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A dynamic model of Cyber-entrepreneurship and cluster formation: applications in the United States and in the Low Countries

Harry Bouwman [a,*], Wim Hulsink [b]

[a] *Faculty of Technology, Policy and Management, Delft University of Technology, P.O. Box 5015, 2600 GA Delft, The Netherlands*

[b] *Faculty of Business Administration, Erasmus University Rotterdam, P.O. Box 1738, 3000 DR Rotterdam, The Netherlands*

Abstract

Policy-makers and captains of industry in the Netherlands and Flanders have come up with plans, actions, and measures to stimulate innovation and entrepreneurship in the ICT-industries. Inspired by the vision and experiences with new business development and cluster formation in Silicon Valley, Route 128 and Silicon Alley, they seek to create indigenous technopoles in the Low Countries. Some of these new ideas and plans have recently been put forward: Amsterdam Multimedia Corridor, Louvain Technology Corridor, Flanders Language Valley, Twente and Dommel Valley. This paper seeks to address the following research questions: Is it possible to emulate the success of Silicon Valley in the polders of the Low Countries? And what are the preconditions for growing a Silicon Valley in the Netherlands and Flanders? In order to explain the path-dependent rise of ICT-technopoles in general, a dynamic model is presented and discussed. Furthermore, analyzing and comparing the aforementioned ICT-clusters in the Netherlands and Flanders validates the model.

1. Introduction

The geographical structure of high-technology industries is often very concentrated, with a multitude of linkages between core firms, their spin-offs and local subcontractors, top-class universities and research centres, and local/regional

* Corresponding author. Tel.: +31-15-278-80-69; fax: +31-15-278-79-25.

E-mail addresses: h.bouwman@tbm.tudelft.nl (H. Bouwman), whulsink@fbk.eur.nl (W. Hulsink).

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authorities. Probably the most inspirational and well-known clusters in the field of Information and Communication Technologies (ICT) are Silicon Valley, Route 128, Massachusetts and Silicon Alley (New York). All of them are based on the spontaneous cross-fertilisation between local universities and research laboratories and established high-technology companies through dominant practices such as subcontracting non-core business activities, partnering in research and product development, permanent intra- and entrepreneurship, and practising knowledge diffusion by job-hopping and the creation of spin-offs.

In everyday practice, politicians and civil servants, entrepreneurs and investors, development companies and knowledge centres concern themselves with the significance of information and communication technologies to local and regional developments. They are especially interested in the growth and development potential of local and regional economies and the possible positive effects on employment. Usually, Silicon Valley is seen as the example. The inspiration and imitation of Silicon Valley even makes people refer to its name, as for example in Silicon Alley (New York), Silicon Forest (Seattle), Silicon Hills (Austin-San Antonio), Silicon Dominion (Washington, DC), Silicon Valley (Fairfield, Iowa), Silicon Fen (Cambridge, GB), Shalom Valley, also called Silicon Wady (Israel), Silicon Plateau (Bangalore, India), Multimedia Super Corridor (Malaysia) or Silicon Valley on Ice (Oulu, Finland). Finally, we see the same kind of names in the Low Countries as well: Silicon Polder (referring to the Low Countries in general), Amsterdam Alley, Dommel Valley (Eindhoven, the Netherlands) and Flanders Language Valley (Ypres, Belgium), nowadays also known as S.AI.L Port Flanders. It is often unclear what is the unique character of the developments in some of these areas, in some cases it is more or less obscure (e.g. Multimedia Super Corridor, Malaysia). Other areas follow their own paths, such as for instance Oulu in Finland, Sophia Antipolis in Nice (France) and Hsinchu Science Park in Taiwan. Many analyses focus on the reasons why these areas are successful in building an innovative ICT-cluster within a certain region (e.g. Braczyk et al., 1999; Cooper, 2000; Druilhe and Garnsey, 2000).

In this paper, which deals with the potential of ICT-regions in the Netherlands and Flanders, we describe a cluster as the geographical concentration of mutually interdependent companies with vertical as well as horizontal, and with co-operative as well as competitive relational patterns, companies that in addition operate within the same branch or on the basis of the same basic technology (Jacobs and De Man, 1996). When clustering takes place within high-tech sectors (e.g. biotechnology, information technology, new materials), other terms that are being used are 'technopole' (Castells and Hall, 1994) and 'technopolis' (Smilor et al., 1988). To describe the growth of successful techno-industrial-scientific complexes (e.g. technology parks, science cities, and techno-industrial districts), Castells and Hall (1994) have introduced the concept of *technopoles*. The concept refers to "various deliberate attempts to plan and promote within one concentrated area, technologically innovative, industrial-related production" (Castells and Hall, 1994, p. 8). There have been various attempts to create and develop *technopoles* all around the world. Such a policy serves

three purposes (Castells and Hall, 1994): to develop new industries as a national policy, to regenerate a declining or stagnant region, and to develop a milieu of innovation. Those objectives are pursued through furthering collaboration between leading research universities, corporate laboratories, core firms with their subcontractors and spin-offs, and venture capitalists. Another related concept relevant to understanding dynamic techno-industrial districts is *milieux of innovation*, defined by Castells and Hall (1994, p. 9) as "social, institutional, organisational, economic and territorial structures that create the conditions for the continuous generation of synergy, (...) both for the units of production that are part of the milieu and for the milieu as a whole".

In this paper, we will talk mainly about regional clustering (Brusco, 1982; Becattini, 1991; Best, 1993; Scott, 1994; Saxenian, 1994) in general, and more specifically about clustering within the context of Internet and multimedia technology (Braczyk et al., 1999). In *Silicon Valley in the Polder* (Bouwman and Hulsink, 2000), we dedicated, in addition to a number of chapters on emerging ICT-clusters in the Netherlands and Belgium, a section on the analysis of internationally well-known *milieux of high-tech innovation*. One example is found in Boston, also known as Route 128, after the highway along which the principal companies are located (Raytheon, DEC, etc.) (Rosegrant and Lampe, 1992; Saxenian, 1994). Others are Silicon Valley, the region between San Francisco and San José (Rogers and Larsen, 1984; Saxenian, 1994; Kenney, 2000; Lee et al., 2000), and Silicon Alley, situated in Manhattan, New York, where Internet and e-commerce companies are concentrated (Coopers and Lybrand, 1997; Pavlik, 1999; Heydebrand, 1999; PriceWaterhouse-Coopers, 2000). The analyses of these technopoles in the United States and the emerging ICT-clusters in the Netherlands and in Flanders, as well as in other places, along with a number of specific concepts, such as the role played by incubation centres (e.g. the Twinning centres in the Netherlands), venture capitalists and change agents, have led to a dynamic model for the analysis of ICT clustering. This model will be used in this paper to provide a critical description, analysis and comparison of a number of ICT-clusters in the Low Countries. First of all, an introduction and discussion of the model is given.

2. A dynamic model for ICT clustering

The achievement of a lasting concentration of economic activity within a certain geographical area depends on a number of aspects. One may think of technological innovations and the role played by knowledge centres, the degree of entrepreneurship, company networks and other institutions, and a shared culture where collective learning and mutual trust are essential. Smilor et al. (1988) have introduced a conceptual framework to describe the process of high-technology development and economic growth in a techno-industrial district. Their *technopolis wheel* reflects the interaction of seven major segments in the institutional make-up of a technopolis:

the research university (e.g. knowledge centres, natural sciences, engineering, business), large technology companies (key establishments: headquarters and relevant branches, major sales and/or R&D, major employer), emerging companies (academic and corporate spin-offs, specialised suppliers), governments (local, national, federal) and support groups (chambers of commerce, trade platforms) (Smilor et al., 1988). The segments of the wheel are linked by key influences that make things happen for the entrepreneurial region (e.g. lobby for the location of government research establishments, attract foreign direct investments, and promote the area's quality of life).

In our model the following aspects play a role: innovative ideas and concepts, high-tech entrepreneurs, the clustering of supply and demand, the creation of technology networks, the clustering of investors, local authorities and knowledge centres, socio-institutional embeddedness, and increasing returns (chance & necessity) (see Fig. 1). In our attempts to combine these seven elements we find that it is nearly impossible to represent the complex dynamics involved. Not only is there a multi-level problem, but there are also complex feedback relationships, mutual relationships between the actors, relations between the elements of a network, relationships between parties and resources, and relationships between the variables that have to be explained and the variables that will help explain them. Some rela-

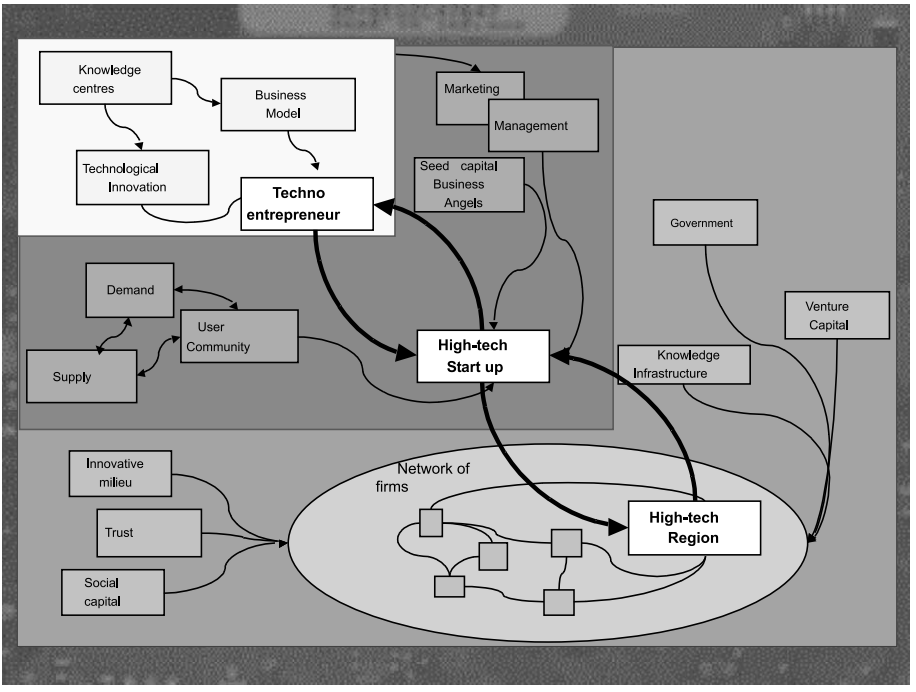

Fig. 1. A dynamic model of Cyber-entrepreneurship and cluster formation.

tionships represent path dependency, others merely the input of a necessary resource or a dependency in time. It is possible, however, to deduce a number of relevant criteria that will help determine to what extent a region can be considered a high-tech region.

Notwithstanding all this, the wheeling and dealing of entrepreneurs and venture capitalists, the continuous creation of start-ups and the high level of workforce mobility, produce a rich network containing a large and varied number of actors. Within that network there is a process at work of increasing returns, a continuous growth of capital, information, creativity and entrepreneurial talent that is available for reinvestment (Krugman, 1991; Arthur, 1994). Important parts of the process are talent recruitment, workforce mobility and spin-off creation. The floatation of Lernout & Hauspie and the FLV Fund meant that successful entrepreneurship and popular capitalism in the Flemish Westhoek region was rewarded and that, in addition, the proceeds of their initial public offerings in 1995 and 1996, and in 1998, respectively were reinvested in the region (e.g. expansion of the technology park and participation in young local companies). New technologies and (nascent) entrepreneurs meet when employees (alone or with others) leave a large company or university to start their own company. This kind of spin-offs usually is about further developing and marketing new technologies, for which the organisation that the budding entrepreneurs have left gave them insufficient room. The large majority of starters in Silicon Valley are spin-offs, and that process feeds and rejuvenates the high-tech cluster.

2.1. Innovative ideas and business concepts

Any region wanting to be seen as a high-tech region will have to pay attention to a specific technology or a set of key technologies (Roberts, 1991). An important element in the promotion of regional development is, therefore, the presence of top class knowledge centres and research universities (Castells and Hall, 1994; Slaughter and Leslie, 1997). In addition to achieving academic and scientific pre-eminence in basic research, these R&D centres should create and develop new technologies and applications for emerging industries and large established businesses. Furthermore, an ambitious university should attract the best scientists, engineers and best students in order to have an outstanding regional knowledge and talent pool at its disposal. When successful in (more) applied research, the R&D centre may succeed in churning out homegrown inventions and academic spin-off companies and attract large non-indigenous firms. In addition, both the transfer of technologies and business ideas and the various processes of sharing them, are essential. The acquisition of talent and technologies from elsewhere, licensing and other partnering agreements between universities, large companies and small firms, and job mobility, all contribute to a innovative milieu on campus where new ideas and innovative concepts float around in a kind of primordial soup.

Simultaneously, however, some technologists and engineers, may see commercial opportunities for the capabilities and technologies developed. Start-up companies

and small businesses are exceptionally capable of translating innovative ideas and concepts that are being explored within the knowledge institutions into products that can be further exploited in the marketplace. Research universities and large technology corporations may then act as incubators or seedbeds for potential and/or nascent entrepreneurs, who appropriate the shared knowledge and are selling or licensing it for their private benefit (Roberts, 1991). Leading research institutions provide an ideal environment for entrepreneurs to spot opportunities in the knowledge pool and eventually commercialise innovative ideas, technologies, products and new business models for Internet services, web content and e-commerce applications. Before the final phases of technological invention and a successful diffusion of the innovation can be accomplished, there is the initial process of ideation, which transforms the outcomes of basic scientific research into the testing of solutions (e.g. prototyping) (Winston, 1998). For instance, the large-scale availability of the microcomputer in the late 1970s (as pioneered by Apple) was critically dependent upon the invention of the central processing unit by Ted Hoff in 1969, which would in turn not have been possible without the integrated circuit prototypes as developed by Jack Kilby (Texas Instruments) and Robert Noyce (Intel) in 1959. The underlying knowledge infrastructure (e.g. silicon, germanium, radar, transistor) supporting those inventions and technologies had been provided in the late nineteenth and early twentieth century in universities and research laboratories (e.g. Bell Labs, National Physics Laboratory and University of Birmingham) (Winston, 1998).

2.2. High-tech entrepreneurs

High-tech entrepreneurs and start-ups play a crucial part in the innovations in the ICT arena. Whiz kids and engineers translate fundamental technological developments into marketable products and services. Large vertically integrated firms have great difficulties in judging their technological advantage on its proper merits, or making it marketable (e.g. Xerox or Philips). Although these companies have a large number of innovations to their names (for instance the computer mouse, graphic interface, VCR technology, CD-i technology, HDTV), they have not been able to turn them into commercial successes. Start-up firms, often spinning out from universities and research laboratories, are characterised by their strong interest in new technologies, and they are very alert to any interesting possibilities and opportunities in the marketplace. An effective translation of an idea into an ICT or Internet company depends on the success with which the new product or service is exploited commercially. Although technological expertise and inventiveness play a crucial role for a majority of starters, an excessive focus on making the technology as perfect as possible does not make for a successful high-tech start-up (Nesheim, 1997). Successful start-ups must not only qualify in terms of technology. Management skills and marketing expertise are essential. Involvement of a person with experience in starting and building a company will have a positive impact. What is interesting to see here is that there is a group of people who have specialised in starting and

building up companies. Jim Clark, for instance, after founding Silicon Graphics and Netscape, has recently started a third company called Healtheon. This phenomenon is also known as serial entrepreneurship. These permanent entrepreneurs are fully aware of what awaits a vulnerable company: not only do they have a proven track record (which investors find very important), they also provide a network of head-hunters, law firms, lease companies etc., which is necessary if a new firm is to outlive its growing pains (Elfring and Hulsink, 2000).

2.3. Clustering of supply and demand

It is important to keep in mind that innovation within companies is above all initiated by customers, users and suppliers (Scott, 1994; Saxenian, 1994). As far as the suppliers are concerned, we can see a concentration of high-tech and start-up companies around locations where a similar companies are already located. Also the geographical proximity of universities, technical colleges, financial institutions and infrastructural hubs, allowing the new technology-based firm access to critical resources, will help determine the location. It can hardly be called shocking to find that many high-tech companies or ICT service providers form clusters around areas where there customers are located, such as defence institutions, financial and service companies, the media and advertising sector (for instance in New York) or near large companies (e.g. either supplier, distributor or customer) in their sectors. Silicon Valley and Silicon Hills (Texas) were finally recognised as technopoles by large companies and the American federal government when IBM and Xerox decided to locate their key research establishments in San José and Palo Alto, and the research consortia MCC and Sematech chose Austin as their home base. Developments with regards to the demand for new hardware and software especially take place around commercial centres and the high-tech areas themselves. Silicon Valley illustrates the move from being a core centre in semiconductors and personal computers towards the commercial and media branches and the possible convergence of content, hardware and software, and the increased significance of electronic commerce.

2.4. Clustering of companies: the creation of technology networks

Techno-starters do not operate in a vacuum and bringing about innovations is not a solitary activity. As a rule, in Silicon Valley successful start-ups take part in more or less decentralised production networks, where lasting and mutual transactions take place between large flagship firms and specialised companies (Saxenian, 1991). An example of a long-term trust-based production network can be found at Apple. Their network consists of specialised suppliers, for instance of switches, software, disk drives, microprocessors or keyboards, and Apple itself is responsible for the design and marketing, the manufacturing of core components and the assembly of computers. The economic activities of technological companies are embedded in

social networks in which small and large companies have made long-term commitments and interaction takes place in more or less informal structures (Grabher, 1993). The contacts that entrepreneurs make or already have offered them opportunities and possibilities, but also pose a restriction to them as a result of obligations and competitive pressure (Burt, 1992).

There are a number of reasons for the emergence of networks within the ICT sector: a shortening of the product life cycle (a need for shared knowledge development), the minimisation of R&D and production costs, the need for system integration in a converging market, the concentration on core competencies and the contracting out of peripheral activities, and an increased say in standardisation processes (Nohria and Eccles, 1992). In this strategic process there are considerations that have to do with an increase in companies' internal efficiency as well as purely strategic aspects: what market will be chosen, what partner will be selected to enter that market and what will be the nature of the co-operation (cross-licensing, joint R&D, joint venture, etc.). The type of network can be seen as a deliberate choice by management, made to increase the strategic flexibility and responsiveness of the core companies and to help carry through product and/or process innovations (Quinn et al., 1997). Leading ICT firms as well as high-tech start-ups, try to follow a kind of spider's web strategy, in that they try to develop and maintain direct and (almost) exclusive relationships with satellite companies from the strategic centre where the core company is located. In this strategic web of hardware suppliers, software programmers, application developers and advisors investments have been made by the core company, often in the shape of (minor) equity stakes in preferred suppliers and spin-off companies, a joint information system and shared knowledge and co-manufacturing between the core company and its satellites.

2.5. Clustering with investors, local authorities and knowledge institutions

In the early phase the financing of the new companies tends to be haphazard and opportunistic. More often than not, start-ups rely on the savings or mortgage of the founder(s), contributions by friends and relatives and/or a bank loan, depending on the need for capital. However, these funds may not be sufficient, and an appeal may have to be made to private investors, such as informal investors and venture capitalists. Whereas informal investors, also known as business angels, tend to favour start-up companies, venture capitalists invest in fast-growing companies on their way to maturity (i.e. stock market floatation or a traded sale of the company). In addition to capital, business angels contribute expertise with regards to investment and the management of technology companies. Venture capitalists are network brokers *par excellence*: they provide the missing links in the management of new companies. Through new contacts with clients, distributors and new management, they provide the young and vulnerable company with a broader techno-economic base and a greater degree of social legitimacy. All these activities by the venture capitalists, the

ongoing creation of spin-offs and the high labour market mobility together produce a rich network (Cohan, 1999; Kaplan, 2000). The outcome is a cycle of 'increasing returns' (Krugman, 1991; Arthur, 1994), a continuous increase in capital available for reinvestment. This approach allows start-ups to keep increasing their opportunities. If this is not (yet) taking place, other financiers have to provide an impulse. Government can play a stimulating part here. The Dutch central government, for instance, invests in the creation of Twinning incubation centres, whereby the availability of venture capital, housing and counselling is used to stimulate the emergence and growth of start-ups (Elfring and Hulsink, 2000). Regular subsidies are another way the government tries to contribute to technological innovation by stimulating companies to work together on pre-competitive R&D projects and creating an advanced knowledge infrastructure (Bouwman, 1999).

2.6. Social capital and mutual trust

In addition to the factors mentioned above, the availability of 'social capital' also plays an important part in the theory on regional development (Putnam, 1993; Fukuyama, 1995). Social capital refers to the complex of local institutions and trust relationships between local actors within a region, based on the historically determined local culture (Cohen and Fields, 1999). The horizontal networks between individuals, companies, collective organisations and institutions within and between which information is exchanged and resources are shared, and the trust on which the relationships are based, add up to the region's social capital. The availability of social capital has a strong influence on local politics and the economy, characterised by an open exchange of information between indigenous organisations in dense and overlapping networks and a high level of local/regional cohesion and reliability. Companies that have participated in the same horizontal networks will understand each other more quickly. The transaction costs of the co-ordination of economic activities are low: they do not have to face the bureaucracy and rigidity associated with the internalisation and (vertical) integration within a company's hierarchy or the dynamic and chaotic market, where every transaction requires a separate contract and where there are additional costs incurred in monitoring the parties' compliance (Best, 1993). The social capital and the (lack or presence of) mutual trust associated with it, may, in short, result in a competitive advantage. The lack or presence of this factor helps to explain the differences in regional productivity and innovativeness.

2.7. Chance and path dependency

When we look back on the relative successes of, for example, Route 128 and Silicon Valley, we are tempted to see these high-tech districts as the outcome of the vision and strategy of a leading technology university, visionary and driven entrepreneurs or of core businesses in a region (Saxenian, 1994; Kaplan, 2000).

Nothing could be further from the truth: one cannot plan the rise of successful clusters. Particularly in the early stages chance and fortunate coincidences have produced, for example in the case of Silicon Valley, a process of co-evolution of technology, market dynamics and institutions, that was to develop further along a path of innovation, depending on the influence of specific local circumstances (Krugman, 1991; Arthur, 1994; Kenney and Von Burg, 1999). With circumstances that will push the chain of events in a certain direction (thereby more or less excluding any alternatives), one may think of a dominant technology or branch, flagship firms, specific core knowledge institutions, the nature of the demand, and certain institutional arrangements facilitating the transfer of knowledge.

While these circumstances serve as a more or less successful breeding ground for regional entrepreneurship and cluster activities and for the structuring of the techno-industrial processes along certain trajectories, it is the spark of local initiative that is needed to start the fire of high-tech region formation. An initial combination of local entrepreneurship, chance, 'lucky success' and a positive feedback on business within the region will lead to a self-reinforcing and cumulative process of the location of several high-tech start-ups, their growth into independent knowledge-intensive businesses and the clustering of these core businesses with new companies (such as spin-offs and specialised suppliers), educational institutions and R&D laboratories. It is indeed a remarkable phenomenon that the accumulation of minor events and coincidences, that have a positive combined impact on the decision by companies and institutions where to locate within a certain region, should gradually lead to the concentration of an industry or branch in a specific region (Krugman, 1991). The presence of new companies and dynamic research institutes in itself has an additional appeal to a new generation of companies, professionals and institutions looking for a place to locate. At a certain point in time it is possible that the young and somewhat specialised high-tech cluster will reach a critical mass that will enable it to broaden its technological base or expand into new sectors.

3. A critical evaluation of the Valleys and Alleys in the Low Countries

The extent to which Dutch and Flemish ICT-clusters will be able to emulate the success of Silicon Valley and other regions can be assessed on the basis of the above-mentioned criteria. If we use these criteria to arrive at a preliminary qualitative assessment with regards to a number of existing local ICT-networks in the Low Countries, five regions stand out (Bouwman and Hulsink, 2000):

- The Louvain Technology Corridor, in which a central role is played by the Inter-university Centre for Micro Electronics (IMEC) and an entrepreneurial university (Catholic University of Louvain, CU Leuven).
- Amsterdam Alley, running from Hoofddorp, through the centre of Amsterdam, via the science and technology park Watergraafsmeer, to Hilversum, and containing a large variety of multimedia companies.

- Dommel Valley (Eindhoven), home of powerhouse Philips and a selection of spin-offs (e.g. ASML, Simac), that have by now achieved international success as well.
- Twente, a rising ICT-region, characterised by an entrepreneurial university, a number of large public research establishments institutions and company R&D centres, heavily subsidised by local/regional, national and European governments.
- Flanders Language Valley: also a developing cluster, around the speech and language technology company of L&H in Western Flanders (Ypres).

In our view, Eindhoven, Louvain and Amsterdam have a better starting position than Twente and Flanders Language Valley. The lack of large dynamic domestic companies that can serve as a regional catalyst (Twente), and the dependence on L&H, a company that has recently made less than favourable headlines (e.g. accounting irregularities, threat of litigation from disgruntled shareholders, a dramatic corporate restructuring) together with the lack of a central knowledge institution (Flanders Language Valley), give us reasons to believe that these regions face a less certain future than the other three, i.e. Eindhoven, Louvain and Amsterdam.

3.1. Amsterdam Alley

The Amsterdam-based ICT-cluster is characterised by the same unique combination of elements that can be found in Silicon Valley and Silicon Alley. Like Silicon Valley, Amsterdam Alley is technology-oriented. This holds true both for the knowledge infrastructure, which is centred around the government-funded Centre for Mathematics and Information (CWI) and the National Institute for Nuclear Physics and High Energy Physics (NIKHEF). Both institutes, together with the city's two universities' computer centre SARA, have been involved almost from the outset in the developments concerning the Internet. It is hardly surprising, then, that the link-up to the Internet's backbone (the Amsterdam Internet eXchange or AMSIX) is located on the premises of SARA and NIKHEF (physically speaking there are two co-location points). In due course a third collocation point will be opened. These two research centres have their premises at the Amsterdam Science Park (Watergraafsmeer); another relevant organisation located at the Science Park is the aforementioned 'Twinning', an incubator that is partly funded by the national government. Around 100 start-ups have already used the services of the Science Park.

An important spin-off of CWI-NIKHEF was NLnet, the first commercial Internet Service Provider (ISP) that started in 1982. By now, NLnet has become a part of MCI/Worldcom. In the early 1990s other ISPs like XS4ALL (set up by hackers) and Planet Internet (set up by graduates from the University of Amsterdam) followed in its footsteps. Since the liberalisation of the telecommunications market a number of large companies (among others MCI/WorldCom, Telfort/BT, UPC) and

small ones (among others Versatel, Colt Telecom, Global Crossing) have opted in favour of locating themselves in the vicinity of the financial district and the media and advertising cluster in and near Amsterdam. The telecommunications companies in turn attract other players. Cisco has chosen Amsterdam to establish its European headquarters because it wanted to be near one of its largest customers, namely WorldCom (apparently the No. 1 Internet company was also lured to Amsterdam by an attractive fiscal package). In addition, Amsterdam and its immediate environment houses such companies as Adobe, Nortel, PeopleSoft, Epson and @Home. According to the Amsterdam Chamber of Commerce, the total number of companies in the ICT-cluster in 1999 was 3705. At the more creative end, especially projects like the Digital City and activities surrounding the community centres De Balie (culture & theatre) and De Waag, where the Society for New and Old Media is located, have contributed to the familiarity and acceptance of the Internet in the early 1990s. All kinds of activities in the fields of culture and advertising have contributed to the creation of a whole new industry in Amsterdam: the multimedia sector. The presence of the Amsterdam New Media Association (www.anma.org), which brings together parties that are active in the area of new media and ICT in the Amsterdam region, stimulates the formation of a network of companies.

The sector is still young, and it is as yet hard to say anything about the number of companies, the number of employees or turnover statistics. There are indications, based on research conducted in 1998, that around 1300 companies are in some way active in the field of multimedia content production and distribution. The majority of the companies are also active in other areas. The number of 'pure' multimedia companies is limited. Turnover figures indicate that the multimedia sector contains a large number of small companies. Just over a quarter of the companies has a turnover (both from multimedia and other activities) of less than 70.000 Euro. The business model of these companies can be compared to the one used by dot.com companies in Silicon Alley. Larger companies are predominantly concerned with content and publishing. To provide an indication of the total turnover with regard to multimedia products and services, we have multiplied the average turnover by the number of companies in the multimedia sector. The result is a total turnover of over 450 million Euro. Almost 40% of that turnover is realised in the content phase, one sixth in the publishing phase, one seventh in the distribution phase and over one tenth in the user support phase. The remainder is related to research and consultancy.

3.2. Dommel Valley

Eindhoven likes to call itself *the* technopolis of the Netherlands. The reason for this is the presence of many international companies (Philips, ASML, DAF and NedCar), the high level of education among the professional population and the presence of knowledge institutions like the Technical University of Eindhoven, Fontys Polytechnics, Philips NatLabs, Microcentrum Nederland, TNO

Industries, The Design Academy and the European Design Centre. It is the region with the highest technological potential where a great deal of attention is paid to product innovation. Of the total national budget for R&D, 50% is said to go to this region (www.rede.nl). In international terms the region is very significant as well. The electro-technical industry is strongly represented in Eindhoven and the surrounding area: it is the (de facto) home base of global market leaders Philips and ASML. High-tech companies are also strongly represented: 25% of the region's companies fall within this category compared to a national average of 12%.

If we see Eindhoven as an ICT-cluster, we must recognise that Dommel Valley is dominated by a few large vertically integrated organisations. These organisations are inter-related. ASML Lithography and Simac have come from Philips. Apart from these two companies, Philips hardly produces any spin-offs at all. Philips is especially internally oriented and, as a consequence, its knowledge/technology transfer programme is limited: research activities and business development are concentrated on the Philips high-tech campus or carried out within the company and its many divisions. In Eindhoven, there are a few interesting multimedia companies such as Calibre, active in the field of interactive visualisation and simulation, Ilse, the Dutch search engine, currently owned by Amsterdam-based publisher VNU, Turpin Vision and Codim. The latter two are active in the area of digital animation production for CD-ROM and the Internet. In all, some 1200 companies are said to be active in the ICT domain. The majority of these companies, however, has a traditional profile and has emerged from the automation, graphic or marketing communication sectors. There are hardly any dynamics to speak of that have to do with starting companies around the Eindhoven-based ICT-cluster. For instance, the Twinning subsidiary, located at the campus of the Technical University, has great difficulties finding companies that are interested.

The question is what may be expected from Philips' high-tech campus, centred around its famous NatLabs, as a catalyst for the local economy. At first sight, it seems to be first and foremost an impulse for the internal R&D-activities of Philips itself. Co-operation with the Technical University of Eindhoven, the concentration of the number of employees and the influx of (international) talent mean that one of the conditions for the creation of a successful cluster is apparently met. However, the other two aspects, a supporting infrastructure and network dynamics, are less evident. There is no highly developed network in which start-ups can participate. The region's key player Philips is dominating existing networks too much. Although there are investors and investment companies active in the region and both the local investment company NV Rede and the incubator Twinning have a VC fund, these opportunities are hardly used by starting companies.

3.3. Twente

Twente's ICT-cluster can be characterised as an R&D-cluster. The number of organisations for which ICT is an important part of business is around 200. In 1997, around 6000 people were employed in Twente's ICT-sector (including the knowledge

institutions). Around 40% of these are working at a limited number of institutions,namely at (parts of) Signaal, Ericsson and the various knowledge institutions (Twente Polytechnic, the Telematics Institute and the University of Twente). The ICT value chain is fairly balanced. It contains network owners (for example, KPN and CasTel), hardware manufacturers (for example, Fluke Industrial BV), developers of telecommunications equipment (for example, Ericsson and De Haar Telecom) and software producers (for example, V&L, Matrix and Origin). Many small ICT-companies that have emerged from the knowledge infrastructure are growing very rapidly. The role played by the knowledge infrastructure is a large one, not only because of the presence of the knowledge institutions mentioned earlier. There is also a large number of companies that have opened an R&D subsidiary in the vicinity of the University of Twente (close to Enschede); examples of these are CMG-Telecommunications, Lucent Technologies, TNO-FEL and KPN-Research. The emphasis, therefore, is on research, design and development.

There is no clearly defined user community in Twente, although organisations like the Foundation Teleport Twente, the Technology Circle Twente and the Twinning Centre (their third subsidiary) do play a modest role. The engines behind developments in the area of ICT are especially the university, the Overijssel Development and Investment Company (OOM), the municipality of Enschede and the Province of Overijssel. Some of these parties are involved, for example, in the development of NDIX, the Dutch–German Internet Exchange. Other relevant initiatives are:

- The Temporary Entrepreneur Places scheme aimed at helping starting entrepreneurs to build their company. In 1999, 35–40 companies started with the help of this scheme. Around 40% of the companies were active in the field of ICT. Knowledge diffusion from science to the business community is an important objective.
- The Technological Spearheads project, aimed at attractive high-quality technological companies, a project that fits in with the university's technological spearheads. The companies are being located at the 'Business & Science Park', or in the immediate vicinity of the university. One of the spearheads is telematics (next to laser technology, biomedical technology and microsystems technology).
- The *Palo Alto project* is aimed at matching companies from Twente with companies from Palo Alto (Twente's Californian twin town) to exchange knowledge and technologies and to do business. Thanks to this project co-operation takes place between OVSoftware (Almelo) and the American Hansen Information Technologies.

Although there is a wide variety of activities to stimulate ICT in Twente, there is no coherent vision to connect the various initiatives. It is true that a large number of parties are taking part, but there is hardly any co-operation between them. Fur-

thermore, the (lack of) availability of venture capital and experienced (general) managers is also a bottleneck for the Twente region.

3.4. Louvain Technology Corridor

The pivot in the Louvain innovation network is the Catholic University of Louvain (CU Leuven) and IMEC, the Inter-university Centre of Micro-Electronics linked to the university. In addition to being an internationally renowned knowledge centre, KU Leuven has also become known for its active policy with regards to academic entrepreneurship and the transfer of knowledge. Tangible examples of this are the creation and exploitation of a large science park, several innovation and incubation centres and a subsidiary for licensing and contract research. The Louvain region is a fertile breeding ground for young and innovative companies: in the course of time KU Leuven has produced nearly 40 spin-offs, a number of which have entered the stock-market (for example, ICOS Vision Systems Netvision/Ubizen), and all of which are located on campus. In the commercialisation of knowledge through spin-offs and important role is played by two venture capital funds that KU Leuven has established with, among others, private financial investors Fortis Bank, GIMV and KBC: the ICT venture fund IT-Partners and the generic Gemma Frisius Fund. Finally, also active within this techno-academic region is the L.Inc platform (Louvain Innovation Networking Circle), which aims at building a bridge between innovative entrepreneurs, consultants, financiers and various intermediary organisations (e.g. accountancy & consultancy firms) in Flemish Brabant. Apart from KU Leuven and IMEC, there are a number of commercial parties, the City of Louvain, the regional Chamber of Commerce and the local utilities company that are involved in expanding the L.Inc project.

Since its foundation in 1984, IMEC has built its own impressive technology portfolio and, in addition, has attracted a close group of leading research organisations and international contract partners in the field of microelectronics. In 1999, IMEC's total budget was 80 million Euro (a third of which was provided by the Flemish government), with contract research reaching 40 million Euro. In close cooperation with large ICT-companies and organisations such as Philips, Alcatel, Agfa, ASML and Sematech, IMEC has established a variety of specific research and training programmes. The presence of these multinational companies has to compensate for the lack of a local core company. The other conditions for a successful high-tech cluster have been met reasonably well. KU Leuven, the intellectual powerhouse with its large educational variety, produces highly trained people; as a consequence the supporting network can be characterised as adequate. A significant contribution to the necessary network dynamics was made by the creation of the Digital Signal Processing Valley (DSP) in 1994. DSP was established by IMEC and a number of its partners and spin-offs to create a catalyst for the use of digital signal processing technology in new applications, and the creation of a new generation of start-ups. In addition to creating spin-offs (some 20 companies that are still in

business), IMEC's activities are aimed at attracting foreign expertise and investments in the field of microelectronics in the Louvain region. Since it was founded, DSP Valley has grown considerably: the number of companies participating has risen enormously and the number of DSP experts in the region went up from 350 in 1994 to around 1200 in the year 2000.

3.5. Flanders Language Valley

In November 1999, the technology park *Flanders Language Valley* (FLV) was officially opened. This centre, situated in a rural environment near Ypres in the Westhoek region of Belgium, was established to attract and combine knowledge, talent and investment in the field of speech and language technology. The FLV campus, designed in the shape of a human ear (the symbol for communication), houses an education centre, auditoriums, offices and laboratories for starting and established companies and a service zone with, among other things, supporting knowledge institutions (of local universities and polytechnics) and a large number of service companies (among other things, a bank, an employment agency, a restaurant and a child day-care centre). At the centre of this extensive network is one of the world's leading companies in the field of speech and language technology, Lernout & Hauspie Speech Products (L&H). This company, originally found by two entrepreneurs from the Westhoek-region, Jo Lernout and Pol Hauspie, experienced a difficult pioneer phase between 1987 and 1994, but has grown into a 'high-tech flyer' listed at the New York (NASDAQ) and Brussels (EASDAQ) stockexchanges. At the end of 2000, the company employed around 5000 people and had offices in a number of European and Asian countries as well as the USA. L&H, with a market capitalisation of around $2 billion, in 1998 realised a turnover of $212 million, at a profit of $38 million. [1] L&H develop a range of products for speech and language technology in several languages and for all types of processor. Their products include automatic translation devices, dictation systems, various speech control applications, advanced applications for browsing the Internet and software designed to compress speech. L&H is one of the few long-term success-stories in the European ICT-industry. Since 1994, the company has continually doubled its yearly turnover (after a spate of aggressive acquisitions), and it

[1] Between August and October 2000, the company came under attack from business journalists (especially by the Wall Street Journal Europe!), quickly followed by auditors, and institutional investors and other shareholders complaining about allegedly creative bookkeeping. After a thorough investigation by the SEC/NASDAQ, EASDAQ and an internal audit by KPMG in November, the company admitted severe accounting irregularities and is now facing threats of litigation from disgruntled shareholders. After a boardroom shuffle and a profit warning, together with the pending investigations, the future of the once leading and independent provider of voice and language technology is looking bleak.

is in business with both Microsoft and Intel (both companies hold minority stakes in L&H).

L&H is strongly rooted in its region of birth, and its headquarters and extensive R&D-activities are located there. In addition, L&H is the core company of the Flanders Language Valley (FLV), where at the end of 1999 nearly 20 specialised suppliers, distributors and customers of L&Hs technologies, have established themselves. A number of other partners have promised to move into the FLV business park in the foreseeable future. An important role in attracting investments to the technology park and promoting local knowledge transfer and technological dynamics is played by the FLV Fund, which specialises in investments in speech and language technologies. In addition to the presence of L&H as a technology developer, the expected synergy between L&H and its business partners in the development of new applications and the availability of business support and incubation services (as provided by the FLV Foundation), this FLV Fund, as the provider of venture capital, is the fourth leg of the regional innovation system of speech and language technology. In addition to all this, Jo Lernout and Pol Hauspie are now actively involved in the exportation of the FLV concept. In November 1999, it was announced that an international network of nine centres of excellence would be constructed around Flanders Language Valley (by now renamed SAIL Port Flanders), designed to stimulate world-wide technologies in the field of *Speech*, *Artificial Intelligence* & *Language* (S.AI.L) technologies.

Until recently the pride of 'High-tech Flanders', L&H has become the 'pariah' of the international stock-markets. The two entrepreneurs from Western Flanders have succeeded in building a local cluster of partner companies and knowledge institutions around the company in Ypres. In addition, the company was in the process of building an international network of local clusters. However, recent problems with foreign investors in the fall of 2000 are extremely unwelcome. It is not unthinkable that L&H will be taken over by large international competitors such as IBM, Oracle or Philips, or that its non-exclusive partner Microsoft will take the company under its wings. If that should happen it remains to be seen whether the intended campus around L&H and the industrial area attached to it will ever be completely filled. Partly as a result of imploded stock prices, commitment among L&Hs employees will decrease (share options have lost their value already) and people will start to vote with their feet, thus rendering the company's recovery process de facto impossible. The high-tech flyer from the Low Countries was expecting to be in for a rough flight, but now faces serious turbulence, and is bracing itself for a rough landing (see Table 1).

4. Conclusion and discussion

We have briefly described a model that can be used to describe and evaluate the dynamics of ICT-cluster formation. Based on the model we assessed five clusters,

Table 1
Comparing high-tech regions in the Low Countries (based on Bouwman and Hulsink, 2000)

	IMEC (Louvain's Technology Corridor)	Flanders Language Valley (SAIL Port Flanders)	Amsterdam Silicon Alley	Dommel Valley (Eindhoven)	Twente
Techno-entrepreneur	More than 40 CU Louvain spin-offs (18 from IMEC)	18 Firms	100 Start ups	Small number of start-ups	54 Start ups (TOP: temporary entrepreneurship position provisions)
Technology, knowledge, innovation	IMEC chip technology (digital signal processing)	Speech & language technology, artificial intelligence	Multimedia, content, electronic commerce	Consumer electronics; chips, language & display technologies	Software & knowledge management technology, middle-ware applications
Business models	Hard and software production (niche/ focus)	Software	Content related	Hardware	Focus on research, design, and development
Start-up					
D = demand	D: industrial partners (e.g. Philips, Alcatel, Agfa)	D: L&H & business partners (Microsoft, Intel)	D: Advertising & media companies (content), financial services	D: Philips, ASML, Simac, etc. (1200 ICT companies)	D: not clear (intra-corporate R&D (Ericsson, Lucent, Philips AXR)
S = supply	S: IMEC as independent R&D laboratory & incubator	S: dedicated start-ups (speech & language technology)	S: 135 specialised multimedia (MM) firms, 1300 firms active in the field of MM	S: small number of new technology-based firms	S: 200 ICT firms
User community	Partnership & Affiliation programmes; collaboration with Flemish firms	Fellow researchers (SAIL labs), local universities (CU Louvain, Ghent University)	Clustering around AMSIX; telecom companies Telfort, MCI Worldcom, XS4ALL; e-commerce start-ups (Lost Boys)	Large users ((Philips), TU Eindhoven)	Teleport Twente Foundation; Technology Circle Twente; Twinning centre

Marketing & management orientation	Part of CU Louvain (e.g. Louvain R&D)	Not yet specified	Business economics (University of Amsterdam, Free University of Amsterdam)	Technical Business Engineering (TUE)	Twente School of Management
Start-up capital	Private, venture Fund CU Louvain	Private, business angels (e.g. Lernout, Hauspie)	Private	Private	Private, TOP provisions
Trust & social capital	Local: (Louvain Innovation Networking Circle); international: through partnership & residentship programmes	Local bonds (Westhoek); international professional orientation (alfa informatics)	Amsterdam New Media Association (ANMA); Society for Old and New Media	RED: Region Eindhoven Digital EMMA: Eindhoven MultiMedia Association	Local orientation, alumni University Twente;
Innovative milieu	Academic entrepreneurship (national)	L&H's webstrategy: patents, licensing, partnering	Fast follower of American (e.g. NY) trends, original marketing	Innovation, R&D within companies (Philips, ASML)	Entrepreneurial university (regional)
Knowledge infrastructure	CU Louvain, Gand University, FU Brussels/ULB, corporate R&D Labs (Philips, Telinfo)	Virtual network of international universities (USA, Japan)	University of Amsterdam, CWI (National Centre for Mathematics & Computer Science), NIKHEF, RIPE	TU Eindhoven Philips NatLab	Twente University (CTIT, TSM), Telematics Institute; KPN research, TNO-FEL
Government	Flemish government; municipality of Louvain	Flemish & local governments	Municipality of Amsterdam	Municipality of Eindhoven, ReDe (regional development company)	Provincial authority of Overijssel
Venture capital	IT-Partners, GIMV	FLV Fund, GIMV	Twinning	Twinning; VC-fund NV Rede	Twinning
Network-development	Attracting foreign investors; commercialising science parks (CU Louvain)	Attracting local investments; rolling out 10 international SAIL Ports (withdrawn in 2000)	Attracting foreign investments (e.g. Cisco, Worldcom)	Promotion needed subcontracting (Philips, ASML)	Location of R&D centres and businesses (regional & national)

namely Dommel Valley (Eindhoven), the Louvain Technology Corridor, Flanders Language Valley, Amsterdam Alley and Twente. Until now we have used qualitative data to assess the potential of these five regions in the Low Countries. The results as presented in this paper are promising and ask for further, more quantitative validation of the model. We have to conclude that the (further) growth potential of Twente is as yet unclear. Twente is a developing region where basic research and corporate R&D play an important role, above all stimulated by a promising knowledge infrastructure (a number of large technology institutes and companies' research laboratories), but it is presently handicapped by its peripheral location and a conservative local culture. There is also a lack of important core companies, key venture capital firms and informal investors that could serve as a catalyst to the region.

Eindhoven and Amsterdam would appear to have better chances of becoming successful high-tech clusters. Dommel Valley is dominated by one large and vertically integrated company (Philips), which may have at its disposal high-quality expertise, but which does not market its technologies and products to their full potential. In addition, regional-economic dynamics are limited, and there is relatively little outsourcing taking place within the ICT-domain, there is little co-operation with suppliers, and the number of spin-offs from the mother company is low. The spin-offs that do take place are very successful. Based on our initial assessment we must conclude that Amsterdam has a good chance of becoming a successful high-tech cluster, especially thanks to the strong emphasis on innovation (both in terms of technology and services), the presence of (highly) educated professionals, an advanced supporting infrastructure and the presence of large foreign ICT-players in the region. With the exception of venture capital, which has hardly found its way to Amsterdam, and the availability of successful entrepreneurs that can serve as role-models and informal investors to the new generation, Amsterdam Alley faces an optimistic future.

Both high-tech locations in Flanders until recently certainly had it in them to evolve into international specialised technology regions. After the collapse of Lernout & Hauspie (L&H) and the Flanders Language Fund, the momentum of the Flanders Language Valley has subsided, leaving a question mark over the future of the core company of L&H, the local speech and language technology-cluster and the dynamic Flemish Westhoek region. The evolution of the core company L&H in the Flanders Language Valley offers a perfect illustration of the law of increasing returns: while the company in its successful growth and expansion period benefited from a 'virtuous circle' (*success breeds its own success*), in its current crisis the company seems to be faced with a 'vicious circle' (*if things go wrong they really go wrong*). For the region as such the slimming down of L&H does not necessarily have to be a bad thing: the failure of Shockley and Fairchild in the 1950s and 1960s helped create a new generation of core companies in Silicon Valley (i.e. Intel and National Semiconductor). For the Flemish region it might even turn out to be a blessing in disguise, if former L&H employees move to smaller local partner companies or even start their own companies. This way,

the region would be less dependent on a single large company. The Louvain Technology Corridor has a number of interesting elements that make the region 'promising': an innovative university that is not only part of the European elite in a number of areas, but that also actively promotes entrepreneurship and the transfer of knowledge. However, the Louvain Technology Corridor lacks a certain balance. Whereas IMEC, with its international and local research partners, has developed a successful mini-cluster around microchip technology (i.e. DSP Valley), business networks around other key technologies are as yet insufficiently developed.

An interesting new combination could be the cluster of Louvain and Eindhoven that crosses the Belgium-Dutch border. These two regions, that are already connected with regards to microchip technology through Philips, ASML and IMEC, offer a greater potential for synergy (among other things, a favourable business climate for starters and a leading core company that can serve as incubator and as leading edge customer). It would, therefore, be interesting to map further the current state of affairs with regards to the interweaving between Eindhoven and Louvain and to analyse the synergetic potential that exists between Dutch and Flemish Brabant. Together, these two regions have the potential to evolve into an internationally successful cluster. Will the Low Countries, with the relative success of Amsterdam and the potential of Eindhoven and Louvain, see the dawning of another Golden Age?

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