on the idea that it is possible to calculate order quantities/ shipment frequencies, involving minimal 'total logistics costs' (TLCs). These TLCs are the sum of the ordering/set-up costs, the costs of

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[2] This paper does not prove that the logistical solutions reported in this article are perfectly optimal. However, the data do show that the companies have adopted the modern comprehensive logistics management principles and that their systems are at least less sub-optimal than the systems organized on traditional Fordist principles.

[3] The criteria are arbitrary. Some authors reserve the term 'true JIT' for cases involving multiple deliveries a day (Morris, 1989; Morris, 1992).

holding inventories and the costs of transporting goods. The ordering/set-up costs included the administration costs involved in organizing an individual purchase, plus the labor costs involved in machinery set-up. The inventory holding costs were traditionally reduced to interest costs. The EOQ was derived by balancing these cost components.[4]

The modern comprehensive logistics management principles that underlie JIT, involve a more inclusive interpretation of inventory holding costs. According to McCann (1998), compared to the traditional models, two extra cost factors are considered and are believed to represent a significant part of the inventory holding costs: space costs and total quality costs (TQCs).

The space costs of inventory are the space and space handling costs of storage and warehouse space, comprising the land costs and the labor costs involved in inventory handling operations. The quality costs are the combined costs of lost market share due to poor quality and reliability of the final product and the costs of final quality control administration, which are the costs of expediting materials, the costs of lost orders, back-orders, scrap and rejects. The greater the average volume of inventory held, the greater is the risk that faults in individual components will go undetected during the production process – the greater the quality costs.

These cost components were not included in traditional Western purchasing techniques, which, as a consequence, underestimated the real costs of holding inventories. In other words the adoption of the comprehensive logistics management principles creates an incentive to further reduce the average volume of inventories by reducing the shipment size and increasing the shipment frequency. In modern quality-competitive markets the significance of TQCs and space costs may be so

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[4] The traditional formulation of the EOQ is expressed as $Q^* = \sqrt{\frac{2mS}{Ic}}$, where Q^* is the economic order quantity, m is the quantity of input per time period, S is the ordering/set-up costs of conducting each individual shipment, I is the rate of interest and c is the source price per unit of input (McCann, 1998). With his broader logistics costs model McCann (1996; 1998) shows how total input logistics costs are generally a positive function of transport costs and, thus, of distance. Correspondingly, the EOQ is dependent on transport costs and distance. Integration of this idea, and assuming shipment economies of scale, leads to the following formulation for the EOQ $Q_i^* = \sqrt{\frac{2m(S + ad_i)}{Ic}}$, where a is movement costs per mile and d is delivery distance.

great that the EOQ tends towards zero, i.e. lot sizes of one.[5] However, if shipment sizes go down, and shipment frequencies go up, the transport cost and ordering/set-up cost components of the TLCs will rise. There are two ways this can be prevented. First, firms can work towards a reduction of the ordering/set-up costs of conducting each individual shipment, for example by streamlining the order entry system. Secondly, and more importantly for the present discussion, firms can attempt to reduce the input delivery distance. This is the basic logic behind the JIT-proximity argument (Mair, 1992; McCann, 1996; McCann, 1998).

The idea that there are forces that drive customer-supplier proximity is obviously not new. Even the traditional logistics models and the traditional way of calculating the EOQ could lead to a situation where the transport costs and the interest costs of holding inventories would drive customer-supplier co-location. In fact, one could consider buyer-supplier co-location as the 'normal' situation. It is only because of issues such as differences in labor costs between locations, economies of scale in component production, and a whole range of reasons related to history, the technological capabilities of a region's suppliers and locational inertia, that customers use suppliers located in other regions. The difference with the comprehensive logistics management principles that underlie JIT is that the forces tending towards buyer-supplier proximity are stronger due to a greater appreciation of the role of space costs and TQCs.

However, the specifics of the logistical arrangements and the effects on linkage distance remain dependent on a range of component characteristics and contextual conditions. Paraphrasing Christopher (1992), companies still have to make a range of 'trade-offs' in working towards the improvement of total supply chain cost effectiveness – the ultimate goal of any logistics system. Here we briefly consider the four issues which were investigated in the course of the study: differences in labor cost among production locations; value, volume and weight of components; minimum efficient scale of component production; and component variety. Other issues, notably superior technological capability and locational inertia will not be discussed since, because they were clearly less relevant for our case, they were not specifically addressed in the study.

Labor cost differences among regions, as reflected in the price of components, are very important. More distant suppliers may be able to compete with lower prices because of cheaper labor costs. If these price

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[5] Taking account of the space costs and TQC, the new formulation of the EOQ becomes: $Q_i{*} = \sqrt{\frac{2m(S + ad_i)}{q + s + Ic_i}}$, where *s* is the logistics space cost coefficient and *q* expresses the impact of the TQC. Thus the higher the value of *s* and *q* the closer the EOQ will be to zero (McCann, 1998).

advantages outweigh the efficiencies gained by co-location, then a firm might operate JIT supply over longer distances (McCann, 1998) or operate logistics systems that diverge substantially from the prototypical true JIT system.

Another oft-cited issue relates to the value and the bulk or weight of individual components. The incentive for increasing shipment frequency, decreasing order size and decreasing linkage distance will be greater for high value components than for low value components (Christopher, 1992), *ceteris paribus*, since components with a high value will incur much higher interest and insurance costs. Likewise, the incentives for increasing shipment frequency and decreasing linkage distance are greater for physically bulky and heavy components than for small and light components, *ceteris paribus* (Lubben, 1988; McKinnon, 1997), since physically bulky components will incur higher space costs while the transport costs are higher for both physically bulky and heavy components.

The minimum efficient scale of component production also impinges on the logistical arrangements and linkage distance. Production at minimum efficient scale often means that component manufacturers need to supply several customers, which can mean that suppliers are located at considerable distances from some of these customers (Bordenave and Lung, 1996; Jones and North, 1991; McKinnon, 1997; Milne, 1990; Morris, 1992; Schamp, 1991).

Finally, the incentives for increasing the shipment frequency and proximity will be stronger for component categories involving a high variety of options (e.g. different colors or styles) than for more standardized component categories. This is because the greater the variety of options within a component category, the higher the inventory holding costs involved in stockpiling a certain level of finished components in all possible permutations (Christopher, 1992; van Hoek, 1998; Bordenave and Lung, 1996), particularly in situations of highly unpredictable demand. Therefore, the greater the variety of options, the greater the incentive to delay the final assembly of component materials into finished components. The greater the delay in final assembly, the greater the shipment frequency, the greater the drive for buyer-supplier proximity.

All these component characteristics and the difference in labor costs among regions mean that the adoption of comprehensive logistics management principles can have a variety of outcomes, involving both local and overseas sources and a combination of delivery methods (Lubben, 1988). At one end of the spectrum, the pipeline of some components will be organized along the lines of a true JIT system with suppliers located in close proximity to the customer. Because of technical developments in transport and logistics, even such a true JIT system does not necessarily involve buyer-supplier co-location. Indeed, some companies have been reported to operate such systems with suppliers located in other countries or even other continents (Clarke and Beany, 1993; Glasmeier and McCluskey, 1987; Lamming, 1993; McCann, 1998; Milne, 1990). However, these examples remain the exceptions. Frequency, distance, speed, reliability and the cost of transport are interrelated issues that have to be traded off against one another (McKinnon, 1997). In general, the literature suggests maximum workable distances for true JIT supply ranging from 30 to 150 miles (Estall, 1985; Kenney and Florida, 1992; Mair, 1992; Mair, Florida and Kenney, 1988; Sayer, 1986; Schoenberger, 1997).

Alternatively, the adoption of comprehensive logistics management principles might lead to a "JIT-type" supply system (Crowley, 1996) involving slightly less frequent shipments and slightly higher buffer inventories and suppliers somewhat further away. In such instances, "the meaning of JIT delivery starts to change" (Lubben, 1988, p. 192). At the other end of the spectrum of outcomes, the pipelines of components might involve even less frequent shipments, still higher (though tightly managed) buffer inventory levels, and suppliers located at great distances (Fawcett and Birou, 1992).

Geography of production linkages

This section outlines the sources of the parts and components used by the 11 focal companies. Interviewees provided the names of their suppliers as well as the location of manufacturing. The precise detail of the geographical configuration of the supplier networks differed from company to company. However, great commonalities did exist, especially with respect to the regional supply situation. 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 at individual company level, see: van Egeraat, Turok and Jacobson (1999) and van Egeraat, (2002).

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 [6], cables/interconnect and packaging material. Furthermore, 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, network cards, cables, keyboards

[6] 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.

Table 1 Summary of Geographical Sources of Material Inputs of Focal Companies, 1998-1999

Material input	*Main geographical sources**
Enclosures and racks (high volume models)	Mainly local and to a lesser extent Far East;
Enclosures and racks (less current models); Screws, fasteners and other c-class items	USA and, to a lesser extent, 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
Floppy drives; CD-ROM drives; CD-RW drives; DVD drives; low-end technology high capacity disc and tape drives; Batteries and AC-adapter (for portables); Digital cameras; Hard disk drives; Speakers and microphones; Docking stations; Keyboards; mice; joysticks; low-end power supply; portable computers (contract manufacturing)	Far East
High-end high capacity disc and tape drives; high-end power supply	USA, Far East, Europe and England
Heatsinks; Cooling fans	Mainly Far East; to a lesser extent USA, England and Germany
Modems and network components	Mainly Far East and USA, although four suppliers were manufacturing in Ireland
Graphics, video and sound cards; Printers; Other semiconductors; Capacitors and resistors; Memory	Mainly Far East
Cables and interconnect	Mainly the Far East and, to a lesser extent, Ireland and Scotland.
Displays	Mainly Far East; Wales and England for few selected models.
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; Packaging material; Sub-assembly and rework services; Printing of non-English language key-board models	Local
Complete computer systems (contract manufacturing)	Mainly local, England and Taiwan;
Etched boards; Interconnect, jumpers, switches	Mainly Far East and USA

* For the sake of brevity, much of the detail in this table has been omitted. For the complete table, please contact corresponding author.

Source: Company interviews.

and monitors, were manufactured in other regions, notably in the Far East. Only enclosures, packaging, media, kits and non-English language keyboards were mainly sourced from suppliers in Ireland or Scotland.

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. Apart from limited digital printing activity, 11 kitting plants merely packaged media and other language specific parts into a box. Similarly, five keyboard localization plants merely laser printed (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 were good 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 made up 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. 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, inter-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 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 is partly explained by a less inclusive definition of local sourcing in our research. Thus, the IEE figures include expenditure on items bought from local supply-chain-managers but manufactured in other regions as well as expenditure on complete systems manufactured by contract manufacturers with local operations. These items were not considered vertical production linkages and were excluded from the data collected during the company interviews.

Inbound pipeline strategies and structures

The focal companies had always had a mix of logistical arrangements. Before the mid-1990s, a small part of the inputs was manufactured and supplied on a virtually true JIT basis, involving minimal buffer inventories. In fact, Apple had implemented true JIT supply systems for selected components as early as 1983 (*International Business Week*, 14 May 1984). However, the supply chains of most other components still involved larger buffer stocks, in most cases stored in customers' warehouses as customer-owned inventory. These components were typically supplied on the basis of a push model, with vendors reacting to relatively inflexible purchase orders, detailing a fixed amount of product and a fixed delivery date on which customers had to accept the material. Supplies could either come direct from the suppliers' manufacturing facilities or be delivered via the suppliers' regional warehouses.

Since the mid-1990s, the strategy of all focal companies has been shifting towards a 'hubbing' system. In a hubbing system, suppliers that are not able to supply their customers directly from their manufacturing facilities within a certain lead-time are requested to hold an agreed minimum amount of inventory at a location near to their customers – the 'hub'. On a very frequent basis, the customers pull from these hubs, either their exact material requirements or the amount necessary to replenish minimal on-site buffers. The suppliers have the responsibility for maintaining sufficient inventories in the hubs and hold title to these inventories. Customers only own the material from the moment they pull it from the hubs. Suppliers produce and deliver on the basis of very flexible purchase orders, often 'blanket purchase orders'.

Some of the focal companies pulled material from a multitude of hubs, individually organized by the various suppliers, i.e. vendor hubs. However, there was an increasing trend to consolidate the hubbed inventories of multiple suppliers into one or two super hubs. This significantly reduced the complexity of the pull system. Some focal companies managed their own super hub. However, in most cases these super hubs were owned and managed by third-party-logistics (3pl) providers that offered integrated logistics services. These '3pl hubs' could serve several focal companies.

Delivery lead-time requirements of individual focal companies varied from 24 hours to as low as one hour. Most 3pl hubs were therefore located close to the focal companies (see Figure 1) and some focal companies had organized hubbing facilities on-site. Such proximity allowed companies to pull materials multiple times a day, leading to extremely low inbound inventory levels on the books of the customers. It is this hubbing system that partly explains the discrepancy between the use of overseas component sources and the high inventory turns published by some of the focal companies (Casey, 1997; Oram, 1997).

Apart from hubbing, the focal companies still used a range of other pipeline structures, including true JIT. But most structures had one thing in common with the hubbing system: they involved locally stored inventories on the books of the suppliers. Thus, focal companies made increasing use of supply-chain-management companies that not only organized the logistics of components, but actually bought and held title to components until they were delivered to the assembly plants. Items sourced in this way could include many c-class items, cables and interconnect material, mice, keyboards and media. From an inbound logistics point of view there are great parallels between receiving supplies in this way and from a local hub. In both cases the customer pulls on a very frequent basis from agreed buffers located in close proximity and owned by the supplier/supply-chain-manager.

In many cases local suppliers were requested to hold (at their own premises) minimum buffers of finished goods at levels similar to those requested from suppliers delivering through the hubs. Customers did not have to take the material and did not own it until the moment they pulled it from the local suppliers. Again, in those cases there was not that much difference between a hub and a local supplier.

Through the hubbing system, and through most of the other pipeline arrangements, focal companies reduced their inbound inventories to a minimum by requesting suppliers to provide JIT deliveries from finished component inventories, stored in local warehouses. Such supply systems are typically referred to as 'apparent JIT' (Lamming, 1993; Ryan, 1997) or 'pseudo JIT' (Hudson, 1994). It has been suggested that these systems are sub-optimal and hold no benefit for the supply chain as a whole, since the costs of inventory remain in the system (Lamming, 1993). Suppliers are allegedly 'forced to eat inventories' (Morris, Munday, and Wilkinson, 1993; Roper, Prabhu, and van Zwanenberg, 1997) and the burden of inventory is simply transferred from the customers to the suppliers. However, the use of hubs, in itself, does not necessarily mean that the supply system is sub-optimal. The fact that the supply system diverges from the prototypical true JIT picture does not mean that the modern comprehensive logistics management principles are not appreciated. To determine this one requires data on the actual size of the inventories, the shipment frequencies and the mode of transport. These data are presented in the next section. However, additional information regarding the detail of the hubbing arrangements/contracts can already cast some light on the issue.

Figure 1 Location of Main Third Party Logistics Hubs in Ireland and Scotland – 1998/1999

Source: Company interviews

With regard to the idea of suppliers being forced to eat inventories, all but one of the interviewees indicated that suppliers were compensated for hubbing. Focal companies were paying more than the standard price for hubbed components. Furthermore, hubbing contracts could involve different liability clauses which meant that the risk of obsolescence was not always entirely transferred to the supplier. Thus although in the case of many components the focal companies were not liable to take the inventories in the hub at any stage, in other cases, particularly in cases of customised components, focal companies had to take the material in the pipeline after a certain period. Anyway, the risk of obsolescence of hubbed materials was generally kept to a minimum by the intensive sharing of information regarding inventory data and demand forecasts.

So if suppliers are compensated for maintaining inventories in the hubs and the focal companies have to bear the cost of inventories anyway, the question arises: what drives the rise of hubbing? There are several advantages of hubbing. First, a hubbing system, as opposed to a system where each individual focal company carries its own inventories, provides economies of scale in the management of industry standard inventories and allows total inventories to be reduced since inventories in the hubs can be, and are, switched between various focal companies. Secondly, most focal companies were extremely focussed on short-term performance indicators, such as return on investment, and hubbing allowed them to improve some of these indicators. As one interviewee put it: "[our company] is a public company … the first thing a Street analyst will look for is our inventory and our turns. Obviously this is a huge opportunity" (Interview Operations Manager, Gateway EMEA, 1999).

The use of 3pl hubs creates additional advantages over the use of vendor hubs. Both customers and suppliers can tap into the full set of integrated services offered by the 3pl providers. The bigger 3pl providers have developed or acquired core technologies and competencies in the area of logistics and supply-chain-management, notably sophisticated EDI, satellite tracking, radio-frequency scanning and automated customs handling systems.

Logistical efficiency

The focal companies imported the vast majority of components and parts from regions outside Ireland and Britain, notably from the Far East, and the pipelines of most components involved inventories, often hubbed in local warehouses. This section will investigate whether this situation reflects a sub-optimal inbound logistics system organized on traditional Fordist, Mass Production principles, or whether it came about in the context of a more efficient inbound logistics system, taking account of the modern comprehensive logistics management principles underlying JIT and TBC.

The interviews with the focal companies made clear that the costs of holding inventories in the inbound pipeline were well appreciated in all focal companies. This was reflected in the high level of control focal companies kept over the inbound inventories and pipelines, as illustrated by the following quote.

> I give [the suppliers] my material requirements plan every week for that product and I expect them to manage the chain between them and the hub, I expect them to turn it up, down, slow it fasten it and manage it so that I always have 10 days

> [worth of inventory] in the hub. … We run queries here every day by part number which sends out an exception report which shows me what suppliers have less than 10 days. And the buyers call them. And it also shows us what we have too much of. And we than proactively take actions twice a week. … All the vendors are on-line to Irish Express Cargo [the 3pl hub]. All the vendors have the same kind of contact. That is a criterion that Gateway gives (Interview Operations Manager, Gateway Ireland, Sept. 1999).

In order to get an insight into how tightly the inbound inventories were managed, the focal companies were asked to provide a set of key logistics data for individual components from the various source regions. Table 2 summarizes these data. The first column lists the various material inputs. With the exception of data on microprocessors and memory, no data are presented on the components for the board assembly lines. Only four focal companies were assembling limited amounts of printed circuit boards on site. The second column lists the target buffer or inventory levels (average for respondent companies) that companies tried to maintain for the various components. The data on target buffer levels represent buffers kept at hubs, suppliers' local/regional manufacturing facilities, warehouses of the focal companies, supply-chain-managers or at a combination of these facilities. The data do not include the (small) inventories kept at the plants of the focal companies in the context of hubbing or true JIT supply. In most cases the size of these on-site buffers was minimal. Finally, the third column lists the target number of days between shipments from the location of manufacturing into the main buffer (average for respondent companies). This is a measure of the shipment frequency.

The key logistics data paint a picture of tightly managed inbound inventories with modest target buffer levels and high shipment frequencies. To some extent the target buffer levels for individual component pipelines varied, depending on a number of interrelated issues that will be discussed later in this section. However, all companies worked with a generic figure for target inbound inventory that applied to most parts and components. All but two focal companies worked towards a buffer of ten days (of forecasted demand) for most of their material inputs. One managed its inventories even more tightly, working towards a five day generic buffer level and applying a higher shipment frequency than other companies for most of its material inputs. The second worked towards a mixture of ten day and five day target buffer levels.

Broken down by geographical origin, most components manufactured in the Far East and the Americas involved target buffers of between eight and ten days and shipment frequencies between weekly and bi-weekly (averages for respondent companies). For most materials from these regions the typical mode of transport was plane[7], leading to relatively small inventories caught up in transit and relatively small fluctuations in the actual inbound inventory levels. Most components manufactured in Europe again involved target buffer levels of between eight and ten days but shipments were more frequent – ranging from one to five times a week. All European material was trucked by road/ferry and the delivery lead-time was generally under 24 hours.

Finally, regarding material inputs manufactured in the UK and Ireland, although a number of components involved very low target buffer levels – as low as two days (average for respondent companies) – most components involved buffer levels comparable to those applicable to items manufactured in other regions. Table 2 does not show shipment frequencies for locally sourced components since in most cases the main buffers were positioned at the suppliers' manufacturing facilities and fed directly from the manufacturing lines. Focal companies typically pulled materials from these suppliers on a daily basis, or even more frequently.[8]

Where the main buffers were not positioned at the suppliers' manufacturing facilities, the hubs or the customers' facilities were typically supplied very frequently – often daily or every second day. The main exceptions included modem/network cards, which were typically shipped on a weekly or bi-weekly basis.

Thus, the general picture is one of modest inbound target buffer levels and high shipment frequencies.[9] Although modest compared to the traditional Western logistics systems, these inbound target buffer levels were slightly higher than one would expect on the basis of comprehensive logistics management principles alone. The market conditions faced by the focal companies in combination with their production strategy provide an explanation for why the inbound buffer levels were in fact not less than optimal.

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[7] Plane was the typical preferred mode of transport for the following items: microprocessors; memory; partly integrated portables; autoloaders; AC adapters; hard disk drives; CD ROM drives; Zip drives; sound, video and graphics cards; DVD drives; modem and network cards; motherboards; riser cards; mice; screws and fasteners.

[8] Thus, most enclosures, racks, heat sinks, configured hard-disk drives, and cables, manufactured in Ireland or the UK, were pulled on a daily basis or even more frequently, from buffers positioned at the suppliers. Similarly, country kits, wrapped media, non-English language keyboards and packaging were generally pulled daily, or even more frequently, from very small (true JIT) buffers kept at the suppliers' premises.

[9] The figures should be compared to the traditional Western logistics systems during the 1970s in which it was not uncommon for components like processors to be delivered every two or three months and to be transported by ship (personal communication, Dr. Philip McCann).

Table 2. Summary of Key Logistics Data (Averages for Focal Companies)

	Target buffer levels (days)	*Target number of days between shipments*
Material inputs Far East and Americas		
Microprocessors	4	2
Flat panel monitors	5	5
Memory	8	3
LCD displays	8	4
Partly integrated portables	10	4
Tape back-up/ autoloaders; AC adapter; Hard disk drives; CRT monitors; Small plastic metal parts; Floppy drive; CD ROM drive; CD RW drive; Combo drive; Zip drive; Docking stations; Joysticks; Scanner; Server racks; Sound/video/graphics cards; Power supplies; DVD drive; Modem/network cards; Enclosures; Motherboards/backpanels; English language keyboards; Printers; Enclosures for portables; Heat sinks; Microphone; Cooling fans; Riser cards	8-10	5-10
Battery for portable; Speakers; Mice; Power cables	13-14	6-10
Other cables	15	11
Screws and fasteners	35	40
Material inputs Europe		
Power supplies	5	2
m' boards/ backpanels	10	1
CRT monitors; Tape back-up/ autoloaders; Memory; Enclosures for portables; Cooling fans; Hard disk drives; Other cables	8-10	2-4
Printers; Sound/video/graphics cards	10	5
Material Inputs Ireland and UK		
Packaging; Non-English language keyboards; Country kits	2	
CD ROMs (wrapped); Printed media (wrapped)	4	
Heat sinks; Enclosures	5	
Hard disk drives; Server racks	6	
Small plastic metal parts; Modem/network cards; m' boards/ backpanels; Power supplies; CRT monitors; Printers; Flexcircuit	9- 10	
Printed labels; Power cables; Other cables	13	

Source: Company interviews.

All focal companies offered a great variety of product configurations, often customized to individual orders, in combination with extremely short order lead times – typically, the companies applied a target order lead time of less than five days. At the same time, the companies aimed to minimize the inventories of finished computer systems. These objectives are fully consistent with textbook TBC (Hise, 1995; Stalk and Hout, 1990). All focal companies addressed this combination of objectives with a build-to-order (BTO) production strategy for the majority of their output. The focal companies generally did not build systems to stock. Instead, computer assembly activities usually only started after customer order receipt.

The problem was that the focal companies were facing strongly fluctuating and unpredictable demand. In such an environment a BTO strategy in combination with very short lead times results in strongly fluctuating and unpredictable demand from final assembly on upstream functions. Although a JIT manufacturing system is designed to deal with small fluctuations in demand from final assembly, it cannot deal with highly fluctuating and unpredictable demand since this brings the danger of inefficient use of labor and machinery upstream and the build up of in-process inventories (Sayer, 1986). In the factories of the focal companies this problem was partly solved by a reduction of the number of separate phases in the production process. Production typically involved a very short uninterrupted sequence of system assembly, software downloading, testing and packing, with no in-process buffers. In a sense, the first upstream activity to be encountered was component production and that virtually all took place outside the boundaries of the plant, at the component suppliers. The problem of zero productivity of workers was addressed with numerical labor flexibility.

However, as the first upstream function, the suppliers were confronted with a highly irregular and unpredictable sequence of pulls by the focal companies. In such a situation a virtual elimination of buffer inventories on the basis of the comprehensive logistics management principles would lead to an inefficient use of labor at the suppliers or an increased risk of stock-out. A BTO production system with short order lead times in an environment of erratic final demand simply requires certain buffers between the suppliers and the manufacturing lines of the customer, except in situations of extremely short manufacturing cycles at the suppliers. All this is totally consistent with the comprehensive logistics management principles underlying JIT and TBC. In effect, the focal companies were simply trading-off the costs of inbound pipeline inventories against the loss of market share and revenue due to stock-out.[10]

This partly explains why in many cases the supply pipelines of components manufactured in Ireland, the UK and Europe involved similar target buffer levels to those that applied to inputs manufactured in the Far East or the Americas. Many of these components involved target buffer levels of between five and ten days. A number of items manufactured in Ireland or the UK tended to involve lower target buffer levels of (finished) components. However, in most of these cases the suppliers involved were committed to holding the balance of the generic target levels in the form of unfinished or non-configured components

[10] A similar challenge of combining JIT principles, global sourcing and BTO production for a volatile market has been described in an article on the logistics operations at Bose's speaker plant in the USA (Bradley, 1989).

while the final assembly or configuration process was made extremely short.

For example, four focal companies that received hard disks from Quantum in Ireland worked towards relatively low target levels of fully configured/pre-assembled hard disks. However, Quantum was committed to holding the balance of the ten days generic target buffer level in non-configured form, while the configuration cycle was very short and added minimal value. Three other focal companies applied the generic target buffer levels for finished hard disks.

To reiterate, there is abundant evidence that the inbound inventories and logistics pipelines were tightly managed. What can also be shown is that the impact of contextual conditions and component characteristics on the way companies managed their inbound logistics and the geography of the supply linkages was in line with the comprehensive logistics management principles. In the following paragraphs we show the empirical importance of the four main issues we introduced at the theoretical level above. It is essential to note that in all cases the eventual outcome was the result of a complex trade-off among a variety of component characteristics and contextual conditions. The eventual outcome therefore does not always directly reflect the importance of an individual factor. Moreover, the characteristics of some components, notably monitors, were such that companies had a choice of different supply-chain solutions, any one of which would have been equally efficient.

Regional differences in labor costs: These remained a strong force against a reduction of the linkage distance. Interviewees stated that producers in other regions, particularly in the Far East, could offer material inputs at a substantially lower price than producers in Ireland or the UK. This was mainly due to far lower wage rates and high flexibility of the labor force, while currency exchange rates played an important role as well. To attain total supply chain cost effectiveness companies balanced the efficiencies in logistics gained by using local suppliers against material cost price advantages gained by using suppliers in low-wage regions. In many cases the more efficient solution involved suppliers located in the Far East.

> It [the reason for not sourcing monitors locally] is basically an argument between the actual unit cost and the actual component part in terms of labor content, etc. So if labor content is a high proportion of the unit cost then it makes sense to manufacture that in a low labor cost arena. … So you take into account the differential between labor content and the actual transport cost, your [inventory] financing costs, and money while on the sea, etc., etc. (Interview Logistics Manager, Apple Computer Ireland, Dec. 2000).

Value, volume and weight of components: Also in line with the comprehensive logistics management principles was the fact that the inventories of components with a high unit value were most tightly managed. As regards material inputs manufactured in the Far East and the Americas, the inventories of high value microprocessors, flat panel monitors and memory tended to be managed most tightly (see Table 2). For example, on average the focal companies and their suppliers worked towards microprocessor inventory levels that fluctuated between four and six days. The high value of these components led to a higher shipment frequency, which should theoretically increase the tendency towards proximity. However, this force towards proximity was simply outweighed by the labor cost savings and exchange rate advantages involved in producing these items in the Far East in combination with the relatively low costs involved in transporting these items frequently by air. On the other hand, the inventories of items with a low unit value such as mice, cables, screws and printed labels incurred limited inventory holding costs and were managed least tightly.

The effect of bulkiness of individual components is most clearly illustrated by packaging material. Packaging material, although of low unit value, required much warehouse space, thereby incurring extremely high inventory holding costs. Therefore, packaging tended to be sourced locally on a true JIT basis involving buffer levels of less than one to two days and one or more shipments a day. In this case the characteristic of bulkiness weighed stronger than the characteristic of low unit value, resulting in true JIT supply.

The bulkiness and weight of the components also had a more indirect effect on the logistics management and the geography of the supply linkages – via their implications for the mode of transport. Most material inputs manufactured in the Far East or the Americas were typically transported by plane leading to low in-transit inventories and low fluctuations in the target buffer inventories. Companies mentioned transit times typically ranging from three to five days including time lost at customs authorities on both sides. However, airfreight rates rise steeply for components with a high physical volume or weight with the result that for many components airfreight is simply not an option on a continuous basis.

The alternative was ocean freight. The downside of ocean freight is that, compared to airfreight, it involves substantial in-transit inventories. Companies typically mentioned transit times of four to five weeks in the case of ocean freight from the Far East and two to three weeks from the USA. Furthermore, ocean freight involves larger fluctuations in the actual inbound inventory levels than airfreight, even though the target buffer levels might be similar. In spite of these downsides, for many components with lower value-to-weight or value-to-volume ratios the outcome of the trade-off of all factors was sourcing in the Far East and shipment by sea. Thus, power supplies, cooling fans, heat sinks, CRT monitors, keyboards, joysticks, microphones, scanners, speakers, printers, power cables and enclosures sourced in the Far East were typically transported by ship. The downsides of ocean freight were reduced by using different ocean-freight services, offering a range of transit times, and by the occasional use of airfreight services.

In other cases, the combination of component characteristics and regional labor cost differences / exchange rate advantages led to the use of local or regional suppliers. For example, most focal companies sourced enclosures from local suppliers.[11] Sourcing bulky enclosures in the Far East incurred high inventory holding costs due to the space costs of local warehousing and high in-transit inventories associated with ocean freight. This strong force for proximity was not offset by the labor cost savings associated with production in the Far East.

Minimum efficient scale (MES) of component production: This does explain some of the detail in the geographical configuration at a national and regional level. Components such as country kits, packaging and a service like keyboard localization can be produced or offered efficiently at a relatively low scale that requires only one customer. This allowed suppliers to set up relatively small operations in very close proximity to individual customers, often in the same town or city. The production of motherboards, monitors, enclosures and higher-end technology components, involves a higher minimum efficient scale that requires a level of business that can exceed that offered by one or a few individual microcomputer companies. As a result, the larger operations of these suppliers tended to be located at greater distances from at least some of their customers, often in a different country on the British Isles.

Component variety: The variety of options per component category was a relevant issue as well. The research showed that the components with a high variety of options – country kits, shrink-wrapped media, non-English language keyboard models and the customer configured hard disk drives of Quantum – were indeed produced on a true JIT or virtually true JIT basis, generally by local suppliers. Holding standard target buffer levels of these components in all their possible configurations and languages would greatly increase the inventory holding costs. The local supplier facilities were involved in the delayed or postponed final assembly or configuration activities, while they were generally committed

[11] A number of companies imported their volume enclosure models from the Far East. The reason for this lay in the relatively limited volumes required – volumes that did not warrant the costs of developing a local source and the cost of a second tool. Two of the companies that used imported enclosures were in the process of contracting a local supplier. Less current enclosure models and server racks were often imported from the USA. Again, the reason was that the volumes involved did not warrant the development of a second source locally.

to holding higher buffer levels of unfinished or non-configured components, often produced in other regions.

Clearly, component characteristics, regional differences in labor costs, and exchange rate changes affected the way companies managed their inbound logistics and the geography of the supply linkages. In many cases these characteristics led to logistics systems that diverged substantially from the prototypical true JIT system. However, in all cases the divergences were totally consistent with the comprehensive logistics management principles.

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 organized around geographically coherent multinational market regions. One aspect of this model is the idea that the increased focus on reducing order-to-delivery cycles and logistical efficiency will lead to a greater 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, and that the pipelines of most components involved inventories, often hubbed in local warehouses. Some have interpreted such supply systems as apparent JIT or pseudo JIT, a sub-optimal inbound logistics system organized on traditional Fordist, Mass Production principles. We have argued that the logistics systems and the geography of the supply linkages were not sub-optimal. The necessary inbound inventories were tightly managed leading to modest target buffer levels and high shipment frequencies. By sourcing from the Far East, companies were simply trading-off price advantages gained by using suppliers in low-wage regions against the efficiencies in logistics gained by using local suppliers, totally consistent with the modern comprehensive logistics management principles underlying JIT and TBC. Similarly, the effects of various component characteristics were consistent with what could be expected on the basis of the comprehensive logistics management principles.

The inbound inventory levels were slightly higher than one would expect on the basis of comprehensive logistics management principles alone. However, we have shown that this was not indicative of a sub-optimal supply chain solution. Rather, the main reason for the slightly higher levels lay in the BTO production strategies of the focal companies. Clearly, the modern comprehensive logistics management principles underlying JIT and TBC can lead to supply systems that diverge substantially from the prototypical true JIT system.

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, Hood and Peters, 1994, p. 669). The findings of this research suggest that such a strategy is becoming increasingly unsuitable, at least in the context of the microcomputer industry.

The suitability of a strategy of building integrated clusters around subsidiaries of MNEs in the microcomputer assembly industry might well become of theoretical interest only since Ireland and Scotland have recently experienced a wave of plant closures and job losses in the microcomputer assembly industry. During the 1980s and most of the 1990s Ireland and Scotland were important locations for computer assembly activity. Supplying the European market with build-to-order, often customized, bulky and relatively valuable systems with short order lead times required a production location in Europe. Within Europe, Ireland and Scotland offered the required combination of relatively low wages (on a European scale), flexible labor markets, and literate and trainable labor forces. In terms of Schoenberger's (1997) model of concentrated deconcentration, both countries functioned as the "new semi-periphery" of Europe.

The situation started to change during the second half of the 1990s. Wage rates in Ireland and Scotland were rising rapidly. At the same time, Eastern Europe was progressively opening up for capitalist economic activity, which created new production locations, offering low wages and a relatively skilled labor force, at a short distance from, and soon to become part of, the EU market.

As a result, since 1998, much system assembly activity has been shifting to Eastern European countries such as the Czech Republic and Hungary (van Egeraat and Jacobson, 2004). This shift of assembly activity, in combination with a competition-induced shakeout of branded microcomputer makers, has led to a serious reduction in microcomputer assembly activity in Ireland and Scotland. Of the original five focal companies operating in Ireland in 1998, by 2003 only Dell and Apple were still assembling microcomputers, and Apple's system assembly operation was substantially downsized. Similarly, of the six original focal companies in Scotland, only Sun, Packard Bell-NEC, IBM and Compaq/HP were still assembling systems by 2003 and IBM and Compaq/HP had significantly downsized their assembly operations while Packard Bell-NEC was planning to close its plant. The reduction of computer assembly activity resulted in further job-losses in the component sector, notably in plants producing the bulky enclosures that had always required relative proximity to the system assemblers.

Clearly a strategy of building integrated vertical clusters around manufacturing subsidiaries of MNEs does not look very promising in the context of Ireland and Scotland. The alternative route identified by Young, Hood and Peters (1994, p. 669) 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. Both IDA Ireland and Scottish Enterprise have indeed adopted elements of such a strategy.

References

Amin, A. (1994) Post-Fordism: Models, fantasies and phantoms of transition In: Amin, A. ed., *Post-Fordism: A reader.* Oxford, Cambridge: Blackwell.

Angel, D. and Engstrom, J. (1995) Manufacturing systems and technological change: The U.S. personal computer industry. *Economic Geography*, 79(1), 79–102.

Asheim, B. (1992) Flexible specialisation, industrial districts and small firms: A Critical Appraisal In: Emste, H. and Meier, V. eds., *Regional development and contemporary industrial response: Extending flexible specialisation.* London: Belhaven. 45–63.

Bordenave, G. and Lung, Y. (1996) New spatial configuration in the European automobile industry. *European Urban and Regional Studies*, 3(4), 305–21.

Bradley, P. (1989) Global sourcing takes split-second timing. *Purchasing*, 9(July), 52–58.

Casey, C. (1997) Compaq makes $462 million profits despite poor retail sales. *The Sunday Business Post,* 26 January.

Chen, S. (2002) Global production networks and information technology: the case of Taiwan. *Industry and Innovation*, 9(3), 249–265.

Christopher, M. (1992) *Logistics and supply chain management: Strategies for reducing costs and improving services*. London: Pitman.

Clarke, T. and Beany, P. (1993) Between autonomy and dependence: Corporate Strategy, plant status, and local agglomeration in the Scottish electronics industry. *Environment and Planning A*, 25(2), 213–32.

Coriat, B. (1991) Technical flexibility and mass production: Flexible specialisation and dynamic flexibility In: Benko, B. and Dunford, M. eds., *Industrial change and regional development: The transformation of new industrial spaces*. London and New York: Belhaven Press. 134–158.

Crowley, M. (1996) *National linkage programme*. Dublin: Industry Evaluation Unit.

Dedrick, J. and Kraemer, K. (2002) Globalization of the personal computer industry: Trends and implications. Unpublished manuscript, Center for Research on Information Technology and Organizations, University of California, USA.

Egeraat, C. van (2002) 'New high volume production, production linkages and regional development: The case of the microcomputer hardware industry in Ireland and Scotland'. Ph.D. thesis, Dublin City University, Ireland.

Egeraat, C. van and Jacobson, D. (2004) The rise and demise of the Irish and Scottish computer hardware industry. *European Planning Studies*, 12(6), 809–834.

Egeraat, C. van, Jacobson, D. and Phelps, N. (2002) New high volume production and the geographical configuration of production networks: A case study of the microcomputer hardware industry in Ireland and Scotland. Paper presented at the Annual Meeting of the Association of American Geographers, Los Angeles, March.

Egeraat, C. van, Turok, I. and Jacobson, D. (1999) The microcomputer industry in Ireland and Scotland: New high-volume production concepts, location and regional development. Paper presented at the Regional Science Association European Congress, University College Dublin, August.

Estall, R.C. (1985) Stock control in manufacturing: The just-in-time system and its locational implications. *Area*, 17(2), 129–33.

Fawcett, S. and Birou, L. (1992) Exploring the logistics interface between global and JIT sourcing. *International Journal of Physical Distribution & Logistics Management*, 22(1), 3–14.

Gerreffi, G. (2001) Shifting governance structures in global commodity chains, with special reference to the Internet. *American Behavioural Scientist*, 44(10), 1616–1637.

Glasmeier, A. and McCluskey, R. (1987) US auto parts production: An analysis of the organization and location of a changing industry. *Economic Geography*, 63(2), 142–159.

Hise, R. (1995) The implications of time-based competition on international logistics strategies. *Business Horizons*, 38(5), 39–46.

Hudson, R. (1994) New production concepts, new production geographies? Reflections on changes in the automobile industry. *Transactions of the Institute of British Geographers*, 19(3), 331–345.

Hudson, R. (1997) Regional futures: Industrial restructuring, new high volume production concepts and spatial development strategies in the New Europe. *Regional Studies*, 31(5), 467–478.

Hudson, R. (1997b) The end of mass production and of the mass collective worker? Experimenting with production and employment In: Lee, R. and Wills, J. eds., *Geographies of Economies*. London: Arnold. 302–311.

Industrial Policy Research Group (1992) *A time for change: Industrial policy for the 1990s*. Dublin: Stationery Office.

Jessop, B. (1992) Post Fordism and flexible specialisation: Incommensurable, contradictory, complementary, or just plain different perspectives? In: Ernste, H. and Meier, V. eds., *Regional development and contemporary industrial response: Extending flexible specialisation*. London: Belhaven. 25–44.

Jones, P. and North, J. (1991) Japanese motor industry transplants: The West European dimension. *Economic Geography*, 67(2), 105–123.

Kenney, M. and Florida, K. (1992) The Japanese transplants: Production organization and regional development. *Journal of the American Planning Association*, 58(1), 21–38.

Kotha, S. (1995) Mass customisation: Implementing the emerging paradigm for competitive advantage. *Strategic Management Journal*, 16 (special issue), 21–42.

Lamming, R. (1993) *Beyond partnership: Strategies for innovation and lean supply*. New York: Prentice Hall.

Larsson, A. (2000) The effects of globalization and modularization: The changing geographical structure of the domestic supplier-system of Volvo Automotive in Sweden. Paper presented at the 8th International Meeting of the GERPISA Automotive Research Network, Paris, June 8–10.

Lubben, R. (1988) *Just-in-time manufacturing*. New York: McGraw-Hill.

Mair, A. (1992) Just-in-time manufacturing and the spatial structure of the automobile industry: lessons from Japan. *Tijdschrift voor Economische en Sociale Geografie*, 83(2), 82–92.

Mair, A., Florida, R. and Kenney, M. (1988) The new geography of automobile production: Japanese transplants in North America. *Economic Geography*, 64(4), 352–73.

McCann, P. (1996) Logistics costs and the location of the firm: A one dimensional comparative static approach. *Location Science*, 4(1), 101–116.

McCann, P. (1998) *The economics of industrial location: A logistics-costs approach.* Berlin: Springer.

McCann, P. and Fingleton, B. (1996) The regional agglomeration impact of just-in-time input linkages: Evidence from the Scottish electronics industry. *Scottish Journal of Political Economy*, 43(5), 493–518.

McKinnon, A. (1997) Logistics, peripherality and manufacturing competitiveness In: Fynes, B. and Ennis, S. eds. *Competing from the periphery: Core issues in international business.* Dublin: Oak Tree Press. 335–369.

Milne, S. (1990) New forms of manufacturing and their spatial implications: the UK electronics consumer goods industry. *Environment and Planning A*, 22(2), 211–32.

Morgan, K. (1991) Competing and collaboration in electronics: What are the prospects for Britain? *Environment and Planning A*, 23(10), 1459–82.

Morris, J. (1989) Japanese inward investment and the 'importation' of sub contracting complexes: Three case studies. *Area*, 21(3), 269–277.

Morris, J. (1992) Flexible specialisation or the Japanese model: Reconceptualising a new regional industrial order In: Ernste, H. and Meier, V. eds., *Regional development and contemporary industrial response: Extending flexible specialisation.* London: Belhaven. 65–80.

Morris, J., Munday, M. and Wilkinson, B. (1993) *Working for the Japanese: The economic and social consequences of Japanese investment in Wales.* London: Athlone Press.

Oram, H. (1997) The success of a complete service. *The Irish Times*, 10 June.

Pine, B.J. (1993) *Mass customisation: The new frontier in business competition.* Boston (MA): Harvard Business School Press.

Piore, M. and Sabel, C. (1984) *The second industrial divide*. New York: Basic Books.

Pragman, H.P. (1996) JIT II: a purchasing concept for reducing lead times in time-based competition. *Business Horizons*, 39(4), 54–59.

Pyke, F. (1995) Endogenous development in a global context: The scope for industrial districts In: O'Doherty, D. ed., *Globalisation, networking and small firm innovation*. London: Graham and Trotman. 101–108.

Roper, I., Prabhu, V. and Zwanenberg, N. van. (1997) Just-in-time: Japanisation and the non-learning firm. *Work, Employment & Society*, 11(1), 27–46.

Ryan, P. (1997) Industrial markets and neo-modern production: The view from the edge In: Fynes, B. and Ennis, S. eds., *Competing from the periphery: Core issues in international business*. Dublin: Oak Tree Press. 372–397.

Sayer, A. (1986) New developments in manufacturing: the just-in-time system. *Capital and Class*, 30(winter), 43–72.

Schamp, E. (1991) Towards a spatial reorganisation of the German car industry? The implications for new production concepts In: Benko, G. and Dunford, M. eds., *Industrial change and regional development: The transformation of new industrial spaces*. London: Belhaven Press. 159–71.

Schoenberger, E. (1997) *The cultural crisis of the firm*. Blackwell: Oxford.

Schroeder, R.G. (1993) *Operations management: Decision making in the operations function*. (4th ed.). New York: McGraw-Hill.

Stalk, G. (1988) Time – The next source of competitive advantage. *Harvard Business Review*, 66(4), 41–51.

Stalk, G. and Hout, T. (1990) *Competing against time: How time-based competition is reshaping global markets*. New York and London: The Free Press and Collier Macmillan.

Storper, M. and Scott, A. (1989) The geographical foundations and social regulation of flexible production complexes In: Wolch, J. and Dear, M. eds., *The power of geography: How territory shapes social life*. Winchester: Unwin Hyman. 21–40.

Tomaney, J. (1994) A new paradigm of work organisation and technology? In: Amin, A. ed., *Post-Fordism: A reader*. Oxford and Cambridge: Blackwell. 157–194.

Turok, I. (1997) Linkages in the Scottish electronics industry: Further evidence. *Regional Studies*, 31(7), 705–11.

Veltz, P. (1991) New models of production organisation and trends in spatial development In: Benko, G. and Dunford, M. eds., *Industrial change and regional development: The transformation of new industrial spaces*. London and New York: Belhaven Press. 193–204.

Hoek, R. van (1998) *Postponed manufacturing in European supply chains*. Utrecht: KNAG/ Faculteit Ruimtelijke Wetenschappen Universiteit Utrecht.

Womack, P., Jones, D. and Roos, D. (1990) *The machine that changed the world*. New York: Simon & Schuster.

Young, S., Hood, N. and Peters, E. (1994) Multinational enterprises and regional economic development. *Regional Studies*, 28(7), 657–77.