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Abstract

This paper focuses on the Ink Jet Printing (IJP) industry in the vicinity of Cambridge, UK, and explores the emergence and maturation of a knowledge-based cluster of activity. The discussion is organised in terms of the origins and progeny of the firms in the cluster and their business environment. The lineage of firms is examined with reference to their technologies, spin-out activity and reasons for location near Cambridge. Ecological issues are addressed with reference to production chains, competition and new relations of ownership accompanying the globalisation of the mature industry. It is shown that maturation of an industry can be followed by local renewal, which in this case has accompanied recognition of the generic nature of the ink jet technologies as an innovative process for the deposition of valuable substances on substrates. Beyond the original printing and product identification industries, there are wide applications for IJP, which extend to the emergence of intelligent materials.

Key words: Ink Jet Printing industry, high tech, cluster dynamics, genealogical/ecological processes, renewal

Introduction

Local clusters of technology-based firms have been of increasing interest to policy makers and academic researchers. Recent cluster studies have moved from a mainly taxonomic approach, characterising types of cluster, to a more dynamic analysis of the emergence and development of local clusters of firms (Braunerhjelm and Feldman 2006; Menzel and Fornahl 2007). The activities of firms that make up a high tech cluster are distinctive and it is only by understanding the processes through which constituent firms and clusters develop and mature that we can gain understanding of collective trends. We define a cluster as a local concentration of firms that have horizontal (ecological) and/or vertical (genealogical) relations. In this paper we focus on the Ink Jet Printing (IJP) industry in the vicinity of Cambridge, UK, to explore the nature of maturation of a local knowledge-based (high tech) cluster. The Cambridge region is well known as a high tech centre (Garnsey and Heffernan 2005), made up of diverse clusters of mainly small knowledge based firms. What makes IJP distinctive in the area is that it has no direct university lineage and has achieved international market reach by anticipating and responding to global demand, resulting in several firms which are larger than other technology based firms in the area. The local ink jet printing industry more than doubled in size during the 1990s, growing at a much faster rate than the Cambridge tech cluster as a whole.

We organise our discussion in terms of genealogical and ecological issues. We examine the lineage of firms with reference to their technologies, spin-out activity and location near Cambridge. We address ecological issues with reference to production chains, competition and new relations of ownership accompanying the maturation of the international industry. We show how renewal has accompanied recognition of the generic nature of ink jet technologies as an innovative process for the deposition of valuable substances on substrates, with applications that include intelligent materials.

Cluster dynamics

Orthodox economic theory does not address the issue of whether firms reproduce or replicate, but geographers and regional economists have shown interest in this issue. In what follows we summarise what is known about evolutionary processes in local clusters. While dynamic approaches to clusters[1] are still rare, prior work is useful in pointing to ecological processes of interaction and genealogical processes of replication in the development of clusters (Baum and Singh 1994). The genealogy of organizational evolution – the structures of organizational inheritance and speciation - can be traced through new firms that spin-off from other organizations (cf. Garnsey et al. 2008). This process is very localised, as most new firms are sited in the region in which the founder has worked and/or lived (Stam 2007). Ecological processes involve interaction with other firms which are suppliers and customers in shared value chains. This is the vertical dimension of clusters and involves, for example, input-output relations with customers and suppliers (Maskell 2005). The cluster may also consist of firms carrying out similar activities as competitors in the same product-market or drawing on the same pool of labour. Such processes of interaction are not always in proximity; labour markets tend to be local but also transcend the locality, drawing in labour from elsewhere. For specialised high tech firms, competition in product-markets is to be expected from outside the region rather than within the region. Firms may also have interaction with firms in other populations that have dissimilar but complementary capabilities and activities (cf. Richardson 1972). These ecological and genealogical processes contribute to the competence base of the region (cf. Lawson 1999), through processes of collective learning (Keeble et al. 1999).

The literature has recognised three phases of cluster emergence. First, writers have pointed to the more or less ‘random’ location of early entrants. This chance location of successful early entrants sets in motion a self-reinforcing mechanism. The second phase of cluster emergence is said to be shaped by a spin-off process of new firms originating from successful early entrant firms (Klepper 2007; Arthur 1994). Third, there is the attraction of firms and investment from outside the area.

The first phase is said to involve random location of early entrants in the sense that the founding entrepreneurs just happen to be located there. Entrant firms are likely to be founded by local entrepreneurs originating from related industries or knowledge bases. Not all regions have the same probability of being the home region of an emerging cluster. The incubator organizations of these early entrants and of the emerging cluster can be firms, but also public

[1] There is a related literature on the life cycles of industries (see Klepper 1997), but this has no explicit spatial dimension (implicitly it is perhaps the nation that is taken as the context of analysis: see Vernon 1966).

research organizations. Universities and research laboratories often provide the initial knowledge base (including both scientific and technological knowledge and skilled labour) for the emergence and growth of entrepreneurial clusters (Braunerhjelm and Feldman 2006). Early entrants are more likely to be successful if originating from related local industries (Audia et al. 2006; Boschma and Wenting 2007).

The second phase involves spin-off processes from some successful early entrants (cf. Arthur 1994 for a stylized model of agglomeration by spin-off). These successful early entrants may settle and expand, to become 'anchor firms' (Feldman 2003; Lazerson and Lorenzoni 2005; Klepper 2007). A study of biotech clusters in the US by Romanelli and Feldman (2006: 105) found that the start-up of new firms by entrepreneurs from other biotech firms is critical to the overall growth of the cluster. Only those regional clusters that exhibit second-generation growth, i.e. spin-offs created from the early entrants, grow to substantial size in comparison to other potential regional clusters. The Schumpeterian (1934) logic is that clusters grow when the knowledge and other resources created by the early firms are combined and recombined by entrepreneurs who originate from the early entrants. Second-generation activity stimulates diversity of activity because spinoffs tend to avoid direct competition with the company of origin, as illustrated by spin-off firms of Acorn Computers in Cambridge (Garnsey and Heffernan 2005; Garnsey et al. 2008).

In the third phase identified in the literature, investment and talent is attracted from outside the cluster. Investments may include multinational firms investing in the region, or entrepreneurs moving to the area to set up a new independent firm. In addition, 'magnet organizations' (Harrison et al. 2004) attract talented people from outside the locality. These people may move to other firms or start up their own firm nearby later in their career.

We look for evidence from our case history to confirm or challenge these predicted trends. Although we find the evidence to be largely congruent with the three phase model outlined above, developments moved beyond these accounts and expansion was followed by further phases of maturation and renewal. We argue that these further phases require attention - in knowledge-based no less than in rustbelt regions - to inform policy and practice.

Research design and data

On the basis of the initial conceptual model sketched out above, drawn from the literature, our research questions first focused on the following: "How, if at all, has spin-off of new firms from old contributed to the evolution of the local ink jet printing industry in the Cambridge area?" These questions are specified in terms of constructs that depict the emergence and maturation processes of a local industrial cluster. *Genealogical processes* (influences over time) are examined on the basis of evidence on firm spin-offs in the IJP sector and the accumulation of technological knowledge by firms. *Ecological processes* (spatial connections) are examined through evidence concerning horizontal and vertical relations of firms in the IJP cluster.

These constructs (genealogical and ecological processes) are operationalised on the basis of evidence that is both quantitative and qualitative data. Evidence on IJP firms is derived in the form of data from the Cambridge University Engineering Department high-tech database, which includes all establishments in high tech industries in Cambridgeshire in the period 1988-2006. Data on their patents is derived from the database of the European Patent Office. For in-depth information on key firms in the Cambridgeshire IJP industry, case study analysis was undertaken. Seven in-depth case studies were undertaken with IJP companies at different stages of development (Table 1). The cases selected cover the leading firms in the Cambridgeshire IJP industry (CCL, Domino, Linx, Xaar, Xennia, and Inca) and some spin-offs from these IJP firms in closely related industries (Biodot, Inkski). The research strategy was based on semi-structured interviews of senior level personnel and on direct observation during student projects, together with archival evidence, press reports and company websites. The study was undertaken over an extensive period – 1995-2008 - addressing the problem of retrospective bias (cf. Garnsey et al 2008).

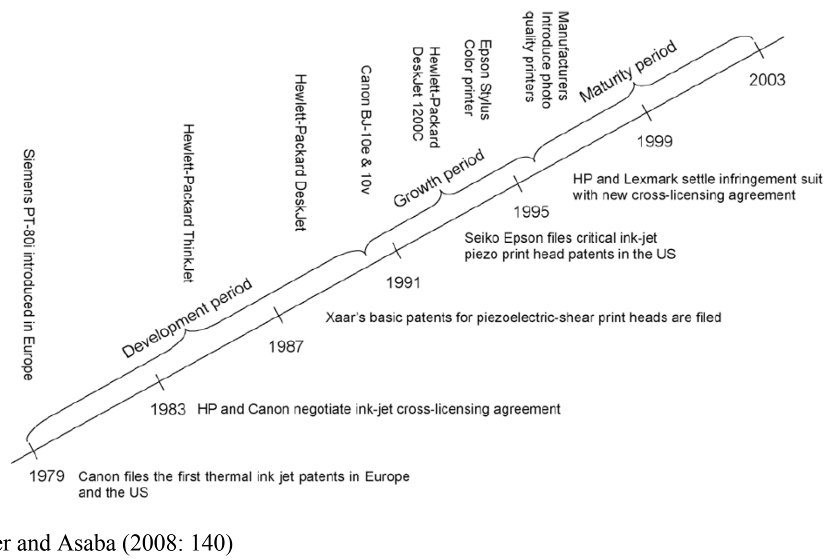
Table 1. Case study IJP companies in the Cambridge area

Company	Number of employees*	Year of founding	SIC code	Core activities
Cambridge Consultants Ltd	213	1960	7310	Technology consulting
Domino Printing Sciences	550	1978	3002	Coding & marking printers, laser marking
Linx Printing Technologies	245	1987	3002	Coding & marking printers, laser marking
Xaar Group	80	1990	7310	Development of DoD printing, manufacturing of industrial printheads
Biodot Ltd	(4)	1994	3320	Rapid Diagnostic test devices, Biosensors and BioChip Arrays
Xennia	30	1996	7310	Contract ink development, test equipment
Inca Digital	100	2000	2956	Digital printing
Inkski Ltd	1	2004	7310	Development of non-impact digital printing technology

* at the Cambridgeshire sites in 2006

Ink Jet Printing is the collective name for a variety of different techniques to generate droplets of ink, which are propelled towards a surface to produce a printed mark. These include continuous (binary, multi-level, greyscale), Drop-on-Demand (DoD) / Valve jet (shutter, array) and impulse jet (piezo activated and chevron) ink jet printing techniques (Garnsey and Minshall, 2000, pp 18-19). Drop-on-demand ink jet printing is a complex technology that converts full pages of electronic text and images into tens of millions of signals, via individual ink jet nozzles in the print head for reproduction. Ink jet printing embodies many different skills and technologies: digital image processing, micro-machine semiconductor processing, mechanical, control, and electronic system design, computational fluid dynamics, chemistry of ink and paper, and precision manufacturing. These technologies have been applied in a wide range of industries and markets that can benefit from the key features of ink jet printing which are that it provides: non-impact / contact process for printing; infinitely variable output on demand; and high speed and high resolution (Garnsey and Minshall 2000).

In the late 1980s and early 1990s ink jet printing disrupted dot matrix printing, then the dominant design in desktop printing,. The ink jet printing industry grew rapidly in the 1990s, with a 6-year average growth rate of 73.3% in the period 1990-1995 and an average annual growth rate of 14.4% in the second half of the 1990s (Clymer and Asaba 2008). The global IJP industry, encompassing office and home printers, emerged in the 1970s. It illustrated three phases of development, entering a second growth phase in the 1990s, with a maturation phase in the late 1990s (see figure 1). Industrial ink jet printing for product identification was at first a niche market overlooked by the main players and offering an opening to alert new entrant firms (Penrose 1995).



Source: Clymer and Asaba (2008: 140)

Figure 1. Three phases in the global ink jet printer industry

The ink jet printing industry is divided between the products developed for industrial applications (marking, labelling and coding for production lines), printing applications (commercial printing) and home and office equipment applications (desktop printing; e.g. provided by HP and Canon). In addition, selling inks can make a substantial contribution to revenues over the lifetime of a printer. The Cambridge firms specialised in the first two applications and markets, together with inks. Further to this there has been a recent shift to laser printing. In the next section we describe the development of the IJP industry in the Cambridge region.

Cambridge Ink Jet Printing Industry: emergence, growth and maturation

The local inkjet printing industry can be traced to one organization, the technical design consultancy Cambridge Consultants Ltd (CCL). At the start of the 1970s CCL, a spin-off from the University of Cambridge, was working on various continuous ink jet printing technologies for the chemical multinational ICI. CCL was contracted to develop ink jet technologies for printing textiles at high speed, over wide widths and in colour. ICI withdrew from this project a few years later on the advice of external consultants when it became clear that the level of complexity required to achieve their quality and cost targets had been underestimated (reflecting the nascent phase of the IJP technology at that time). However, the project manager at CCL, Graeme Minto, saw the commercial potential in ink jet printing. Graeme Minto obtained support from CCL to spin out the technology in a new company founded in 1978: Domino Printing Sciences. Domino was an independent start up which took over the intellectual property in the technology from ICI and CCL.

In the 1980s the cluster was dominated by CCL and Domino Printing Sciences, which made up almost 100% of the IJP employment in the region (see figure 2). In the 1990s – the growth phase of the international IJP industry – a number of further spin-offs occurred by former employees of CCL, partly motivated by the success of Domino. These included Linx, Videojet, Xaar, and Inca (see figures 2 and 3). These firms achieved global expansion on the basis of a set of related technologies. The local IJP industry more than doubled from the late 1980s to the early 2000s, reaching a size of more than 1,300 employees. Employment in the local industry decreased somewhat following 2000, as in the overall global IJP industry that entered the maturity phase in the late 1990s (Clymer and Asaba 2008).

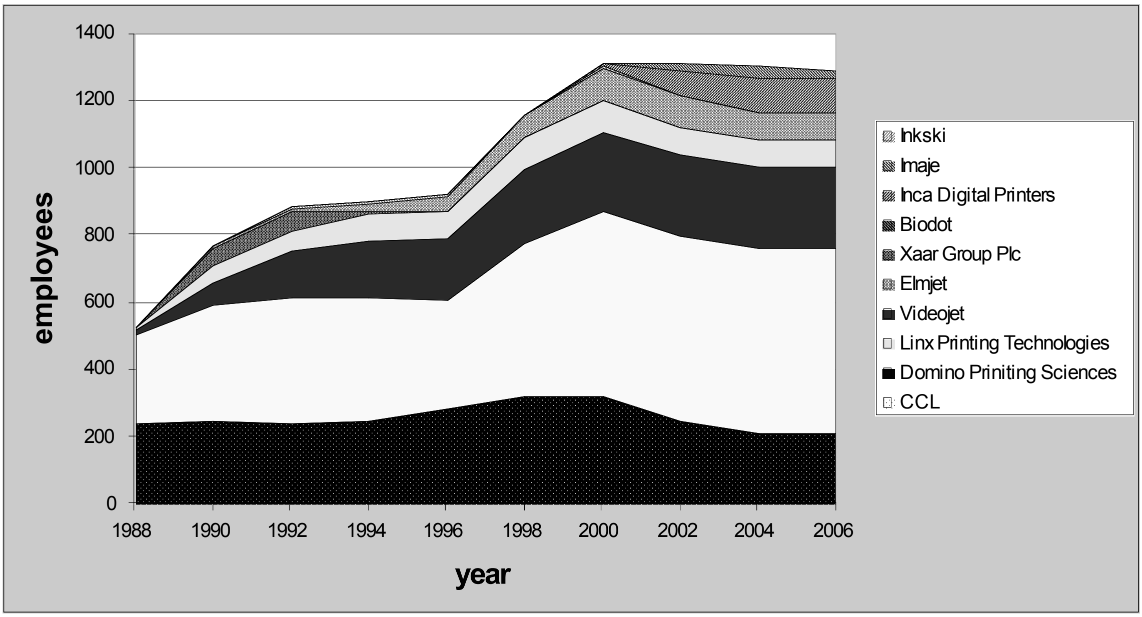


Figure 2. Employment in the Cambridgeshire Ink Jet Printing industry

Source: Cambridge University Engineering Department high-tech database

The early growth of the local industry was stimulated by new European legislation relating to consumer information on food, drink and pharmaceutical packaging, and factory automation gathering momentum. Regulation led to rapid growth in the demand for production line labelling and coding equipment. Interstices in the wider IJP industry, where the market for home and office printers dominated, were created by this new regulation. Incumbent firms were stretched by the home and office printer markets and left a product identification market to new entrants in a manner anticipated by the account given by Penrose (1959) of opportunities for new firms in emerging industries. The need for flexible systems for applying variable data at speed became critical as food, drink and pharmaceutical industries increased their reach into global markets where minor variations in national legislation necessitated differing information on packaging. The legislation was serendipitous for Domino. Although they had not anticipated this development they exploited the potential demand that it represented.

Genealogical processes

The lineage of the IJP companies in Cambridge is shown in Figure 3. Two inkjet printing companies not located in the Cambridge region are Imaje in France and Willett in Corby (UK). The companies were dominant in international markets for non-impact product identification, which is a smaller market than the larger market for desktop ink jet printing.

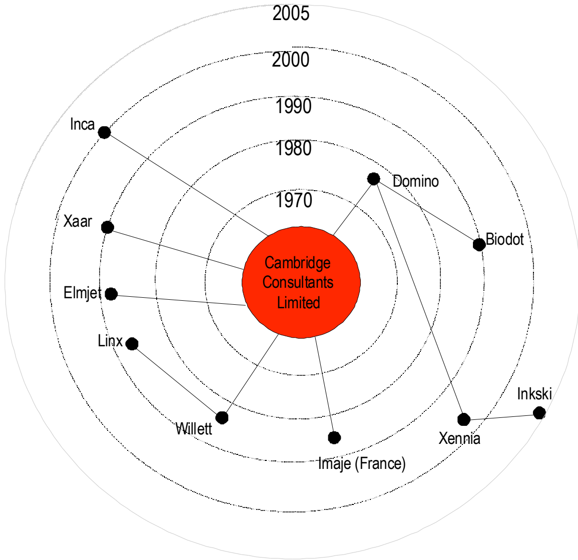


Figure 3. Lineage of Ink Jet Companies in Cambridgeshire

The group of Cambridge IJP firms formed organically after spin out from CCL or its descendants. Interviews with founders of companies showed that the most prominent factor for the original choice of location in the Cambridge area was the unwillingness of the founders to relocate. This does not confirm the prediction of the model that the location of the cluster is initially random, however. There are causal factors at work in the attractions of residence in a university city and in family ties obstructing mobility, leading to structured rather than random incentives to co-locate spin off companies.

Spin off companies must continually innovate and develop new technology and products. The inherited technology and expertise lose importance as this occurs and early ties weaken. We expected linkages between incubator organisation and spin off company to diminish as the spin off company creates its own value chain. We found this to be the case; CCL lost its links with the University of Cambridge, Xaar and other spin offs reduced contact with CCL and Xennia had weakened links with its company of origin, Domino.

In order to achieve reliability and keep ahead of competition, the IJP companies patented their innovations (figure 4). The patent data provides a proxy measure of the steady growth of technical capability in the local cluster.

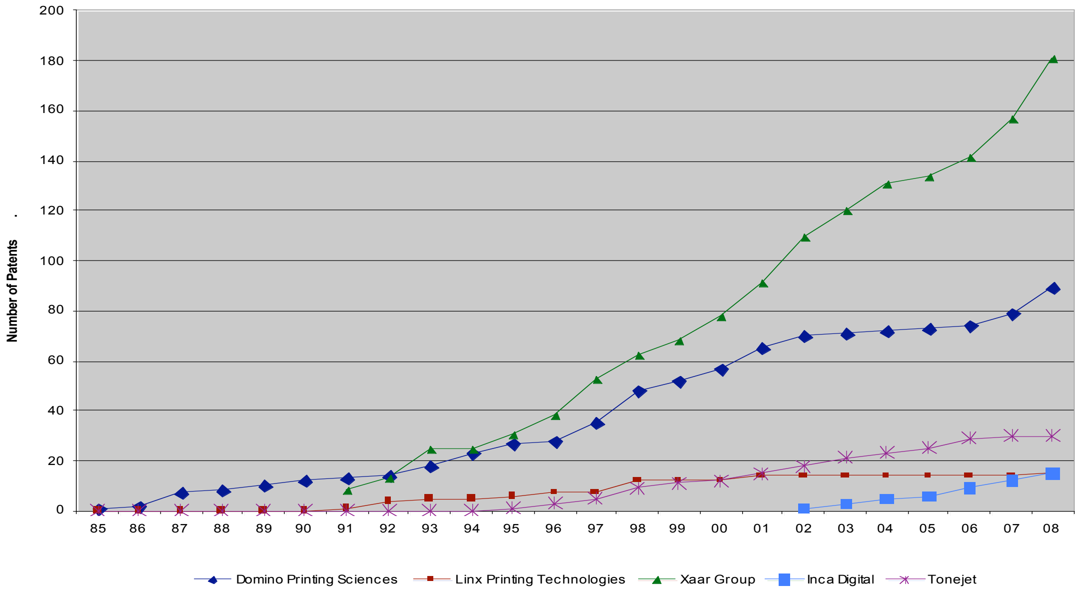


Figure 4. Cumulative Patents for the Cambridgeshire Inkjet Printing companies

Source: European Patent Office

Among inkjet printing patents and other related patents reported for the IJP companies, 55% are made up of inkjet printing patents and 45% of patents in other or related areas. Five (71%) of the firms are specialising in inkjet printing equipment patents. Two companies had most of their patents in other applications for example in inks. We can infer cumulative development of business skills as well as technical expertise as the scale of operations increased.

Ecological processes

There are no close formal links between the companies, which are largely in competition with each other. Interviews did, however, reveal examples of informal knowledge transfer. Knowledge is also transferred through the work of the consultancy Pivotal Resources and by the Ink Jet Academy, a local training course for employees in the IJP and related industries. The movement of personnel between IJP firms is extensive, as measured by manager moves. For example among seven senior staff at Xennia, five had previously worked for inkjet printing companies. Personnel have also moved to inkjet printing companies outside the Cambridge area. Much of the informal social contact has occurred amongst those employed in the Cambridge IJP companies through social networks. For example Graeme Minto met Alan Barrell, who succeeded him as CEO of Domino, through a swimming club. Formal relationships between the Cambridge firms using IJP technology have only emerged recently through the creation of an R&D consortium, as will be discussed later.

As markets expanded, competition became increasingly intense. Barriers to entry for competitor firms were not high. Key competitors included Videojet (USA) and Hitachi (Japan). Domino, Videojet (including Willett) and Linx were already competing directly in product identification markets. Inca is an original equipment manufacturer (OEM) and produces machines for different applications. Xaar produces print heads and Xennia's activity involves inks, so these two firms operate at different stages in the supply chain. Partnerships in the area between complementary firms are predictably more common than among competing firms; Xaar, in particular, has relationships with a number of other companies. Cambridge firms are affected by competition from outside the region. Competition between two leading print head manufacturers and licensers, Xaar (Cambridge) and Spectra (now FUJIFIM Dimatix, USA) is an example of this. These firms started around the same time and competition between them has been a development driver. There was entry into the industry from other sectors by well resourced players including Danaher (US).

Industrial IJP is a small part of the international ink jet printing industry and specialist suppliers have not been drawn to the area (the US firm Micropump being an exception). Manufacturing operations of the IJP companies are largely assembly operations with parts increasingly outsourced, apart from core technology such as the print head. A large number of suppliers is used by each firm and these encompass a wide range of different types of operation. The Cambridge IJP companies use both local and international suppliers. When Domino was founded, there was a policy of working closely with small suppliers in the region and Domino were able to upgrade local suppliers by passing on equipment to them and treating them as an extension of their own activities.

Increasingly, however, suppliers came to be chosen for quality and product price rather than location. For example, Spectra (US) print heads are used by many inkjet companies instead of Xaar heads (Spectra heads produce higher resolution prints than Xaar, as required for certain applications). This shift reflects the rise of low cost global manufacturing centres in the Far East and improved communications. We were told in interviews that at the time of the founding of earlier ink jet companies, parts could not be sourced internationally because of quality issues and the difficulty of transfer of design and blueprint materials. The ease with which computer aided design (CAD) drawings can be transferred digitally has changed the supplier-customer relationship. Local suppliers, who lacked funds to invest in design capability, have not been able to upgrade to satisfy OEMs. Thus the volume of parts sourced locally has decreased over time although local suppliers remain important to the IJP companies and are often used for non specialist and lower value parts, such as casings, printed circuit boards (PCBs) and small components; larger assemblies and specialist parts are sourced further away. Local suppliers are involved with a range of industries and their products tend to be generic. Suppliers of parts such as metalwork, for example, are located near to Cambridge, whereas ink suppliers are further away. Companies generally look for local suppliers before looking further afield. From both the customer and supplier perspective, proximity is helpful, especially at the development stage, but may be superseded by cost considerations. Where production is capital intensive, the high cost of capital in the UK rather than local labour costs is a major disincentive to local production (IfM, 2005). US and Japanese competitors do not enjoy lower labour costs.

As markets for IJP expanded globally, the production chain of the Cambridge ink jet printing firms became international. Initially there was a local production chain as local suppliers were supported and came to be shared by several firms, even those in competition with each other. We have seen that Domino in particular helped suppliers to upgrade their performance and these contractors were used by other local customers in the area to upgrade their products and production processes. Sub-assemblies have come to be sourced internationally as the industry has matured. Supplier relations have emerged with firms in other countries in a global production ecosystem. Ink jet printing firms source jewels from Switzerland, pumps from the United States and precision components from many other areas.

Market reach was extended through further innovation, in recognition of changing market needs. The Cambridge inkjet printing businesses realised that technologies initially used to provide time-dependent product information for the consumer could provide additional value to customers through further applications. They could be used to improve efficiency of production and distribution processes. Technologies used to apply ‘best before’ dates for food packaging could also be used to improve product traceability by printing batch information. As well as the products themselves, ink jet printing technologies were applied to packaging of drink, food and pharmaceuticals. An example of this was the labelling of individual soft gelatine drug capsules using edible inks.

There were also markets in the distribution of newspapers and magazines where inkjet marking, coding and labelling could be used. For addressing, personalising and coding purposes, prior to distribution, IJP made it possible to add variable information. The benefit of technologies for marking products within the factory was seen by firms operating many other production processes, varying from healthcare products to electronics. With new demands for more reliable and flexible systems, inkjet technologies were developed and adapted to cope with these.

Thus the market for the application of ink jet technologies has differentiated into a number of sectors as the industry has matured. Firms in the Cambridge area have made a considerable effort to renew their technologies, as shown by the high level of patenting. Efficiency in existing markets has also been improved. The development of wide web drop-on-demand technologies provides an example. These have had success in product identification and label printing applications but the anticipated revolution in printing and publications markets has not yet occurred.

The expansion to additional locations has allowed the cluster to reach international markets. Around eighty percent of the Cambridge ink jet printing companies' markets are abroad and survival depends on the ability to sell products world wide. Links with international customers and distributors have been developed and since applications for ink jet printing are very specific and customised, a local customer service base has been necessary for the customer interface. As a result there is investment in the global presence with companies having international offices. Biodot has moved its headquarters to the US, while Xaar, and Videojet ceased to manufacture in the area and others such as Linx and Domino manufacture at international locations in addition to the Cambridge area. There is an extensive distributor network through which ink jet printing companies sell their products but none of these distributors are shared by the companies.

Thus the Cambridge area IJP sector is not an industrial district with a local production web, but a cluster of firms related mainly by their origins and shared labour pool. What then are the advantages to these firms of being in a local cluster?[2] Specialist suppliers are no longer a major consideration. But a shared labour market pool and the transfer of tacit knowledge can be a major benefit of proximity. The people, skills and informal knowledge base in the area are a significant benefit of being located near to other IJP firms. The Cambridge address and the prestige associated have also been a consideration in retaining firms in the area. The amplification effects of co-location are apparent in multi-generational effects. Spin-off firms became the source of further spin-offs and attraction of entrepreneurs and firms from outside the region. This latter process has been associated with the third phase of cluster dynamics identified in prior literature: maturation.

The Cambridge IJP firms were pioneers in targeting the industrial product identification market in which larger US and Japanese firms had not shown interest initially. The further

[2] Willett, a spin out from CCL, was located in Corby, with only the R&D unit in Cambridge, suggesting that not all firms saw benefits in co-location.

expansion of these markets resulted in new and better resourced international competitors moving into this sector on a global basis. With increased competition and consolidation of the product identification sector of IJP, there has been a rash of mergers and acquisitions of local ink jet printing firms in the Cambridge area.

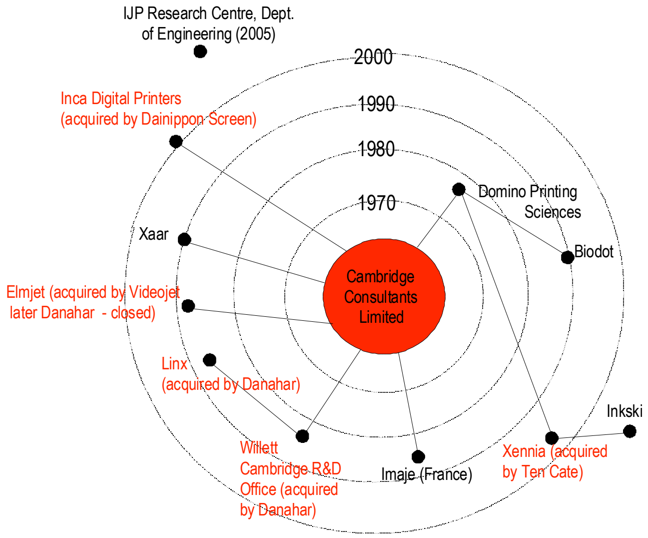


Figure 5. **IJP firms acquired**

In 2001 there were seven industrial inkjet printing companies operating in the Cambridge area. Currently (2009), only two of these companies (Domino and Xaar) have not been acquired. The Danaher Corporation had created their product identification division through takeovers of Videojet (2002), Willett (2003) and Linx (2005), and Dainippon Screen Manufacturing Company bought out Inca in June 2005. The Elmjet site, acquired by Videojet, was closed after a further acquisition by Danaher in 2002, while the manufacturing function of Xaar was relocated to Sweden after a merger. In 2008 Xennia was taken over by Ten Cate from the Netherlands, leaving only two substantial independent players in the Cambridge IJP industry (Domino and Xaar).

There are different views on implications of acquisition. Proponents point to local benefits of capital inflow and the introduction of managerial expertise and marketing power of larger international companies. Critics see negative impacts of loss of independence on the local supplier network, personnel mobility, and attraction of business and personnel. On the other hand, post acquisition spin-off activity can be a source of innovation and a shift into emerging areas via new applications. These new applications indicate a renewal of the cluster, a phase that is not clearly recognised in the prior literature on cluster dynamics. We discuss this phase in the next section.

Cambridge Ink Jet Printing Industry: Renewal

Over time there has been recognition that jet printing technologies have very wide applications, well beyond printing and product identification. New applications are to some extent a response to the maturation of ink jet printing. Continuous IJP, once the foundational technology in the Cambridgeshire ink jet printing industry, is now a mature technology. It was first threatened by drop-on-demand printing and more recently by laser technologies. Domino Printing Sciences has purchased several laser companies in order to gain expertise in a competing technology. The markets served by continuous ink jet printing are established and sustainable and all the companies involved have mitigated threats by developing competencies in the two emerging technologies. Drop on demand printing is a developing technology with rapid progress still being made in terms of performance and reliability, giving rise to new markets through performance improvement. But these markets have differentiated needs and it is difficult for companies to diversify across applications in the face of capital constraints and significant market differences. If cluster companies are to compete across new markets, further R&D and strategic partnerships will be essential. One important development in this respect is the initiative to set up the IJP research centre at the University of Cambridge.

We saw that the stage model of cluster emergence and growth reviewed in the first part of this paper does not address the kind of renewal of local industry through a move from specialist to generic technological applications, as has occurred among Cambridge ink jet printing activities.

Despite the loss of independence of several IJP firms and the move of many manufacturing operations away from the area, it is likely that Cambridge will continue as a centre for R&D. One reason for this is the localized accumulation of knowledge on ink jet technologies and related display technologies. Another is the initiative to set up the Inkjet Research Centre at the University of Cambridge in 2005. This centre has been funded by the UK government through the Engineering and Physical Sciences Research Council (EPSRC) and through industrial partners. Other universities in the UK are in the consortium and the companies involved (including Sun Chemical, Sericol, Xaar, Fujifilm, Domino, Inca, Linx and CDT) originate mostly from the Cambridge area. The Inkjet Research Centre intends to develop understanding of the fundamental behaviour of liquids in environments presented in inkjet printing. The aim of the project is to reduce duplicated research in local companies and to spread the financial burden on the one hand, and to deepen the knowledge of inkjet performance and broadening knowledge about potential applications of the technology on the other. This represents the reconnection of the IJP cluster to the Engineering Department at the University of Cambridge from which it originated several decades earlier. This should help the cluster to be sustained into the future and to add cohesion and build reputation. The development of the consortium has raised many challenges. For example, difficulties arose in the formation of the consortium around the acquisition of Linx by the US company, Danaher. Domino expressd concern that the takeover would mean that knowledge shared through the Research Centre would migrate to the US through Linx and the cluster would not realise the rewards. In order to address this issue contracts require that participating companies maintain or increase their level of R&D investment and deployment in the area – failure to do so leading to removal from the group.

Development of technology in this direction requires a return to basic research. Although inkjet has been a printing technology for more than 50 years, the processes involved are still not completely understood. With modern inkjet printing, droplets are generated at high speeds with fluids containing significant levels of particulates including metals. There is a significant research agenda in elucidating the way IJP can be used to deposit a wide range of substances on varied substrates.

Inkjet technology can be used to develop markets for low cost electronic goods as instanced by disposable radio frequency identification (RFID) chips. This has required complementary research at the University's Auto ID Centre.[3] The Xennia case study (see appendix, p. 27) provides an example of a new printer technique with applications in RFID. The development has involved Xennia with Carcio, a British company which has pioneered a way to print conductive inks with a digital inkjet printer. When Carcio was working on a way to customise cell phones, by printing personal images on the plastic bodies, it commissioned Xennia to find a way to print metallic inks with an inkjet printer. Xennia developed a novel approach which could also print on copper. Carcio and Xennia formed a joint venture called CIT (Conductive Inkjet Technology) to hold the patents for the new technology. The new printing technique could have an important impact on the RFID industry since it could replace the etching process used for making copper antennas which creates toxic waste and is expensive. Other new species of technology have emerged from new technology combinations, with firms

[3] See www.ifm.eng.cam.ac.uk/automation

spinning off from the Physics Cavendish Laboratories using jet printing of polymers for display markets, building on and related to the local knowledge, skills and competences in ink jet technologies. Cambridge Display Technology is the leading company in this area.

Figure 6 shows that over time, the IJP sector has grown more rapidly than the average for Cambridge-area technology sectors, shown at the base of the figure by a diamond trend marker. The sector has also sustained growth better than the more volatile opto-electronics or technical design consultancies.

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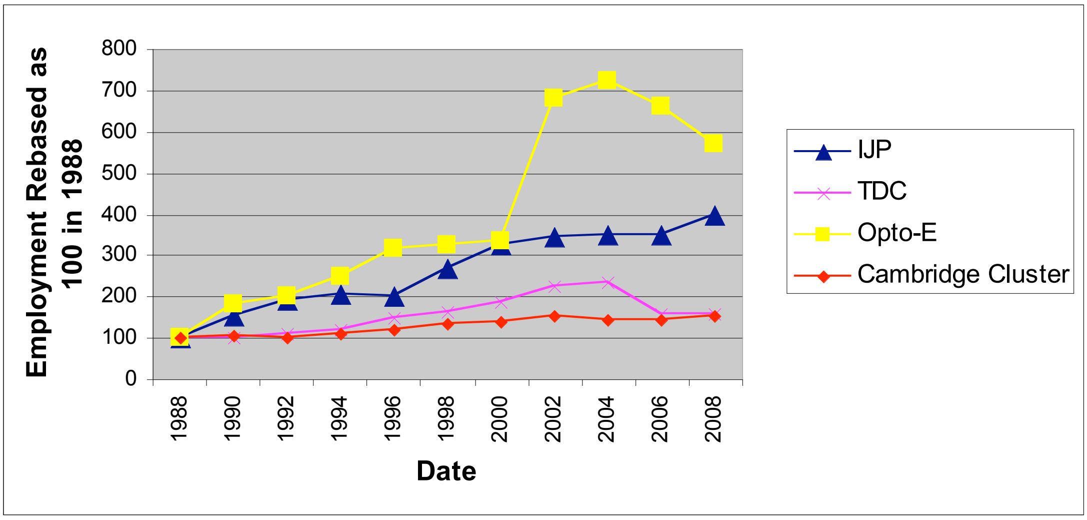

TDC: technical design consultants Opto-E: Opto-electronics firms

Figure 6 The Growth of firms in IJP compared to growth of other sectors in the Cambridge Cluster (source Evans and Garnsey 2009)

The inkjet printing technologies are now being applied to ever more diverse areas. One application is in the production of printed circuit boards where the very precise delivery of conducting material onto an insulating substrate is required (display technologies). Plastic Logic (PL) is a leading firm in this new sector, which has retained R&D activities in Cambridge although PL's manufacturing plant has been built in Dresden, Saxony, with the aid of extensive German government subsidies.

Conclusions

The history of the Cambridge IJP industry reveals some of the mechanisms underlying the dynamic nature of local clusters. The first phase of the cluster started with the Cambridge University spin-off firm CCL undertaking research into IJP in the early 1970s as part of work for ICI. However, this research was not commercialised, and it was only after one of its employees started a focussed IJP firm – Domino Printing Sciences – in 1978 that the local industry started to expand. CCL has remained an import incubator of new firms in the IJP industry, together with its first spin out, Domino. A second, growth phase of the cluster took place in the 1990s, when a second and third generation of spin-offs emerged, with several substantial firms. A third phase was ushered in with the consolidation of the global industry, reflected in a wave of acquisitions of local companies by foreign firms. The very success of the sector has attracted acquirers looking to extend their own innovative portfolios with easy credit for acquisition available during the boom period. A specialist activity for which there is international demand cannot be immune to the forces of globalisation.

The case reveals the way genealogy can be the basis for a cluster through common origins and a shared labour market pool even where there are minimal local production relations. The local ecology evolved gradually, eventually to be dominated by the labour market pool that emerged in the area. This represents knowledgeable supply, but it only remains local because of career opportunities provided in the area by a number of firms, which offer promotion and skill extension possibilities, and the attractions the area offers to residents.

Although certain IJP firms have moved their production operations away from Cambridge to other countries in Europe and America, they have maintained R&D operations at Cambridge. This has brought the cluster back into interaction with the university, from which the parent company, CCL, spun out in the 1960s. With the expansion of potential markets for inkjet products, speed and precision requirements have moved beyond the current state of the art. The need for new applications to open up new markets and recognition that ink jet printing has much wider potential than had yet been realised has resulted in re-involvement with the university after several decades when the IJP firms operated quite autonomously in the business sphere. Renewal has been achieved through recognition of the generic nature of IJP as a deposition technology for valuable materials including intelligent materials.

Renewal is taking place through co-operative efforts between academics and IJP companies. This phase of renewal goes beyond the logic of current models of industry life cycles and cluster dynamics, which emphasise inevitable decline in the maturity phase of the industry and cluster respectively. In line with recent attempts to explain the long term performance of regions (Bathelt, 2001; Glaeser 2005; Martin and Sunley 2006), we recognize that regions can 'reinvent' themselves and escape the inevitable decline of maturing industries by building new industries on the knowledge accumulated in earlier expanding industries. Firms in newly emerging sectors are drawing employees from IJP firms in the area. When IJP technologies were adopted by new entrants who developed advanced materials such as light emitting polymers (Cambridge Display Technology and Plastic Logic) they were able to hire professional staff with experience in the local IJP industry, demonstrating the role of job mobility in the diffusion of competence in the area. Recognition of the generic nature of jet based technologies for purposes of deposition, and the need for advanced R&D to realise new opportunities, illustrates to the way new technological trajectories emerge as old technologies diffuse and mature.

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References

Arthur, W.B. (1994) *Increasing Returns and Path Dependency in the Economy*. Michigan: Michigan University Press.

Audia, P.G., Freeman, J.H. and Reynolds, P. (2006) Organizational Foundings in Community Context: Instruments Manufacturers and their Inter-relationship with Other Organizations. *Administrative Science Quarterly* 51: 381-419.

Bathelt, H. (2001) Regional competence and economic recovery: divergent growth paths in Boston's high technology economy, *Entrepreneurship and Regional Development* 13(4): 287-314.

Baum, J.A.C. and Singh, J.V. (1994) *Evolutionary Dynamics of Organizations*. New York: Oxford University Press.

Boschma, R. and Wenting, R. (2007) Spatial evolution of the British automobile industry: Does location matter? *Industrial and Corporate Change* 16(2): 213-238

Braunerhjelm, P. and Feldman, M. (2006) *Cluster Genesis. Technology-Based Industrial Development*. Oxford: Oxford University Press.

Clymer, N. and Asaba, S. (2008) A new approach for understanding dominant design: The case of the ink-jet printer. *Journal of Engineering Technology Management* 25: 137-156.

Feldman, M. (2003) The Locational Dynamics of the US Biotech Industry: Knowledge Externalities and the Anchor Hypothesis. *Industry and Innovation* 10(3): 311-329.

Garnsey, E. (2002) Case Study – BioDot/Polaris, Centre for Technology Management Institute for Manufacturing, University of Cambidge.

Garnsey E., Ferriani S. and Lorenzoni G. (2008) Speciation through entrepreneurial spin-off: The Acorn-ARM story, *Research Policy* 37: 210- 224.

Garnsey E. and Heffernan P. (2005) High Tech Clustering through Spin Out and Attraction; the Cambridge Case, *Regional Studies* 39(8): 1127-1144.

Garnsey, E. and Minshall, T. (2000) Ink Jet Printing and Domino Printing Sciences, Case Profile, Centre for Technology Management, Institute for Manufacturing, University of Cambridge.

Glaeser, E.L. (2005) Reinventing Boston: 1630–2003 *Journal of Economic Geography* 5: 119-153.

Harrison, R.T., Cooper, S.Y. and Mason, C.M. (2004) Entrepreneurial activity and the dynamics of technology-based cluster development: the case of Ottawa, *Urban Studies* 41: 1045-1070.

Institute for Manufacturing (IfM) (2005) Growth through High-Value Manufacturing, Engineering Department, University of Cambridge, Cambridge.

Keeble, D., Lawson, C., Moore, B. and Wilkinson, F. (1999) Collective learning processes, networking and institutional thickness in the Cambridge region, *Regional Studies* 34(4): 319-332.

Klepper, S. (1997) Industry Life Cycles. *Industrial and Corporate Change* 6(1): 145-181.

Klepper, S. (2007) Disagreements, Spinoffs, and the Evolution of Detroit as the Capital of the U.S. Automobile Industry. *Management Science* 53: 616-631.

Lawson, C. (1999) Towards a competence theory of the region. *Cambridge Journal of Economics*, 23: 151-166.

Lazerson, M.H. and Lorenzoni, G. (2005) The Firms That Feed Industrial Districts: A Return to the Italian Source. In: Breschi, S. and Malerba, F. (eds) *Clusters, Networks, and Innovation*. Oxford: Oxford University Press.

Martin, R. and Sunley, P. (2006) Path dependence and regional economic evolution. *Journal of Economic Geography* 6: 395–437.

Maskell, P. (2005) Towards a knowledge-based theory of the geographical cluster. In: Breschi, S. and Malerba, F. (eds) *Clusters, Networks, and Innovation*. Oxford: Oxford University Press. pp. 411-432.

Menzel, M.-P. and Fornahl, D. (2007) Cluster Life Cycles - Dimensions and Rationales of Cluster Development. Jena Economic Research Paper No. 2007-076.

Penrose, E.T. (1959) *The theory of the growth of the firm* (3rd edition 1995). Oxford University Press: Oxford.

Richardson, G.B. (1972) The Organisation of Industry, *Economic Journal* 82(327): 883-896.

Romanelli, E. and Feldman, M.P. (2006) Anatomy of Cluster Development: The Case of U.S. Biopharmaceuticals, 1976-2002. in: Braunerhjelm, P. and Feldman, M. (eds) *Cluster Genesis. Technology-Based Industrial Development.* Oxford: Oxford University Press.

Schumpeter, J.A. (1934) *The theory of economic development*. Cambridge, Mass: Harvard University Press.

Stam, E. (2007) Why Butterflies Don't Leave. Locational behaviour of entrepreneurial firms. *Economic Geography* 83.1: 27-50.

Vernon, R (1966) International Investment and International Trade in the Product Cycle, *Quarterly Journal of Economics* 80: 190-207.

APPENDIX

Case Studies

Case study findings for seven companies in the Ink Jet Printing cluster are summarised below.

Domino Printing Sciences[4]

Domino was built around products utilising single jet ink jet technology, with CCL continuing to develop multi-jet versions. In its infancy Domino was supported and nurtured by CCL and development work continued to be undertaken for them following spin off. A licence agreement allowed the company non-exclusive access to CCL know-how and patents enabling it to manufacture and sell inkjet systems. In return CCL received royalties on sales of all Domino products and was entitled to grant licences to other companies if sales fell below a certain threshold (Domino was obliged to offer CCL 'first refusal' on development programmes for further inkjet products).

The company went public in 1985 with an initial valuation of £26m rising to £40m and in the same year the company received the Queen's Award for innovation. Domino's machines consist of a collection of electronics which guide the ink nozzles and, because they are operated by electro-magnetic impulses and not by compressed air, the machine can be installed in a small metal or plastic cabinet. The essential elements of the machine are the microprocessors and their development and Domino has spent most of its time developing this part of the business rather than construction of machines. Continued leverage of connections with CCL was attempted and in 1987 a new company called Elmjet spun off from CCL exploiting further technologies developed originally as part of the ICI project. This new spinoff had the aim to design and manufacture wide web full colour printings and Domino's chairman and founder, Graeme Minto, also acted as company chairman. Through Domino being an investor in Elmjet and the latter being contracted to develop new printing devices to complement and extend the range of Domino products, the two businesses were linked not only by their personnel.

Domino now employs over one thousand people world wide and continues to develop, sell and support industrial ink jet and laser printing systems for international packaging and printing markets and remains a major player in the industrial ink jet printing industry. Most of Domino’s activities are in product development and marketing (the company's operations are concerned with product development and subsidiaries (specifically Domino Amjet) focus on

[4] This case is largely based on Garnsey and Minshall (2000).

marketing the product in Europe). Domino's marketing orientation led it into a joint distribution deal with American Technologies Incorporate (ATI) and exploitation of A. B. Dicks European weaknesses of poor after sales services. Domino has stressed quality and flexibility, instituted a rigorous programme of product development, concentrated on developing its research and development (R&D) capability, encouraged strong co-ordination among functions in R&D, product development and marketing, and nurtured strong co-operation from its distribution channels, especially in the US with ATI, and in Europe after the formation of Domino Amjet. There has been a recent shift to laser printing with Domino buying US and German laser firms.

BioDot Ltd[5]

One of the smallest ink jet printing companies in the area is BioDot, which was founded as a spinoff from Domino in 1994. The company was formed following Philip Shaw, an employee of Domino Printing Sciences, taking redundancy who concluded an agreement with Domino granting him access to IP relating to enzyme printing. It was agreed that the company would not produce inkjet printers and Domino would supply components and not produce enzyme printers. The company supplies non-contact nanoliter and low microliter dispensing equipment for the development and manufacture of BioChip Arrays, Biosensors and Rapid Diagnostic test devices. The core technology has descended from ink jet printing. The company was presented with many challenges when starting and there was a need to learn how to build an inkjet machine but advice fortunately came from former colleagues at Domino. One of the early orders came from Domino concerning manufacture of a special application machine allowing rapid change over of inks. This helped the firm's early cash flow situation. The operating costs were covered by revenues within the first years despite the challenges.

In March 1994 Biodot commenced trading and included Selwyn Image a colleague at Domino who took a 5% stake in the business, but left soon afterwards moving to Willet, another Cambridge based ink jet firm, since he found himself more suited to working in a large business.

It was estimated by Philip Shaw that he needed £45,000 to start up the firm - he had £20,000 in redundancy compensation from Domino and it was found difficult to raise more money. This arose due to venture capitalists not being interested in investing small amounts; few venture capitalists were active at this time and there was reluctance by banks to invest in

[5] This case is largely based on Garnsey (2002)

technology based ventures. There was also the need for premises. Since rents were high in Cambridge the company found premises in Diddington, near St Neots. Although the contract did not include right of renewal the company stayed there without additional capital through having low cost premises and dealing with company matters in house. Biodot moved its European headquarters from Huntingdon to a larger site in Chichester (West Sussex) in 2005. Its global headquarters is now located in Irvine (California, US).

Linx Printing Technologies plc[6]

Linx Printing Technologies plc was founded in 1987 by two former members of the Cambridge Consultants ink jet team at Willett, to exploit legislation driven marking/coding opportunities in the United Kingdom (UK) and the European market. The company is involved particularly in the manufacture and marketing of ink jet and laser coders to a range of global industry sectors including food, beverage, pharmaceutical, and industrial customers for 'on-line' variable information marking/coding. Linx Printing Technologies has been a developer of industrial coding and marking equipment, based on ink jet and laser technologies, used to print variable information such as serial numbers and 'sell-by' dates on products and product packaging at manufacturing line speeds. Following the company being founded (venture capital backed), main market flotation took place in 1992 and a FTSE fledgling stock in 2004. In 1999 the company acquired a Chinese distributor and in 2000 acquired Xymark, the laser company, from GSI-Lumonics. The company was acquired by the Danaher Corporation (USA)[7] for £85m ($171 million) in 2005. It has about 718 employees worldwide and it had estimated revenues of £52.1m in 2004. The company has five locations with two sites in the UK (St Ives and Hull), one in France, one in the USA and two in China.

By operating through direct subsidiaries, representing 50% of total revenues, and a worldwide network of specialist distributors, Linx has served a global customer base in a wide range of manufacturing industries. For the Linx product range major overseas markets have included China, France, Germany, Italy, Japan, Spain and the USA. There are 350 to 400 employees in a Chinese factory and R&D is in Cambridge with manufacturing. The company spends 7% of sales on in-house R&D.

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[6] This case is largely based on IfM (2005).

[7] Danaher (www.danaher.com) has a carefully considered strategy of acquisition centred around the purchase of companies that have a 'high performance potential'. They also acquire companies with well-known trademarked brands, high market shares, a reputation for innovative technology, and extensive distribution channels on which to build (IDCH, 1993). The three main qualities they seek in acquisition targets are strong brands, market leadership and proprietary technology. Revenues increased from $300 million to $1 billion within a decade and by 2004 the company was approaching $7 billion and averaging dozens of acquisitions a year. The company has 35,000 employees (17,000 in the US) and international sales from acquisitions (a total of 47 companies had been acquired for $3.4 billion).

Xaar Group plc[8]

The Xaar Group plc spun off from CCL in 1990 and although the initial business plan was for licensing only this has now been transformed to manufacturing since licensing was not sustainable. The main sector of work is printing, ink jet, wide format graphics (posters), involving the design and manufacture of ink jet print heads. It is a world leader in ink jet print heads design and manufacture. For the Xaar Group plc some 20% of turnover goes into R&D covering technology which is even higher than the figure given by Inca Digital Printings Ltd. Following foundation in 1990 with £1m venture capital (VC) money, the first licence was sold in 1991, followed by a second round of VC in 1992 (approximately £1.5m), and private placement in 1996 which raised £12m. There was flotation in 1997 on the London Stock Exchange (LSE), which raised £10m, and in 1999 the company bought MIT (an ex-IBM licensee) and established manufacturing in Sweden. Whereas there were four employees in 1990 by mid 2004 there were about 250 employees with revenues of £30m in 2004. There are two locations with prototyping in Cambridge and volume manufacturing in Sweden, and four sales offices with two in China and one each in Japan and the USA.

Competition is mainly from own licensees and the main challenge is to expand into new markets. The main market is wide format graphics, with Chinese machinery makers dominant, and coding and marking was becoming significant in 2004. Over the whole period the intellectual property rights (IPR) portfolio was continuously developed. Original strategic intentions were to produce a dominant digital printing technology and this remained the same in 2005. For the expansion of the market for digital printing active business development and the promotion of new initiatives through joint ventures has been started. Xaar has found that bootstrapping from an R&D company to a volume manufacturer is not easy and conservatism in the market place has been an impediment, which Xaar has attempted to address.

Xennia Technology Ltd[9]

Xennia was founded in 1996 by Alan Hudd, ex Domino ink and R&D group leader, who saw an opportunity in industrial ink jet from the drop on demand (DoD) techniques that were being developed. The company was founded to provide ink formulation for DoD, although the background of the founder was continuous ink jet. The company is in the industrial ink jet, chemistry layered integrator sector and its activities include new solutions for manufacturing companies, starting from fluids to provide solutions in hardware and software for specific applications. It is a world leader in drop-on-demand industrial ink jet technology,

[8] This case is largely based on IfM (2005).
[9] This case is largely based on IfM (2005).

and provides its customers a one-stop shop for customised solutions for inks, hardware and software as a total package. The firm has a breadth and knowledge of all print head types.

Xennia is independent and has specific expertise around "difficult" materials in ink jet printing. These include dense or large inorganic materials like metals, phosphors, pigments, biomedical fluids, structural scaffold materials, conductive inks and materials for displays. The company is active in electronics, resistive, conductive displays, biomedical reagents, enzymes, DNA materials for forensics, diagnostics for pregnancy tests, product decoration for mobile phones, packaging and coatings (optical or protective). An interesting development involving Xennia has been with Carcio, a British company which has pioneered a way to print conductive inks with a digital inkjet printer. When Carcio was working on a way to customise cell phones, by printing personal images on the plastic bodies, it commissioned Xennia to find a way to print metallic inks with an inkjet printer. Xennia developed a novel approach which could also print on copper. Carcio and Xennia formed a joint venture called CIT (Conductive Inkjet Technology) to hold the patents for the new technology. The new printing technique could have an important impact on the Radio Frequency Identification (RFID) industry since it could replace the etching process used for making copper antennas which creates toxic waste and is expensive.

The firm employed 30 staff members and had an estimated value of £3.5m in 2004. Xennia has grown organically without capital inputs from investors. The firm had one site at Royston. Although in 2005 production was not important by 2006/7 it was considered to be significant with relocation to Stevenage to facilitate manufacturing and accommodate the growth in the number of employees. The company is not interested in products for markets but in delivering customised solutions for specific customers. One of the major obstacles has been in recruiting high-skilled foreign workers, due to government regulations. Competition is in the USA and there are companies that are customers, partners and competitors at the same time. Therefore relationships are complex where Xennia competes and co-operates simultaneously. All Xennia's activities involve R&D and are paid for by clients and the company. Most of the personnel are involved in R&D, which is mainly specific development work for clients and contract research.

Inca Digital Printers Ltd[10]

Inca Digital Printers Ltd was founded in 2000 by Will Eve and Bill Baxter from Cambridge Consultants Ltd. The business idea was to sell high end assembled printers through ink

[10] This case is largely based on IfM (2005).

distributors, while retaining an excellent set of engineers to build machines. The founders believed the ultimate selling point was in the "art" of assembly of super fast, efficient wide format machines. They regarded it as an art, since empirical methods were still used, rather than fluid mechanical mathematical models, and since engineering and assembly are reliant upon the jetting of inks, they too are an "art" in this case. The company is in the industrial ink jet printing sector, in particular wide format, and flatbed machines and it is a world leader in flat bed printing for the signage market. Research and development (R&D) roots have continued to play an important role in the business. The successful combination of R&D with commercial awareness explains the success that the company has already had. Strength is in the core technology for industrial ink jet printers and partners in its markets help it define what customers need to take the product to market. It uses existing equipment (for handling the product into and out of its printer) so that it can supply core print engines to its OEM partners.

When the founders were at CCL, customers enquired if it was possible to print packaging at the end of production lines. Following this a sample printer was made and it was exhibited at Ipex 1998, when it became obvious that there was a clear opportunity to develop machines for the display and signage markets. Inca Digital Printers began trading in 2000 and it progressed through the normal rounds of private venture capital finance to 2004. It has around 100 employees and it had estimated sales of £18m in 2004. The company has one main site located in Cambridge.

The original strategic intentions were to access the market though a distributor while retaining excellent engineering staff. The distributor was an ink formulation and sales company since consumables companies have good access to customers. Inca does not rely on IPR to protect and build market share since it takes out patents where useful but it always underplays them. Slightly less than 14% of sales are spent on R&D, with about 30% of Inca Digital's staff working in R&D.

<u>Inkski Ltd</u>[11]

Inkski Ltd was founded in March 2004 by Dr. Daniel Hall, who following his PhD degree in Computing Science at the University of Cambridge, had the idea of designing an innovative digital print head which was initiated by his observation on ink drop ejection. In early 2004 Daniel Hall observed that ink drops can be transported in, and then ejected from, an immiscible carrier liquid, with the carrier liquid imparting all the necessary momentum and

[11] This case is largely based on Feng (2008).

direction to the transported ink drop. From this simple observation, the ideas behind Inkski's technology evolved, and with help from contacts in the University of Cambridge Cavendish Laboratory, and initial funding from Providence Investment, Inkski was set up to start the formal development and exploration of the technology. The company has received venture capital and R&D grants in multiple rounds. When the company was founded Daniel Hall held 75% equity stake and venture funding of £25,000 from Providence Investment Company representing 25% stake of the business. It then experienced another three rounds of venture funding (by institutional investors, corporate investors (Xaar) and Cambridge business angel investors), bringing the total institutional investment to £635,000, until the most recent funding in 2007. The largest external investors in the company have been Providence Investment Company and Xaar plc, with 26% and 9% of the business respectively.

These investments enabled further development of Inkski's unique Light Initiated Liquid Output (LILO) technology and protecting this intellectual property with patents, without resources generated from production. By early 2005, a lab/workshop space had been established in a light industrial unit and with a laser module installed. By late 2006 Inkski started testing its system with a pico-second laser. By late 2007 the company demonstrated the controlled ejection of conventional black pigmented ink onto a paper substrate. Towards the end of 2007 the company had four patents covering its technology and intends to apply for more as a result of further research and development. The patent plan had delayed the pace to scale up as well as the progress of prototypes. The company contacted a German university with a technology platform to help accelerate the production of prototypes. Inkski received Department of Trade and Industry (DTI) funded R&D grants in 2005 totalling £60,000 through EEDA (East of England Development Agency) over a 9 month period.

Inkski Ltd's technology has attracted the interest of a number of players in the Ink jet printing industry which has helped the company to build a collaborative partnership and commercial contacts with companies such as FUJIFILM and ManRoland. Since then the company has faced challenges in its technology development and target market, both of which have restricted its attractiveness to micro funds investors and potential customers. In relation to the company's evolution and analysis of its outlook, key breakthrough and demonstration of technology is considered to be the most important driver of future funding and long-term success of the business.