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THE EVOLUTION OF INDUSTRIAL CLUSTERS: A CASE STUDY OF SCOTLAND

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ABSTRACT

The aim of this study was to look at the evolution process of industrial clusters, which was noted in the study as one of the most fundamental concepts that can be used to examine and predict the probable course of industrial clusters in Scotland. It was noted that a typical industrial cluster's life cycle, is marked by four distinctive stages, namely embryonic, growth, maturity and decline, although industrial clusters do not evolve into the exact stages that one would expect because some technologies die quickly, whilst others continue to evolve and remain in the decline stage for a prolonged time before rotating back into the embryonic stage through the development of new technology. With regard to the stages themselves, meanwhile, it was noted that the embryonic stage begins in most cases with a group of firms known as lead or anchor firms, situated in the same geographical area, where they find a new technology idea and develop it into actual technology. Another interesting result arising from this study is the presence of characteristics of genuine industrial clusters in the embryonic stage – features such as geographical proximity, innovation, communication, interactions and linkages, to name but a few. In addition, it emerged that the embryonic stage is also known as a period of slow sales growth as technology is introduced to the market. Profits are negative or nonexistent in this stage because of the heavy expenses of technology introduction and distribution. A great deal of money is needed to attract distributors and build inventories, meaning that the embryonic stage is characterised by high expenditures (for market research, test marketing and launch costs) and possibly by financial losses. By contrast, it was noted that the growth stage is a period of rapid market acceptance and increasing profits, hence the establishment of vertical linkages by the original occupiers of an industrial cluster. Although not many industrial clusters have reached the mature and decline stages it was noted in the study that, at the beginning of the mature stage of any industrial cluster, the cooperation and proximity of suppliers and customers become still less important than was the case in the initial stages of the industrial cluster's life cycle. The maturity stage, as this study revealed, is known as a period of slowdown in sales growth because the technology will have achieved acceptance by most potential buyers. Profits during the maturity stage level off or decline due to the increased marketing expenses that are meant to defend products against competition. Firms in a mature cluster encounter diseconomies of externalities that are associated with the problems of managerial co-ordination experienced by most small firms as they develop into large firms. In fact, in the mature phase, the overall rate of innovation fades and technology becomes less competitive, since firms that have been located near to their competitors will discontinue exchanging information with one another for fear of labour-market poaching.

The decline stage is also known as a period when market saturation causes sales to fall off and profits to drop, leading to a loss of confidence on the part of investors, falling share prices and eventually to bankruptcy. This study showed that the evolution process of industrial clusters is the most fundamental concepts used to examine and predict the probable course that clusters may take and this is good for regional economic strategists for future planning.

KEYWORDS: Industrial clusters, Technology, Evlution of technology, Evolution of Technology, Scotland

INTRODUCTION

Fundamentally, this study seeks to predict the course that technology is likely to take during its life span, and this will be achieved by using the case study method. This will be used to examine and evaluate the importance of the evolution of technology within industrial clusters, with particular reference to high technology. It is also significant to note that the concepts of evolution is essential because it is also used by policy makers when formulating strategies, since there is an assumption that genuine industrial clusters will pass through a number of phases or stages during their natural life cycle. As such, this study will place under scrutiny the transformations that take place over a period of time in both technology and industrial clusters. The main focus, however, will be on the way in which gradual technical advances lead technology itself to evolve, since the evolution of industrial clusters is thought to have a strong basis in technological transformation.

The Theory of the Evolution of Industrial Clusters

Although industrial clusters have become a frequently analysed and discussed regional economic development phenomenon, their evolution has rarely been discussed and explained, something that is particularly surprising given the statement in literature that the evolution of industrial clusters does in fact exist (Brenner, 2005; Munyoro and Dewhurst, 2010). Lorenzen (2005) suggests that even though scholars and policy makers have spent time and energy on the study of successful clusters, most economists and regional specialists have preoccupied themselves with the growth and survival of industrial clusters, rather than with their evolution. One of the major contributors to the emerging field of evolution are the authors of 'An Evolutionary Theory of Economic Change', Nelson and Winter, who published their work on evolution in 1982. These authors focused their work mostly on the issue of changes in technology and routines, suggesting a framework for their analysis. Their work on evolution stresses the existence of differences in technology, productivity and profitability among firms. Nelson and Winter (1982) recognise that firms differ in their rates and paths of adaptation and are the drivers of change at the industry level. They suggested that if there was a change in the industry or firm then some kind of evolutionary process might have been in action, and they equated this to Darwinian work on evolution. Nelson and Winter (1982) proposed that markets acted as the major catalyst for these changes. For example, their argument was based on the notion that when firms compete, weak performers will fail to capture an appropriate market share, go bankrupt and will have to exit the industry, as observed by Porter (2004) and De Wit and Meyer (1998). The seminal work by Nelson and Winter (1982) builds on earlier work published from the 1940s and 1950s by the likes of Joseph Schumpeter, Herbert Simon and Edith Penrose.

Other pioneers in this field of study are Hannan and Freeman, who in 1989 also advocated the evolution approach through their own version of the theory of organizational ecology. This theory was derived from sociology, economics and biology and was focused on the ingress and egress of firms as its main premise. Furthermore, organizational ecology utilizes insights in these subjects and employs statistical analysis to try and understand the conditions, under which

organizations emerge, grow and die. Hannan and Freeman (1989) consider that long-term change in the diversity of organizational forms within a population occurs through selection rather adaptation because most organizations have structural inertia that hinders adaptation when the environment changes. Those organizations that become incompatible with the environment are eventually replaced through competition with new organizations better suited to external demands, as suggested by Porter (2004), De Wit and Meyer (1998). In biology, evolution is seen as change in the inherited traits of a population of organisms from one generation to the next. Therefore, organizational change is viewed by population ecologists as an evolutionary process. Carroll and Hannan (2000) define population ecology as the study of dynamic changes within a given set of organizations, using the population as their level analysis. Population ecologists examine statistically the birth and mortality of organizations and organizational forms within the population over long periods. Analysis in population ecology has two main levels, that is, explaining birth and death rates within an industry and explaining vital-rate interaction between firms. Population level changes in industries are usually slow yet continual, according to Carroll and Hannan (2000).

However, the Darwinian-based evolutionary approach (Nelson and Winter, 1982) has been criticized in the literature through the suggestion that there is no mechanism in evolving economic entities that could correspond with the complex interactions of organisms' genetic and phenotypic spheres. Unlike in biology, no separation exists between what could be analogous to genotypic level and phenotypic level, and there is no sufficient inertia in the 'unit of inheritance' for social behaviour comparable with the 'germ plasm' of genes. Also, variation and selection occur in a less constrained form, allowing a greater degree of freedom compared to that of biological evolving entities. At the same time, one of the shortcomings of organizational ecology (Hannan and Freeman, 1989 and Carroll and Hannan, 2000) is the lack of attention to individual firms. Although the school of industrial organization does pay attention to individual firms, in the literature on industrial organization too little attention is given to the relationship between industry dynamics such as the entry, exit and age of firms. In addition, the theory of evolution in industrial clusters is complicated in that the definition remains essentially intricate and qualitative in many respects, as evidenced by Brenner's work of 2000, 2001, 2003. In fact, the evolution of industrial clusters remains a concept that is poorly understood, despite widespread acceptance of its significance. In relation to the UK, Scotland offers a good example of the difficulties of applying a simple definition of the evolution of industrial clusters, because industrial clusters in Scotland started at different times and in different ways. ICT, for example, started in the 1940s as an electronic industry and is still growing, yet industries such as ship-building, heavy engineering, steel and coal mines, wool industry, agriculture, jute and whisky are on the decline. Any discussion of the evolution of industrial clusters will be incomplete, however, without first outlining and understanding the forms that these industrial clusters take and then the causes of their decline. It is also worth mentioning that industrial clusters adopt numerous forms of development, including differences in technology, demand, competition, infrastructure, income levels per capita of the consumers, rates of growth or rates of unemployment within the region, economies of scale or externalities within the industry, output and consumption structures of the region, productiveness of the industry or the productivity and labour market conditions across different regions, and access to public services. Other considerations include government support, geographical factors, institutional factors such as the centralization of public institutions, differences in the availability of resources, education of management and training of labour, firms' population density and the pattern of migration of firms within the industrial clusters.

In this study the work will be based on both the product life cycle model and organizational evolution because in recent years technological change has played such a powerful role in competition in industrial clusters. Subsequently, forecasting the path of technological evolution is now extremely significant because it allows business and economic strategy to anticipate technological changes and thereby improve its position, as argued by Porter (2004), who also claims that most recent research on how technology evolves in an industry has grown out of the product life cycle concept. According to the life cycle model, technological evolution early in the life cycle is focused on product innovations, whilst the manufacturing process remains flexible. As an industry matures, product designs begin to change more slowly and mass production techniques are introduced, and so on. A typical industrial cluster's life cycle is marked by four distinctive stages, namely embryonic, growth, maturity and decline. It is important to note that although it is easy to say that industrial clusters evolve through four stages, the concept of the evolution of industrial clusters is nonetheless challenging and complex. For example, Hannan and Freeman (1989) suggest that organisational ecology utilises insights from biology, economics and sociology and employs statistical analysis to try and understand the conditions under which organisations emerge, grow and die. This theory looks at the death of firms (that is, firm mortality) and the birth of new firms (that is, firm formation) as well as organisational growth and change. As Brenner (2005) and Dalum et al (2005) argue, one reason for this is that the stages do not follow the exact linear progression that one would expect. One of the main reasons for this is that some technologies die quickly, whilst others continue to evolve and remain in the decline stage for a prolonged time before rotating back into the embryonic stage through the development of new technology. In fact, there is a range of factors that affect the evolution of industrial clusters, such as the type of technology involved in the cluster, competition outwith the cluster, government policy towards industrial clusters, entry barriers, infrastructure and the economic, social, political, cultural and historical situation of the country.

The Methodology used in Analysing the Evolution of Industrial Clusters

The research methods are selected depending on the requirements of the research objectives, along with their flexibility. In addition, the methods should be chosen depending on their appropriateness to the study as suggested by Reiter, Glenn and Bruce (2011). The good thing about the method selected in this study is that it is convincing, dependable, fast and easy to use, as well as being relevant to the study (Ball, 1991., Lapin, 1998., Saunders etal, 2000., Curwin and Slater, 2004). In this study, the term "case study" refers to the development of detailed, intensive knowledge about a small number of related "cases" such as the ICT and Biotechnology industrial clusters (Saunders et al, 2000). These two case studies (Information and Technology Information and Biotechnology industrial clusters) are of particular interest because they provide a rich understanding of how industrial clusters evolve and the characteristics that are likely to be found in each stage of development. This strategy of using two case studies is of particular interest to the study because these two case studies will enable the study to show how industrial clusters in Scotland have evolved over the years. The fascinating thing about these case studies is that one is still in its formative years whilst the other is now established after being revived by new technology. Biotechnology and Information and Communication Technology industrial clusters will be discussed in detail and will give an understanding of how industrial clusters evolve, as well as the characteristics that are likely to be found in each stage of their development. It is essential to note that the use of case studies is not new to economic studies. The only negative aspect of using secondary data is that the data has been collected for purposes other than the current study (Saunders etal, 2000). In order to analyse the evolution stages of industrial clusters, this study reviewed the relevant literature on the history of Scottish regions and industrial clusters, and thus was able to investigate and compare how

different industrial clusters in various regions in the different parts of the country have evolved over the years. As shown below, the study developed a framework of analysis with the help of literature in the fields of regional and urban economics, and industrial clusters in particular, which enabled four distinctive stages of the evolution of industrial clusters to be identified.

Findings

The Evolution of Information and Communication Technology Industrial Cluster

The ICT industrial sector started in the 1940s as a result of the government initiative around that time which was aimed at encouraging foreign-owned manufacturing firms to locate production facilities in United Kingdom, including Scotland and this was aimed at rebuilding Great Britain's depleted regional manufacturing bases (McCann, 1995). Scotland benefited from the establishment of the electronics industrial sector, which was born out of the introduction of American multinational companies. The first American electronics presence began with investment by NCR, Honeywell and Burroughs in the late 1940s. This was aimed at building the British defence industry which had been affected by the First and Second World Wars. This was then followed by a British defence contractor, Ferranti, who set up a plant near Edinburgh in 1943, and subsequently by IBM in 1951, who set up a plant in Greenock near Glasgow. Basically, the development of the ICT industrial cluster came as a result of the lead or anchor firms mentioned above, whose presence led to the development of the whole industrial cluster. These few critical firms fed the growth of numerous firms, both smaller and larger, such as Hughes Aircraft Corporation and Motorola in the early 1960s and National Semiconductor and General Instrument in the late 1960s, and finally they were followed by Burr-Brown and Nippon Electric (NEC) in the early 1980s. Up to the present, the ICT industry is still dominated by American corporations in terms of the number of firms and employment levels, as suggested by Henderson (1987). Silicon Glen was born as a result of the location of electronics firms in Glenrothes, Livingstone and East Kilbride, with engineers and R and D facilities supplied by the universities in Glasgow and Edinburgh, as suggested by Henderson (1987), Turok (1993) and McCann (1995). The presence of these major anchor firms in the industrial cluster is understood to have acted as a magnet, attracting both allies and rivals to the Lothian region then later to the Strathclyde region, ultimately resulting in the formation of Silicon Glen, a Scottish version of Silicon Valley. Indeed, according to Raines et al (2001), foreign multinationals became more embedded within a region by developing strong linkages among local suppliers by reinforcing and catalysing the innovation capacity of the region as a whole. For a very long time, foreign firms have acted as conduits of new technologies to local suppliers and this has always resulted in the increased competitiveness of both local and international firms and the region at large, and a good example of this is the interaction that has existed in the ICT industrial sector for years between IBM and Ferranti, and local firms. Nonetheless, it is clear once more that most of the anchor firms in the ICT cluster were foreign-based firms lured to Scotland by the British government in conjunction with economic development agencies such as Locate in Scotland (LIC). The government was instrumental in the stimulation of foreign direct investment (FDI) in Scotland through tax incentives, investment subsidies, provision of industrial sites and infrastructure. Generally speaking, the collaboration on sophisticated high-level services such as research and development (R & D) or product development and management consultancy is considerably lower in the ICT industrial clusters because the vast majority of foreign-owned MNCs have assemblies and conduct little or no real R& D in the host region, resulting in relatively low levels of regional 'embeddedness'. Instead, R&D and design activities in the ICT sector are conducted at the firms' HQs, hence the dominance of large firms in the initial stages of the development of the industrial cluster.

This situation did change, however, as discussed below.

Brown et al (2000) and Collinson (2002) point out that other firms dominating in the ICT industrial sector from the 1940s to the present are Hewlett Packard, Mitsubishi, JVC and Sun Microsystems, whose products include personal computers (PCs), laptops, servers, workstations, televisions, video cassette recorders (VCRs), audio equipment, cellular telephones, photocopiers, microwave and instrumentation equipment, automated teller machines (ATMs) and active electronic components, such as analogue and digital semiconductors. Fortunately, however, it is Brown et al's (2000) contention that indigenous firms are also featuring more in both specialist areas such as defence and lower value segments of the supply chain than during the period between the 1940s and the 1980s. In fact, there has been a growing awareness in recent years of the need to formulate policies that promote knowledge-based industries, since Information and Communication Technology (ICT) industries impact on other industrial sectors. Such policies have been directly based on the production, distribution (marketing) and the use of knowledge and information by other industries, since software and e-business suppliers are critical to the growth of e-business in Scotland. Indeed, this is the reason that ICT has been one of the leading and best-developed industrial sectors in the country. According to Turok (1993) and McCann (1995), the ICT industrial sector is one of the few sources of significant industrial growth in Scotland in the last few decades, dating back to the 1950s. Relative to other industrial sectors, according to McCann (1995), ICT is the most deeply embedded sector in the local economy in terms of local linkages, since software and e-business suppliers provide products and services required by all companies to do business online. The actors that are involved in this cluster, as well as firms that supply software and e-business, include buyers such as corporate organisations and universities and colleges. They also provide products and services to industrial clusters such as Financial Services, Oil and Gas, Utilities and the Public Sector, all of which are large purchasers in Scotland.

It is also argued that forward linkages were established where immigrant firms relieved production bottlenecks and provided cheaper inputs to local firms. Backward linkages, on the other hand, occurred when immigrant firms expanded their output, incidentally leading to a transfer of technology as they introduced new technologies of production, as Armstrong and Taylor (2004) have noted. For instance, corporate organisations such as Exacta began as suppliers of NCR and Digital, whilst Prestwick was the supplier of OKI, Ford and IBM as well as being a main subassembly contractor (Turok, 1993). It is clear that these firms were formed as a result of the government's desire to promote entrepreneurship. To make sure this policy was fruitful, the large firms engaged in buying software and e-businesses had a requirement to develop or purchase software from local firms rather than outsiders. The encouraging point to note is that ICT developments in Scotland have tended to have significant spatial links with entrepreneurship as all regions have, in recent years, increasingly become focal points for knowledge-creation and learning. According to Scottish Enterprise, corporate organisations involved in supplying software and e-businesses are IBM, Oracle, Microsoft and SAIC, all of whom have a presence in Scotland. Corporate organisations that are involved in buying software and e-businesses are NCR, Agilent Technologies, Standard Life, The Royal Bank of Scotland and Scottish Power. Firms engaged in buying software and e-businesses have a requirement to develop or purchase software to include in their own products or to help provide their own services, and also require in-house IT departments. The encouraging point to note is that ICT developments in Scotland have tended to have significant spatial links with entrepreneurship, since all regions have in recent years increasingly become focal points for knowledge-creation and learning. In fact, McQuaid (2002) believes that the cluster is going from strength to strength due to increases in the use of the Internet. It is estimated that by 2010 that half of all jobs in

Scotland will be in industries that are major producers or intensive users of information and communication technology products and services. In this light, the involvement of local entrepreneurs is very encouraging - and, indeed, to be promoted - for the reason that small businesses are viewed as innovators of new technology capable of stimulating economic development.

Scotland has had specific strengths in the software industry for some time, but particularly in the past last two decades, through the activities of larger electronics and defence-related companies such as Ferranti and Marconi, as Collinson (2002) has noted. It has also long been an academic centre for software-related research, as well as artificial intelligence, parallel computing, computer sciences, distance learning and research into human-computer interfaces, going back to the days of Marconi Electronic Systems and World War II. The growth of small start-up firms, particularly small-firm-based multimedia establishments in the software industry, has been linked to the presence of ICT multinational companies and educational institutes and is strengthening rapidly. Collinson (2002) estimates that the total number of people employed in the Scottish software industry is around 19,600, including 7,400 people employed in 220 indigenous software companies, 250 sole traders and 3,000 individual contractors. The remaining 8,950 employees work in the software divisions and subsidiaries of non-Scottish software firms and major local users. Marks and Lockyer (2004) and Collinson (2002) still feel that the links and exchanges between incumbent electronics MNCs and small multimedia firms in Scotland are limited, as product changes or improvements in processing technologies are still coming from customers and suppliers outside the Scottish region. There is limited interaction with large firms in the form of joint ventures, new product development alliances or cooperative R&D, such as that taking place in regions like Silicon Valley. One significant reason for the lack of interaction between small firms and MNCs is that the vast majority of foreign-owned MNCs in Scotland are assemblies and conduct little or no real R& D in the region, resulting in relatively low levels of regional 'embeddedness'. In fact, the R&D and design activities are conducted at the firms' HQs and at other global centres in Europe and / or Asia. MNCs that operate in such a manner include IBM, Digital, Compaq, JVC, Motorola, Sun Microsystems, Hewlett-Packard, NCR, AT&T, Phillips, NEC and Mitsubishi (Brown et al, 2000). To give but one example, Hewlett-Packard conducts its R&D mainly at the company's birth place in Palo Alto, California, near the heart of Silicon Valley, and its European R&D laboratories are based in Bristol. NEC, meanwhile, has most of its R&D activities based at corporate HQ in Japan, in addition to a large research institute based strategically in New Jersey, home of AT&T's famous Bell Laboratories. Philips' main R&D and design centres are concentrated in Eindhoven (the Netherlands), and Mitsubishi's are in Tokyo.

On the contrary, the regional innovation systems that were introduced in the ICT sector since its inception in Scotland at least resulted in the encouragement of marketing relationships, however minimal they may have been, which allowed firms to take their cues from customers and competitors to determine the needs of their markets. Obviously, the overall objective of these firms belonging to the ICT market-driven clusters was to demonstrate a pervasive commitment to a set of processes, beliefs and values, reflecting the philosophy that all decisions start with the customer and are guided by a deep and shared understanding of customers' needs and behaviour, as well as competitors' capabilities and intentions. In addition, this encourages the shifts in customers' demands or needs to be met by ICT firms, challenges from rivals to be countered by all firms in the ICT clusters, impending market entries by outside firms to be monitored and rebuffed if necessary, and excessive pricing by suppliers to be resisted. In short, market-driven firms in the ICT industrial clusters are seen as superior at market positioning, understanding and responding to external developments, and this is one

of the strengths of firms operating in Scottish industrial clusters. For example, the sector introduced new software, such as the market-leading Grand Theft Auto series developed by Rockstar North in response to the growing customer demand for products of this nature. In addition, the sector developed Micro Electric Mechanical Systems (MEMS) and Nanotechnology. As Ketels (2003), de Wit and Meyer (2000) and Kotler (1998) argue, it is possible for firms with strong-market driven convictions, such as ICT's, to collaborate because they facilitate the exchange of information, whereas loner firms inhibit the communications that are necessary to effective market-sensing, hence the significance of market relationships in the ICT industrial clusters. Such relations are made possible by firms that work together in strategic issues such as sharing of information. Of particular importance with respect to market relations is the fact that firms are unable to identify what their customers want and need at the embryonic stage are likely to struggle in the later stages of the cluster.

As suggested by Engelstoft et al (2005), firms supplying inputs to other firms in the ICT industrial cluster experienced greater benefits from positive externalities at the growth stage than those firms that were operating outwith clusters. The reason for this is that average costs tend to fall in this stage as a result of the cramming of individuals and occupations into one industrial cluster, as argued by Glaeser et al (1992). Furthermore, apart from the spatial concentration of firms in the ICT industrial clusters, Brenner (2000) also regards the level of co-operation being experienced between ICT firms and other actors in the clusters, especially their suppliers and customers, as being profitable. Co-operation is in fact deemed to be the back-bone of the Scottish ICT industrial clusters, because it is considered to be based on the expectation of reciprocal actions, such as the supplier's willingness to share information on the true costs of production, as well as to invest in dedicated production capacity with the expectation that this will reward both parties - supplier and producer - with future work orders, as Perry (2005) contends. As complicated as it is, firms in an industrial cluster in the growth stage tend to co-operate in seeking new work and may also bid together on large projects, as witnessed in the Scottish ICT clusters. In addition, this not only reduces costs but also increases the number of innovations in the clusters, leading to improved productiveness with no extra financial outlay. Christensen et al (2002) have observed that continuous innovation at this stage, especially as a result of co-operation among firms in the same industrial cluster, involves the ability of the cluster to generate key innovations in products, process, designs, marketing, logistics and management, as experienced in the ICT industrial clusters. Firms in close spatial proximity to one another, as is the case with those belonging to ICT industrial clusters in Scotland, have benefited from spillover externalities, since they have been allowed to learn, compare, compete and collaborate with others without any difficulties. The competitive advantage that firms in the Scottish ICT industrial clusters had while at growth stage, therefore, was that they gained synergies from locating near to like firms. The argument behind this is that firms in close spatial proximity such as IBM, NCR, Currie and Mill, Exacta and Bepi Circuits, MEPD, BHK Circuits, Border Circuits and PAK Systems, Balray, Tweedbank Circuit Supplies and Dynamit Nobel, Static, Keltek and Extacto, Cirtech, Prestwick, Rolls Royce, Standard Telephones and Cables are more visible to each other and thus have the opportunity to observe, monitor and benchmark what their neighbours are doing, thereby making them aware of the market trend and enabling them to react to market needs without having to pay for the information (Dalum et al, 2005; Ketels, 2004; Klepper and Simons, 2001).

As ICT industrial clusters have now reached the mature stage, it is important to note that co-operation and proximity of suppliers and customers are now becoming less important than was the case in the initial stages of the industrial cluster's life cycle. What remains, according to Brenner (2000), is a slightly higher intensity of contacts of

suppliers and customers due to the fact that they are located near to each other. Firms' productivity is expected to decrease, therefore leading to less competitiveness in the region. Collaboration on sophisticated high-level services such as research and development (R & D) or product development and management consultancy is probably going to be considerably lower than was the case in the initial stages, although the reason given is that the vast majority of foreign-owned MNCs in Scotland are assemblies and therefore conduct little or no real R& D in the region. As a result, there is a relatively low level of regional 'embeddedness', and interaction between MNCs and small firms is now minimal. In addition, the maturity stage is known as a period of slowdown in sales growth because the technology will have been accepted by most potential buyers. Profits during the maturity stage level off or decline due to the increased marketing expenses required to defend the product against competition. The firms encounter diseconomies of externalities, which are associated with the problems of managerial co-ordination that occur as most small firms develop into large firms. In fact, in the mature phase, the overall rate of innovation fades and technology becomes less competitive (Dalum et al, 2005). This is not surprising, given that in recent years companies in the ICT industrial sector have been closing down and leaving the industrial clusters. For example, in 2000, Viasystems, National Semiconductor and Chunghwa each laid off a substantial number of employees or closed factories completely. In addition, Digital sold their Alpha facility to Motorola who eventually closed it down, while Motorola also closed their own factory in Bathgate and NEC closed its plant in Livingston. This resulted in the number of people employed in the sector dropping from 48,000 people in 2000 to 25,000 in 2004, according to NOMIS figures.

The Evolution of Biotechnology Industrial Cluster

Although the presence of externalities associated with knowledge spill-overs resulting from geographical proximity is deemed to have inspired the formation of both the Edinburgh and Dundee Biotechnology industrial clusters, by facilitating the swift and easy transmission of ideas and intellectual breakthroughs, government policy also played a significant role. Indeed, the government influenced the existence of public research institutions such as the Moredun Research Institute, which is dedicated to veterinary science, the Royal (Dick) Veterinary, the Protein Fractionation Centre, Microsulis Medical and Roslin BioCentre, which is a subsidiary of the Roslin Institute, all of which have strong links with the University of Edinburgh. In fact, the Edinburgh biotechnology industrial cluster was formed around the Roslin Institute, the centre of excellence for life sciences and the birthplace of the world's most celebrated biotechnology product, Dolly the Sheep. These research institutes were crucial to the development of the biotechnology industrial cluster in Edinburgh, which was founded upon innovations including cloning technology, stem cell research, clinical trials and neuro-science research. These areas are among the clusters' particular strengths in Scotland, and have served to attract quite a number of firms and labour force. Among the biotechnology companies concentrated in the Edinburgh biotechnology industrial cluster are Excell Biotech, Viragen and BioBest, Geron Bio-Med, MicroScience Technologies, PPL Therapeutics, Aquapharm Bio-Discovery, Ardana Bioscience, Pan Therix, an anti-infectives company and diagnostic company, R-Biopharm Rhone, which were attracted by the level of technology available in the cluster. The Edinburgh industrial cluster also boasts spinouts from Scottish universities such as In-Phage Ltd and Ingenza from University of Edinburgh and Nandi Biotechnology Ltd from Heriot Watt University, among others.

The Dundee biotechnology industrial cluster, meanwhile, arose primarily as a result of the University of Dundee and the Welcome Trust Biocentre, based at the Wellcome Trust building within the university. Ninewells Hospital and Medical School, one of the largest and most modern teaching hospitals in Europe, and the Scottish Crop Research Institute

in Invergowrie, near Dundee, also played a part in the development of the Dundee Biotechnology industrial cluster. The University of Dundee campus offered companies such as Upstate Limited and RA Laboratories opportunities to be innovative through collaboration with medical researchers from Ninewells Hospital and the Scottish Crop Research Institute. In addition, this resulted in the concentration of biotechnology companies such as Axis Shield, an international diagnostics company that specialises in in-vitro diagnostics for a range of clinical applications and whose headquarters are based in Dundee. The Dundee biotechnology industrial cluster is also home to in-vitro drug metabolism system manufacturer, Cypex, and micropropagation company, GenTech Propagation, in addition to boasting spinouts from the University of Dundee such as Kinasource. The presence of this last firm is a sign of entrepreneurship activities taking place in the cluster, even though the cluster is dominated by large firms. Indeed, as suggested by Brenner (2003), in the embryonic and growth stages start-ups and spin-offs tend to increase in number, meaning that it is not surprising to find small firms in these clusters. Entrepreneurship itself is in turn deemed to be stimulated by the continuous introduction of innovations that characterises the embryonic and growth stages, resulting in more firms joining in these stages. For example, the continual invention of drugs in the Scottish industrial clusters by multinational companies such as Organon and Quintiles has led to a successful formation of small home-grown companies such as ProStraken and Cyclacel. It is clear that both small entrepreneurial firms and large firms in the Edinburgh and Dundee biotechnology industrial clusters are aware that, to be successful, they must be innovative ad infinitum. Firms at this stage, irrespective of their size, are also conscious that in order to survive to the next stage they must not only keep developing new technology, but should also look for all types of innovation that will keep them ahead of their competitors. Within the Scottish biotechnology industrial clusters, for example, firms are offering several innovations including cloning technology; stem cell research, clinical trials and neuro-science research. As is always the case with industrial clusters, the embryonic stage is a combination of innovation and imitation, but firms in the Scottish biotechnology sector are aware that they need to generate key innovations in technology, processes, designs, marketing, logistics and management even when they form or join an industrial cluster later on in their life cycle, as has been witnessed in the Scottish biotechnology sector in recent years. These industrial clusters are offering a full spectrum of expertise in the following areas such as drug discovery and development to biomanufacturing, stem cell research, bioinformatics, neuroscience, cancer research, genomics and proteomics. What this means is that Scotland's life sciences community has gone beyond Dolly the Sheep, cloned by Roslin Institute in 1996, which came to symbolise Scotland as a world-leading innovation in the life sciences, all of which, Brenner (2003) argues, are the result of continuous, quality and highly sophisticated innovations. Co-operation, collaboration and movement of information are high at this stage in all Scottish industrial clusters because it is argued that information can be easily transmitted over long distances. Knowledge, on the other hand, is often tacit and tends to involve face-to-face interaction and frequent and repeated contacts, meaning that it is not as easy to transmit information over distance as argued by Christensen et al (2002), Storper and Venables (2003) and Cooke et al (2003). The embryonic stage is also known as a period of slow sales growth, as technology is introduced to the market. Profits are negative or non-existent in this stage because of the heavy expenses associated with technology introduction and distribution. Firms also require a great deal of money to attract distributors and build their inventories. In the same way, high promotion spending is unavoidable, since customers need to be informed of the presence of new technology in order to want it. Early customers will be attracted by the novelty of the item, as witnessed by the Scottish Government's decision to spend part of £40 million equity fund to support innovative businesses in biotechnology.

In addition, Scottish Enterprise pledged £1.85 million to support the commercialisation of stem cell research for a period of ten years, whilst a further £600 million was spent on building Edinburgh BioQuarter, a landmark biotechnology facility, which is making Scotland one of the world's top ten centres for biomedical commercialisation (Scottish Government, 2008 and Scottish Enterprise, 2008).

As the Scotland's biotechnology industrial clusters reach the growth stage, there will be some rapid market acceptance by the customers and increasing profits, and this will lead to the establishment of vertical linkages by original occupiers and this will involve setting up linkages with suppliers and distributors. In the case of biotechnology industrial clusters, for instance, it will mean immigrant firms providing cheaper inputs to local firms, whilst backward linkages will occur when the expansion of output by immigrant firms such as Organon and Quintiles, which results in local purchases of inputs. Foreign firms will also provide local firms with new techniques of production, and all of this may generate a high start-up rate of local entrepreneurial firms and an increase of talented workers, which will not be a problem given Scotland's enterprising culture and supportive legislative environment, which have also helped create a dynamic and progressive environment not only in the biotechnology industrial sector but also in other sectors. In most cases, as the literature suggests, immigrant firms also tend to provide an appropriate training ground for potential entrepreneurs, such as the founders of ProStraken and Cyclacel, and workers, hence the concentration in one geographical area of firms who wish to benefit from the trained workforce. As suggested in the literature, Scottish biotechnology companies and scientists are currently producing a myriad of exciting ideas that are shaping the biotechnology industrial sector. As well as trading with foreign firms, entrepreneurs are also involved with government subcontracting when their firms reach the growth stage, producing rather mundane products such as medical tests kits and reagents for biotechnology, as Feldman et al (2005) have remarked.

CONCLUSIONS

This study shows that, despite a widespread lack of interest in the area, the evolution process of industrial clusters is deemed to be one of the most fundamental concepts used to examine and predict the probable course that clusters may take in their life spans. Coming to an understanding of this concept also enabled the study to review and evaluate the evolution of some of the industrial clusters in Scotland, from their formation up to the present. In order to achieve this, the main focus was placed on the way technology has evolved over the years, especially in the ICT and Biotechnology industrial sectors. The presence or absence of innovation, trust, cooperation, communication and information spill-overs, linkages, market relationships, interactions, social and economic embeddedness, spatial proximity, sectoral specialisation and local support, serve to indicate the stage of evolution of industrial clusters. Nevertheless, it is worth remembering that, as shown in the study, the development of high-technology clusters is not a deterministic process; rather, there are several factors that influence the evolution of industrial clusters from one stage to another. Having said that, however, it was still difficult to precisely define the stages in which a cluster starts and ends, since industrial clusters do not develop evenly but the presence of research institutions are furthermore vital to the development of industrial clusters especially in the embryonic stage, also known as the development stage, because this stage is known mainly for research and development products only. On the other hand, the growth and maturity stages are known for production and distribution, while the decline stage is clearly marked by the absence of innovation, trust, cooperation, communication and information spill-overs, linkages, lack of market relationship, interactions, social and economic embeddedness, spatial proximity, sectoral specialisation and local support. At this stage, the only alternatives left to firms still operating in the industrial cluster are to

enter into new industrial sectors through diversification - as being witnessed in the Oil and Gas industrial cluster - or cease to exist.

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