Competitive Paper
Clusters, spillovers and choice of locations:
countries versus regions versus cities?

Growth of Indigenous Software Firms and Knowledge Spillovers in Cities

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Abstract: Despite the prediction of the demise of cities with the advance of new information and communication technologies in the New Economy, the software industry has emerged from cities in the USA, Europe and Asia in the past two decades. This paper explores the reasons why cities are centers of software clusters, with reference to Boston, London and Dublin. It is suggested that cities' roles as centres of knowledge flows and creativity are the key determinants of their competitiveness in the knowledge-intensive software industry.

INTRODUCTION

The software industry has been one of the fastest growing knowledge-intensive industries in the past decade and was valued at more than US$260,000 million in 2000. The software industry, which encompasses both software production and software service, is a knowledge-intensive industry on the grounds that it requires a high level of research and development as well as skilled labour input. A notable theme of the industry is its unifying growth experience in the past decades within city localities such as San Francisco, San Jose, Boston, Cambridge, London, Dublin, Bangalore, Beijing and Amsterdam, despite pessimistic predictions about the obsolescence of cities in the information age, where technology reduce the needs for individuals to conduct face-to-face interaction (Toffler 1970).

Cities that target knowledge-intensive industries indeed share basic conditions such as human capital and information infrastructure. A recent industry report by an Irish consultancy firm stated that the most critical factors that influenced a location's desirability were the level of research and development and human capital[1]. Innovation has led to the emergence of a software industry in city localities and innovation that underlies a differentiation strategy creates competitive advantage and sustains the growth of city software industries. Porter (1990 p.45) stated that innovation is an attempt 'to create competitive advantage by perceiving or discovering new and better ways of competing in an industry and bringing them to market'.

The generation of knowledge that provides the basis for innovation is of particular importance in the software industry; various innovation models developed since the

[1] Reported by Dublin's HotOrigin. See Karlin Lillington, 'Growing software sector relies on the few', The Irish Times, 9 May 2001.

1950s such as the linear-sequential model, the chain-lined model and the integrated model supported the critical role of knowledge within the innovation process. As knowledge is a public good that can be easily transferred, the prime source of innovation advantage which cities provide to industries is derived from the transmission of knowledge from its generators to exploiters. As Glaeser et al. (1992 p.1127) pointed out 'intellectual breakthroughs must cross hallways and streets more easily than oceans and continents'. A number of studies have discussed the spillovers of knowledge among firms which would subsequently generate growth; furthermore, theorists have identified the geography of knowledge spillovers by examining variables such as patent activity, labour mobility, firm size, university research and development and innovation rates.

In this exploratory paper, I will examine the role of knowledge spillovers among higher educational institutions, leading US software firms as well as other knowledge-intensive clusters in the growth of the indigenous software industry in Boston, London and Dublin. The geographical boundary of Dublin County will be adopted in this paper. However, London includes towns extended from the inner west of the city and incorporates Guildford (south of London), Milton Keynes (north of London) as well as Maidenhead and Reading (west of London). Though Reading is about 30 miles from London; it is close temporally as direct train services from Reading to London takes approximately 30 minutes. On the other hand, the boundary of Boston refers to nearby towns situated along Route 128 such as Bedford and Burlington (which are less than 20 miles north-west of the city). The methodology of this paper is based on direct and indirect methods of data collection. The former include interviews conducted at firms' premises in Boston, Maidenhead and Dublin during the summer of 2002. The interviews

lasted for 1 ½ to 2 3/4 hours; Table 1 illustrates examples of some questions used in the interviews. The latter consists of content analysis of primary and secondary materials at the firm and industry level.

THEORETICAL PERSPECTIVES

In this section, I will first discuss the development of software as well as the knowledge embodied in it; I will then proceed to summarise the existing literature in relation to the growth of indigenous industry in city localities. The launch of a software product involves three stages: design, production and marketing; it has been generally acknowledged that great designs come from great designers rather than good designers. Brooks (1987 p.18) pointed out that 'the differences are not minor — they are rather like the differences between Salieri and Mozart. Study after study shows that the very best designers produce structures that are faster, smaller, simpler, cleaner and produced with less effort'. The provision of software services, on the other hand, includes firms that provide services directly to the design of software and is a relatively simplified process.

Knowledge involved in the software industry includes creativity, technical knowledge and customer-base knowledge (OECD 1999); creativity is a tacit knowledge and is therefore not readily transferable beyond the context in which it is embedded. Technical and customer-base knowledge, on the other hand, contain elements of both explicit and tacit knowledge and hence can be articulated and transferred to some extent. Creativity has been explained in terms of 'experience life in one's own way, to perceive from one's own person, to draw upon one's own resources, capacities and roots' (Moustakas 1967 p.27). Creativity embodied in software design can be compared to an

art, which has been described as 'you can't pick it up and imitate it so easily. You can't crave it, measure it; you can't even see it'.[2] The foundation of technical knowledge is derived from scientific literature and manuals, which are explicit in nature. However, it is underpinned by recruiting Computer Science graduates or individuals who have received systematic on-the-job training from leading software firms in its tacit form. Bill Gates once stated that he could screen the best programmers among new graduate recruits in three or four years, and he could not think of any initially mediocre programmer at Microsoft who later become a world-class programmer (Stross 1998). Finally, face-to-face communication with researchers through conferences or seminars is also another source of tacit technical knowledge as it enables individuals to clarify techniques used or interpretations of published materials. Customer base knowledge represents market trends and new market opportunities. Customer base knowledge can be acquired through information exchange among firms as well as secondary resources such as industry publications; the former is tacit in nature while the latter relates to explicit knowledge.

Tacit knowledge forms the basis of innovative activity in the software industry. Polanyi (1966) encapsulated the importance of tacit knowledge in the phrase 'we know more than we can tell'; in other words, direct experience of tacit knowledge is a prerequisite during its acquisition and is essential as such knowledge cannot be communicated in any codified way. Howells (2002) pointed out that the geographical limitation in transferring tacit knowledge was linked to the fact that such knowledge was embedded within the cognitive, social, cultural and economic circumstances of localities

[2] Comment by Doug Jerger of ADAPSO, the predecessor of the Information Technology Association of America (ITAA) in 'Software: Japan trying to catch up with US', Los Angeles Times, 8 July 1990 p.D17.

where it was generated; subsequently, its transfer was constrained by distance in terms of acquisition barriers and scanning costs.

The growth of city industry in the context of knowledge spillover was first recognized by Marshall (1890) who suggested that industrial concentration would allow knowledge flows in addition to human capital and specialized inputs that fueled innovation. He wrote (ibid. p.21): 'when an industry has thus chosen a locality for itself, it is likely to stay there long: so great are the advantages which people following the same skilled trade get from near neighbourhood to one another… Good work is rightly appreciated, inventions and improvements in machinery, in processes and the general organization of the business have their merits promptly discussed: if one man starts a new idea, it is taken by others and combined with suggestions of their own; and thus it becomes the source of further new ideas'. Marshall, therefore, suggested a geographical boundary to knowledge spillovers among the firms in an industry as well as the role of knowledge transfer towards growth. The notion that industrial concentration is conducive to growth can be seen in the formalized models of Arrow (1962) and Romer (1986) as well as studies such as Henderson (1986) and Arthur (1989). The implication of this stream of work is that spillovers of economic knowledge within an industry tends to take place within a geographically concentrated area; hence, cities should specialize in a few industries so as to enhance the transfer of knowledge.

Jacobs (1969), on the other hand, discussed the importance of knowledge spill-overs from diversified industry bases in cities as the basis to enhance cross-fertilisation of ideas and subsequent growth of the industries. Bairoch (1988 p.336) supported this view and wrote: 'the diversity of urban activities quite naturally encourages attempts to apply

or adopt in one sector (or in one specific problem area) technological solutions adopted in another sector'. The empirical study by Glaeser et al. (op. cit. p.1150) of US manufacturing industries during 1956 and 1987 found that industries grew more slowly in cities in which they were over-represented but faster in cities where the industrial bases were more diverse. They concluded that 'at the city-industry level, specialization hurts, competition helps, and city diversity helps employment growth'.

Porter (1990) argued that the emergence of competitive geographical concentration of firms in city localities was based on knowledge generated by factor conditions such as communication infrastructure and a good education system, sophisticated national and local demands, related and supporting industries as well as competitors. For instance, the presence of local customers means that firms are more able to perceive new buyer needs as a result of proximity; Porter's notion of related and supporting industries was similar to Jacob's view on industrial diversified localities. In addition, Porter emphasised the importance of competitors and their roles in knowledge generation and transfer as 'good ideas are imitated and improved upon by local competitors, raising the overall rate of industry innovation' (ibid. p.120).

The growth of indigenous software industry could therefore be interpreted in the light of the transfer of knowledge among firms within the industry, firms from other high tech sectors as well as spillover from research institutions. Indeed, empirical studies have substantiated the presence of knowledge spillovers in a geographical context. For instance, Audertsch and Feldman (1996) found that knowledge-intensive industries with higher industry R&D, academic research and skilled labour were more geographically concentrated in the USA. Audertsch (1998 p.21) further stated that 'while the marginal

cost of transmitting information across geographic space has been rendered invariant by the telecommunications revolution, the marginal cost of transmitting knowledge, especially tacit knowledge rises with distance'.

SOFTWARE AND KNOWLEDGE SPILLOVERS

Though the global software industry is dominated by Silicon Valley firms, there are a considerable number of start-ups from the three cities — Boston, London and Dublin — that have grown and become successful in terms of sales revenues. The Software 500, which registered the largest firms in terms of sales revenues in business software and services worldwide, shows that there were approximately fifty Boston firms, ten London firms and five Dublin firms on the list in 2001.

According to Marshall (op. cit.), the geographical proximity created by cities brought about a situation whereby 'the mysteries of the trade became no mystery but are, as it were, in the air...'. In this section, I will use industry data collected from the public domain as well as case studies from personal interviews (ie. Firm A of Boston, Firm B of London and Firm C of Dublin) to explore the spillovers of tacit knowledge and explicit knowledge within indigenous software industry. Such knowledge is drawn from local and international sources that comprise higher educational institutions, leading software firms as well as other knowledge-intensive industries.

Firm A, Firm B and Firm C were private firms, which were less than six years old and employed 10 to 80 employees. Firm A was a firm providing biotechnology software while Firm B was predominantly a internet software service firm (though it had recently engaged in a product strategy). Firm C, on the other hand, engaged in internet security

product. Firm A, Firm B and Firm C shared common characteristics in the sense that their founder/co-founders had won business awards or had been short-listed for entrepreneurship competitions. The three founders set up their firms in their thirties and early forties; their motivations of setting up their own firms were similar — they identified market opportunities and wanted to exploit them. In addition, they considered that the opportunity costs of setting up firms were rather low as they would still be very employable if the ventures did not work out. Nevertheless, the entrepreneurial orientations can be classified into two groups. The co-founder of Firm A and the founder of Firm C were serial entrepreneurs who aimed to build up their firms and then sell them off to investors while the founder of Firm B was keen to expand the firm. Indeed, the co-founder of Firm A was in his second venture while that of Firm C was in his fifth venture. The three founders were all well educated. The co-founder of Firm A had obtained a first degree in Mathematics from the University of Chicago and a master's degree in Linguistics from MIT; the founder of Firm B had a BSc in Physics from the University of Kent and was qualified as a certified accountant in the UK. The founder of Firm C, on the other hand, gained a bachelor in Mathematics and a diploma in Philosophy from the University of Limerick.

Higher Education Institutions and Knowledge spillovers

Boston, London and Dublin all possess the fundamental location conditions of excellent scientific research and development institutions that are most appropriate to the growth of indigenous software industry. Some of the commonly cited institutions are MIT and Harvard in Boston, Imperial College and UCL in London as well as Trinity

College in Dublin. The modes of knowledge spillover from research institutions include academic dissemination of research findings to the setting up of new firms from academia that is based on campus research. The most prominent example of a campus firm was the formation of the Irish firm Iona in 1991 by distributed computing researchers Chris Horn, Annrai O'Tooole and Sean Baker of Trinity College. Horn recalled that Iona at the time faced some opposition from the faculties at Trinity College as well as skepticism from state agencies; he added that 'we literally put about 1,000 pounds each in, and bootstrapped it from there'[3]. In 1992, IONA shipped the Orbix, a product that enabled distributed computers and software systems to work together collaboratively.

The extent of tacit technical knowledge acquired by Firm A, Firm B and Firm C from higher education institutions in their cities was evident in the context of recruitment and personal interaction. The Director of Engineering in Firm A, also the co-founder of the firm, was a graduate of MIT; indeed the biosensor product concept of the firm was drawn from his two years of research work in electrochemistry in MIT. Firm A had already obtained two patents for its product in the USA; in addition, it was in the process of filing for two more patents. Though the two founders of Firm A were originally from other parts of America, they decided to stay in Boston (rather than leave for the Silicon Valley) after graduation. This supported the BankBoston's findings in relation to the significance of MIT alumni for business formation in Massachusetts and California. The report concluded that Massachusetts imported founders of new firms as a result of MIT[4].

[3] Karlin Lillington, 'Iona thinks radical in recasting of core business', The Irish Times, 23 March 2001.
[4] See web.mit.edu/newsoffice/founders/Introduction.html

In terms of on-going interactions with research institutions, the managers of Firm B had established personal relationships with the Computer Science Department in the University of Reading and visited the campus from time to time. Firm A also suggested that knowledge spillover was extremely important for the delivery of its product; their engineers were still in contact with researchers in the universities they attended, which included MIT, University of Cambridge and University of Michigan. Nevertheless, its link with researchers outside Boston was also very significant; the reason was that only a few individuals in the world could be regarded as specialists in relation to its specific product area, hence the knowledge transfer with researchers in Australia who were responsible for the testing of the software was also essential. The founder of Firm C also acknowledged that he gained new insights from scanning research publications in the industry even though he had been building network systems for some ten years. He also mentioned that he enjoyed the sense of creativity in new ventures and found it very rewarding. The proprietary network product idea of his fifth venture was derived from reading industry magazines. He stated that he was obsessed with the product idea at the beginning stage of the venture and would keep thinking about it 24 hours a day. After he had finalized the product concept, his firm began the software project without any market research. Firm C recruited software engineers in Dublin primarily through personal introductions based on word of mouth from the founder's personal network; he further explained that 'being Irish' was the theme of this personal network and recalled that this 'Irishness' was the commonality that had drawn him and other Irish together during his two years working in Amsterdam.

Leading US Software Multinationals and Knowledge Spillovers

The software industry has been and is led by US firms; the sales revenues in 2000 of the fifteen largest US multinationals amounted to US$168,480 million. In his discussion of the linkages and spillover generated by multinationals' activities, Dunning (1993) summarized their influence on local suppliers derived from information linkages, technical assistance, financial assistance, procurement assistance, location, pricing assistance as well as managerial and organizational assistance. In addition, he pointed out that employees who left the multinationals and set up their own firms, represented another source of spillovers of knowledge, ie. they received free training from their former employers that could improve the operations of their firms. O'Riain (1997) found that the impact of sub-contracting software localization work (i.e the translation of already developed software products into local formats) by leading US firms Oracle, Lotus, Novell and Microsoft in Dublin since the 1980s had enhanced the technological learning of indigenous firms. Nevertheless, O'Riain (ibid.) also pointed out that the indigenous software industry in Dublin was not simply about software localization, there were also firms that offered innovative products and services. In a study that covered 36 firms involved in localization, software product development and services, O'Malley and O'Gorman (2001) reported that the areas of cooperation and knowledge spillovers between Irish firms and software multinationals were marketing, product development and some exchanges of information. The importance of acquiring tacit knowledge through research colloaboration with leading US software firms was highlighted by Firm B's new research division, which the founder described as a easier way to attract the attention of Reading based US firms to its activities.

The spillover of tacit knowledge due to labour mobility is a characteristic of the software industry. Despite disintegration in work procedures, employees in knowledge-intensive industries are still able to capture degrees of their former employees' technological and marketing knowledge; they may even have links with former colleagues that enable them to update their knowledge. Indeed, O'Malley and O'Gorman (op. cit.) found that a third of indigenous software firm founders were former employees of US software firms in their study. The founders of Firm A, Firm B and Firm C had in fact all worked for US multinationals and they all admitted that they had gained valuable experience from their former employers. For example, the founder of Firm A had been involved with managerial positions in conjunction with the setting up of a new subsidiary, which he recognized as his first exposure to setting up a new venture. The founder of Firm B also mentioned that he was able to transfer the knowledge of asset management that he had acquired in his former position to the financial structure of Firm B. Finally, the founder of Firm C obtained his initial training in software engineering through his employment with a US multinational. Indeed, he added that it was not very satisfying to work on a small part of a big project for two years and be unable to see the final product.

Knowledge-Intensive Cluster and knowledge Spillovers

Other knowledge-intensive industries that serve as customers or related and supporting industries also play a part in knowledge spillovers to the software industry. The knowledge-intensive industries in the three cities include biotechnology in Boston, telecommunications, finance and new media in London, food processing, pharmaceutical

and information technology in Dublin. O'Malley and O'Gorman (op. cit.) observed that indigenous Irish firms that interacted with sophisticated customers subsequently developed new or improved products and services in specific market segments and concluded that multinational customers' demanding standards had significant influences in strengthening the capabilities of indigenous firms.

The transfer of tacit knowledge from other knowledge-intensive industries can be observed in the three firms. Since Firm A pursued a unique software solution (rather than the traditional chemical based solution) to improve the functioning of a medical diagnostic device, it discussed its product concept with hospitals and biotechnology firms in Boston prior to its formation. It also tested its product in laboratories in Boston, which allowed a direct interpersonal channel for the communication of the results. Firm B, whose customer base was in the Thames Valley, had its project teams stationed with its clients. The face-to-face interaction therefore allowed the transfer of tacit information form its IT firm clients to Firm B. Moreover, it was also revealed that Firm B had informal, personal links with its first customer in the Thames Valley before the business transaction. Firm C also consulted US telecommunication firms in Dublin, potential collaborators of its proprietary network product, when finalizing its product concept. This, therefore, illustrates another example of tacit knowledge spillover from knowledge-intensive firms.

Discussion

The preceding sections which have focused specifically on the linkages of software firms with higher educational institutions, leading software firms and other knowledge-

intensive firms illuminates the transfer of tacit technical knowledge and tacit customer base knowledge in the software industry across Boston, London and Dublin. However, it should be noted that the spillover of the creativity element of tacit knowledge was not mentioned among knowledge generating institutions. A possible spillover of creativity can be found in the quality of life in cities, which are influenced by arts diversity, entertainment and lifestyle opportunities. In their interpretation of Bangalore's software cluster, Balasubramanyam and Balasubramanyam (2000 p.352) suggested: 'the city offers excellent schooling, and sports and recreation facilities including clubs and golf courses some of which to this day detail the architecture and traditions of the days of the Raj. It is also frequently remarked that the presence of London-style pubs and restaurants in the city are of allure to the highly paid young software engineers, but it is an untested proposition'. Interestingly, this proposition is consistent with the value of Generation X knowledge workers, who believe in striking a balanced lifestyle. As Hall (1995 p.20) wrote: 'since the sources of the new economic growth are various and finally perhaps so fickle, the possibilities are endless. But one central element is quality of life. It is no accident that, as never before, rankings of cities dominate the media'.

The individualistic outlook in cities, where people are encouraged to create their unique experiences in anonymity, is also conducive to creativity as the foundation of creativity is from within the individual. As Raban (1988) wrote: '… Decide who you are, and the city will again assume a fixed form round you. Decide what it is, and your own identity will be revealed, like a position on a map fixed by triangulation' (p.9). The extreme aspect of individualism in the center of the software industry has been captured by Castells and Hall (1994) in terms of aggressive work behaviours. A recent survey of

social involvement reinforced this view with disconnected social behaviours; it stated that the Silicon Valley was a place where people lived in isolation in terms of informal relationships, where people were less likely to help the poor and the elderly or to join a neighbourhood or civic group compared with demographically similar communities in the USA.

Furthermore, the cluster of software firms in cities is also associated with the values of materialism that are prevalent in cities. One shared quality of the founders in Firm A, Firm B and Firm C was their high achievement values; in a materialistic setting, money becomes an indicator of career achievement and high achievers are likely to challenge themselves in the pursuit of money. Indeed, the founder of Firm A mentioned that after some of his friends made their fortunes by selling off the firms they created, he simply used them as role models and wanted to see if he could be as successful. In such a sense, the values of consumerism and materialism are conducive to the growth of software industry.

Conclusions

This exploratory paper attempts to shed light on the success of indigenous software industry in Boston, London and Dublin with the notion of tacit knowledge spillover. Tacit knowledge is significant in knowledge intensive industries, and the fact that tacit knowledge cannot be codified and formalized means that its spillover is confined by geographical distance and proximity. This paper has explored the role of formal and informal knowledge spillovers in cities towards innovation in software firms and provided preliminary evidence that allows for some tentative conclusions. As the

spillover of tacit knowledge from the higher educational sector and the knowledge intensive sector is significant in relation to the innovation process of firms within the industry, cities that are endowed with human capital and information infrastructure but lack efficient or sufficient ways for transmitting knowledge would hamper the growth of software industry. It has been pointed out that the approach in this paper did not cover the creativity element in software; nevertheless, characteristics of cities such as quality of life and individualism and the value of materialism might reinforce creativity and support the growth of the industry.

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Table 1: Sampled questions used in personal interviews

1. How did you create your firm?

2. Why is it located in Boston/London/Dublin?

3. What kind of experiences prepared you to start your firm?

4. What are the firm's product lines and what competitive advantages do they offer?

5. Who are your customers and where are they located?

6. Does the firm have relationships with local universities and industries?

Knowledge Spillovers in Cities: An Auction Approach. Victor Couture. â^—. University of California, Berkeley. This draft: 10 February 2015. Abstract: This paper proposes a micro-foundation for knowledge spillovers. I model a city in which free knowl-edge transfers are bids by experts to entrepreneurs who auction jobs.Â Consider a closed city with N inhabitants, a number X of which are experts who hold some knowledge, and a number E of which are entrepreneurs who can use that knowledge in production, so that X + E = N. Experts and entrepreneurs play a two-stage game: rst a meeting stage, then a production stage. At the meeting stage, experts learn their type and choose how much knowledge to freely transfer to entrepreneurs that they meet in the city. Knowledge spillover is an exchange of ideas among individuals. In knowledge management economics, knowledge spillovers are non-rival knowledge market costs incurred by a party not agreeing to assume the costs that has a spillover effect of stimulating technological improvements in a neighbor through one's own innovation. Such innovations often come from specialization within an industry. North-South Trade, Knowledge Spillovers and Growth by R. Falvey, N. Foster and D. Greenaway Abstract The endogenous growth literature has stimulated empirical research into links between trade and growth in general and international knowledge spillovers in particular. Results relating to the latter have been mixed and the issue of the appropriate construction of the spillover variable remains contentious. In this paper we develop measures taking account of whether knowledge is a public or private good in the donor and recipient countries, and include these in a dynamic panel model of growth.