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The technological, economic and institutional aspects behind the development of biotechnology industry in Turku region, Finland

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Abstract

This paper examines the recent development of biotechnology related industry in the Finnish city of Turku. The basic aim of the paper is to identify the different technological, economic and institutional factors that have enabled the rapid development of the biotechnology industry. From a regional point of view the paper tries to bring forth the factors that have activated the local community to actively pursue the development process and how this process compares with similar processes elsewhere. Lastly the present state and future challenges of the local industry concentration are analysed briefly.

Keywords: innovation system, biotechnology, Turku, Finland, technological transition, regional development

Introduction

Turku is situated in the southwest corner of Finland and has a population of approximately 250,000 people, if we generously count n not just the city itself, but the region around Turku comprising the towns of Salo, Kaarina, and Raisio etc. The city of Turku city itself is a population of 173,000. Turku is 160 km west from Helsinki and 320 km by sea from Stockholm. Throughout the history, the city has been one of the major ports in Finland and especially connections with Sweden have been dense. The traditional industries in the city have been metal work, shipbuilding, real estate services and construction, food and pharmaceutics and graphics/printing.

This paper examines the recent development of biotechnology related industry in Turku. The growth of biotechnology related activities has grown rapidly and especially pharmaceutical industry has adopted the use of post-1970s molecular biology breakthroughs in "biotechnology". Finland is now listed in numbers of biotech firms as the 7th largest in Europe (Ernst & Young 2001) and Turku is the second biggest concentration of biotechnology related activities in Finland. The interest of study is to scrutinise the dynamics behind the development as a combination of technological, institutional and economic factors. The main objective of this study is to focus on the link between technology and institutions but also on the role of different organisations

in the process of building capability to produce new innovations and new industrial activity.

The paper claims that the rapid development of the biotechnology industry in the 1990s in Turku arises from a much older story, with historical capabilities been gradually built up especially within pharmaceuticals over decades both in industry and university research. Many external factors have also had a big influence in triggering the development process. These involve factors like the global structural change in the pharmaceutical industry, the internationalisation of trade, the recession in Finland in the early 90s and the substantial changes in the national innovation system.

A specific focus in the study has been the interaction between universities and companies, which is one of the key factors in a science based industry like biotechnology. Our findings suggest that the interaction has been primarily driven and institutionalised by larger pharmaceutical and diagnostic companies in the past, and more recently by smaller start-ups and spin-offs. The latter do not have large corporate R&D capabilities and must thus depend to a greater extent on external research links. From the university point of view, the interaction has been more based on resource constraints than a dedicated strategy for developing co-operation in the field of biotechnology.

From the policy standpoint, the development of the innovation system in Turku to support a new technology area has been different from many other Finnish cities, in a way that the local public sector has not played a very active role in the beginning. For a long time, the mobilising of local resources and the successful attempts to influence national S&T policy have mainly been a result of a network of individuals working in the industry and in the universities rather than a general strategy of the universities or the local government. More recently, the City of Turku has been much more active and even instrumental in building new institutions and infrastructure to support the growth of the new industry.

Thus, the rise of Turku should be seen as building on older capabilities, recently driven forward by new institutions that have come about due to resource constraints, external economic shocks and fundamental changes in the global pharmaceutical industry. The new 'BioTurku' has arisen, therefore, more as a reconsolidation of expertise across sectors under a new banner of "biotech", which has in turn, allowed new configurations of innovative actors to link up and create new technological services and products as well. As a result, a variety of earlier unrelated sectors in food,

pharmaceuticals and materials sciences, have now been pulled together with a common technological base. This development has also made it easier for the policy makers to formulate a focused strategy for local innovation policy.

The study is based on written documents, statistical data and total of 36[1] interviews. Interviews were conducted with academics, policy makers at various levels, CEO and R&D heads of companies, as well as business managers. Within the "biotech" industry of Turku, broadly defined. Specifically, the focus was on pharmaceutical (therapeutic) firms involved in drug discovery, development and manufacturing. A central difference with previous studies of Turku[2] is that this study focuses more broadly on the link between technology, economy and institutions, in other words, which institutions and events organisations might have been central to the process of building capability and opportunities for a new industry to emerge and grow.

Biotechnology industry in Turku and in Finland

Biotechnology has developed as one of the fastest growing industries in Finland. It has been selected as one of the key development areas in the national policies and many resources have been directed to the development of both research and industry during the past 15 years.

In Finland as a whole, the biotech industry in 2000 was broadly categorised into the development of medicine (no. of companies 17), large medical companies-Orion, Leiras and Santen (3), diagnostics (30), biomaterials (9), food (12), industrial enzymes (3), agro (6), services (28), others (15), for a total of 123 biotech-related companies nationwide in 1999. The turnover was 1860 million €. However, excluding the top three large companies, the turnover was 663 million €. The employment numbers also demonstrate the dominance of the large pharmaceutical companies: the total employment in the biotech sector within these 123 firms was 10,813, but excluding big pharma was only 4, 178. (Source: FinBio)

In 2000, the Finnish turnover of "life-science" industries was1.4% of GNP and 2.1% of industrial employment (0.4% total employment) and 2/3 of this was in the pharmaceutical industry. (Tulkki et al 2001). From a sectoral standpoint, pharmaceutical production in Finland in 1998, for example, was €575 million compared to €15,980

[1] The interviews were part of the international LIS project and were conducted together by Kimmo Viljamaa and Smita Srinivas from MIT Industrial Performance Center.
[2] Primarily those of Bruun 2002a, 2002b and Bruun et al 2001.

million for the Finnish electrical and electronic industries in the same year, or about 5.75 % of the electrical and electronic industries' production figures. At the same time, the natural and medical sciences jointly published 85.3% of all Finnish academic publications in 1999 compared to 7% in engineering and technology areas. However, with the blurring of engineering and life science areas in biotechnology fields, these publication categories and figures may change. However, if sites for clinical trials and the new chemical entities (NCEs) they introduce into the market are anything to go by, then Finland has a strong advantage. It introduced 8.6% NCEs introduced in clinical trials, had 0.4% of the world pharmaceutical market and 0.1% of the world's population in 1998. (Brännback et al 2001a, 50)

Turku is the second biggest concentration of biotechnology activities in Finland after Helsinki. Other regions with dedicated centres for developing biotechnology are Oulu, Tampere and Kuopio. Moreover, there are also many universities with biotechnology related research and education in Finland. In the Finnish perspective, Turku region is especially strong in biopharmaceuticals, but also has activities in diagnostics, biomaterials and functional foods.

The primary specialisation of firms within the Turku biotech cluster in 1999-2000 was in diagnostics and input materials (35%), followed by pharmaceutical product development (29%), services –research, marketing and consulting (22%), biomaterials and functional foods (7% each). The 1996-2000 period saw the sharpest rise (~65) in new biotech firms in Finland and the development seems to have been very similar also in Turku. Companies started in the 1998-2000 period were broadly categorised as biomedicine (37%), diagnostics (31%), biomaterials (13%) and others (19%) (Orava et al 2001 and FinBio*).*

The pharmaceutical industry is especially strong in Turku. There are two bigger pharmaceutical companies present in the city, Schering and Orion. Both of these companies do R&D in Turku. There are also quite many smaller drug discovery companies like BioTie Therapies, Hormos Medical, Juvantia Pharma etc. Together with the universities and service companies, this sub-field forms a relatively tight network of drug development. Most of the smaller companies have appeared during the last ten years and the number of companies has increased rapidly.

The territorial agglomeration of industrial activities and biotechnology

The approach of the study is to focus on the local concentrations of a particular industry – in this case biotechnology related activities. The local (or regional/territorial) aspect has been seen as an important factor in explaining the development of industrial activities. Industry has the tendency to concentrate in certain locations, which affects the nature of innovation and industrial activities in many ways.

There have been studies focusing on territorial agglomeration for decades, dating back to late 19th and early 20th century and the works of Marshall (see Simmie 2001; Malmberg & Maskell 2001; Moulaert & Sekia 2003) and Weber on the economics of agglomeration. According to Malmberg & Maskell (2001) we can find at least three traditional factors that affect spatial clustering. The traditional *analysis of spatial clustering* tries to analyze the advantages that firms get by locating close to each other (localization economies). Three different mechanisms have been traditionally identified:

1. Reduced costs to produce and maintain a dedicated infrastructure and other collective resources
2. Well-functioning markets for specialized skills
3. Reduced interaction costs for co-located trading partners

During the last few decades the special focus in these studies has been focused in explaining the relation between the spatial clustering of firms and the innovation process. Several different approaches have been developed, amongst them Innovative Milieu, New Industrial Spaces, Spatial Clusters of Innovation, Regional Innovation Systems and Learning Regions (Moulaert & Sekia 2003). The increased interest can be seen as a result of the change in the nature of economic activities as a result of technological change and globalisation. There is talk about information economy, knowledge economy, learning economy etc.

Increasing pressures like world markets, competition, ICT push companies to find new ways of competitiveness. At the same time there are increasing opportunities provided to increase scientific development and new ways to use ICT. This similar influence of external pressures and opportunities leads to a very turbulent environment for the firms (Schienstock & Hämäläinen 2001). There are usually two ways in which the companies respond to this development: specialisation and innovation. They outsource everything they are not best in and with innovation they try to maximize the profits of their core competencies. Both of these developments lead in many situations to increasing local (as well as global) connections. Many services, external functions

have to operate close by (the economics of scale and time, transaction costs etc.). With innovation, the central factor is knowledge generation and transfer, where companies locate near the knowledge sources and each other (time economics, tacit knowledge etc.).

What is essential in this 'new phase' is the increasing role of knowledge, learning and innovations as the source of competitiveness. The recent analysis of spatial clustering is based on the idea of knowledge and innovation, which brings forth a new factor for spatial clustering:

4. A localized cluster of firms that form a basis for the local milieu that may facilitate knowledge spillovers, learning and adaptation.

The general argument is that local industrial structures with many firms competing in the same industry or collaborating across related industries tend to trigger processes, which create not only dynamism and flexibility in general, but also learning and innovation. A local culture with specific norms, values and institutions (formal and informal) makes it also possible to transfer tacit forms of knowledge from one actor to another. The cluster is seen to exist because the co-location of firms cut the expenses of identifying, accessing and transferring knowledge (Malmberg & Maskell 2001).

Although a shared infrastructure and supplier and service network have an important role, in a high tech industry like biotechnology, the role of knowledge becomes especially crucial. Several reasons related to knowledge and expertise that link innovation capability to space can be found.

- **New knowledge**. New knowledge is usually difficult to codify and therefore difficult to transfer. It is best transferred through repeated and frequent face-to-face contacts. Innovation is therefore facilitated by geographical proximity.
- **Knowledge exchange**. Knowledge exchange can happen through knowledge spillovers. On the other hand, most actors are unwilling to share crucial information when there is a danger that it can end up in the hands of the competitors. Information exchange usually happens with known and trusted clients and customers. This may also be the case with long-term co-operation with the universities and research institutions.
- **The availability of a high level workforce** is a very important requirement for innovation. Labour mobility is lower (especially in Europe) than the mobility of other resources and tends to concentrate in certain regions.

Innovation and industry structure in biotechnology

The nature of the agglomeration of innovative activities depends on the industry. First of all, biotechnology has until today been very much dominated by the US and to a

lesser extent in Europe, by U.K. (see Breschi et al 2001, 1). Biotechnology activities also tend to concentrate strongly in specific areas. This concentration goes even so far that a few local concentrations of activities (like Cambridge, MA. and San-Fransisco-San Jose, CA.) are globally in a dominant position (Cooke 2002, 5)

What is important to see is that the nature of an industry and technology has a big influence on the development process and especially the capabilities and resources that are needed for a new industry to develop successfully in a given location. From the R&D point of view biotechnology is a very demanding field. The research in the biosciences demands rapidly evolving and expensive methods and instrumentation (Biotechnology in Finland 2002, 16). Because the cost of R&D is so big it puts special emphasis to funding, both in university research and company R&D. Biotechnology also often requires very time-consuming experimentation with expensive materials and equipment. Many of the innovations are also based on basic research, which means that the time from the innovation to markets is very long.

What is important to notice in the light of biotechnology industry is the notion made by Cooke (2002, 11) that there is a growing evidence that university or public laboratory research with associated spin-off DBFs is at the heart of knowledge generation and exploitation. In this way, the previous world of pharmaceutical R&D dominated by large multinationals has changed. At the same time, the global MNCs increasingly specialise in distribution and marketing. In the light of the value chain it seems that the innovation system in biotechnology is both highly regionalised and globalised at the same time.

The geographical concentration of biotechnology can be seen as the concentration of knowledge. Much of the knowledge can be found at the universities and R&D institutions which make these places local concentrations of knowledge and expertise but also potential workforce for the firms. Many of the knowledge spillovers are also very local by nature, either based on tacit knowledge or because people are usually better informed of the local knowledge base. For example in the study of Jaffe et al. (1993) of the commercial use of university patents it was shown that most of the use of university happened within 50 miles of the university. Also it has been noted that especially in the early phases of the exploitation of biotechnology the successful development required considerable amount of tacit knowledge (Zucker et al 1998)

Of the two ‘localisation effects’ the existence of high level knowledge and research in the area seems to be more important factor than local knowledge spillovers in the

development of local biotechnology clusters. According to Cooke et al (2003) untraded interdependencies mentioned in many studies are not that typical for biosciences. Because techniques used in biotechnology are so specific and not widely known, there is typically not much knowledge transfer through social ties and networking between firms simply because knowledge is very specific. Localisation effects originate because the so called 'star scientists' that are invaluable to R&D tend to locate near their home universities.

Another factor seems to be the increasing multidisciplinary nature of biotechnology R&D. In many cases the development work requires a very heterogeneous set of cognitive skills, which leads to an increasing need for transdisciplinary network relationships (Orsenigo et al (2001). This calls for a concentration of a broad set of expertise, which can usually be found within a larger concentration of related activities.

As what becomes to what Cooke et al (2003) call exploitation knowledge – the translation of basic research into applications, a few localisation factors can be found. Many times small DBFs are reliant on research scientists to translate the non-codified knowledge to them in the form that can be further developed. People with experience of both research and industry tend to be magnets for new companies.

In many cases also the special services play an important role. Especially business services and specialised expert services tend to locate close to key customers and therefore can also increase the attractiveness of the location for new companies. This study also gives indications that even if there is little interaction and knowledge transfer related to actual R&D in the companies, quite a lot of interaction and exchange of experience takes place related to other questions like business expertise and services.

All in all, biotech is typically a very spatially clustered industry. Biotechnology companies are located close to major universities, hospitals, research centres and sometimes with supportive bigger companies with which SMEs have interaction. At least in the initial phases most of the new ideas and new start-up firms seem to be university based. However, Feldman (2002, 14) argues that even though universities seem to be necessary for the development of biotech concentration, the existence of a high 'knowledge base' might not be enough. As Orsenigo (2001) argues from Italian experience, the existence of a strong scientific base does not guarantee that there will be new start-up companies and an industry will emerge. There is also no firm evidence

supporting that there would be a correlation between university financing or the number of patents and the number of start-ups (Feldman 2002, 15)

Especially at the later stages of the industry development, the local industry can also be dependent on few bigger anchor firms (Feldman 2002) as the industry develops from 'science-stage' towards more commercial application oriented activities. The bigger companies can act as pool of skilled labour and demand for special inputs that may benefit smaller start-ups (Feldman 2002, 14). The experienced people in the existing bigger firms can also act as a pool for potential entrepreneurs.

In conclusion it can be said that especially in biotechnology the mechanisms of co-location and spatial clustering seem to be especially strong. However, favourable conditions for locating do not by themselves explain the development of an industry in a particular region. The agglomeration advantages (e.g. strong science base, working labour market) in a particular locale only lay basics for the capabilities and opportunities for the industry to grow but there are other factors affecting the way these opportunities are actually realised. The structure of an industry, technological change, economic factors, changes in the institutional base and local development policy are all factors that come to play.

Technological, economic and institutional changes in the environment

The different factor affecting the opportunities and limits of successful cluster development can be in general divided into external and internal factors. External factors refer to different effects on the external environment. These can for example be changes in the world economy, the changes in the global structure of a given industry, technological change, large scale institutional changes like legislation, trade agreements etc.

Internal factors on the other hand refer to those elements in the local environment that affect the competitiveness and innovation capabilities of the local firms. We can talk about regional or urban competitiveness. These internal factors can further be divided into structural and dynamic factors (Linnamaa 1999). Structural factors like the local infrastructure, industrial structure, living environment and local institutions are very important to the development of firms. In many cases, the structural elements are not enough, though.

Recently there has been a lot more discussion about the dynamic elements and dynamic capabilities of a region. These cover among others the human resources in the

region, the local culture and the social environment where people live and work. These factors affect the way information and knowledge is transferred in the local networks, how supportive the environment is to entrepreneurship etc. There is talk about local buzz, the kind of ongoing processes in the local environment that strengthens information exchange and gives new energy to innovation activities and the local development processes (see. Bathelt et al. 2002, Storper & Venables 2002).

Part of the dynamic capabilities affecting the development of industrial activity in a region is the ability of the local policy networks to support the innovation activities and growth of the firms. All regions have certain resources but not all of them are able to utilize them effectively (Sotarauta 2003, 8). Factors as a shared development view, the ability of local organisations to interact with each other and the ability to create consistent development measures.

In this paper, I take a look at all these different external and internal factors each as elements that have enabled the local biotechnology industry to develop successfully in Turku region. With external factors, a general division into technological, institutional and economic factors is made. These factors are overlapping and often many of the factors have the elements of all of these. After that internal factors are analysed by looking at the development processes that have taken place in Turku in during the last 10-15 years.

Technology – the changes in the biotechnology and life sciences industry

One of the most important factors enabling the growth of the biotech cluster in Turku has been the change in the technologies used especially in the pharmaceuticals. This so called biotechnology revolution has changed the industry structure. The paradigm shift from chemistry based to biology (e.g. genomics) based drug development created totally new phases at the beginning of the R&D process, which opened up new possibilities especially to SMEs. This change is mainly materialised in a shift in the dominant technology of the pharmaceutical field, from random screening to targeted drug discovery that emerged from bioengineering after the 1970s revolution.

Genomics for example is making drug development more focused, cheaper and is making it possible to make more 'tailored' drugs for targeted groups of patients. For example the new biochip technology with the capacity to do testing at a friction of the cost of traditional screening. Prices of the drugs are mainly driven by drug development costs. Traditional drug discovery methods for medicinal chemistry of trial and errors are

being displaced by combinatorial chemistry where thousands of compounds can be screened for each gene target in search for the perfect drug. At the same time it is possibly to target specialized drugs for people with different kinds of genotypes. Another important new factor is the increasing use of modern ICT technology, which has also increasingly modified the research processes and opened up new possibilities e.g. for molecular research.

The use of new technologies has then changed the industry structure. What once used to a right-moving value chain, i.e. with the highest value-added component being marketing and sales, has since the 1980s emerged as a labour specialisation with high value added at both extremes of the chain. In addition to the marketing and sales on the right end also drug discovery on the left has become more and more important – intellectual property and know-how have also become merchandise (Brännback et al 2001b, 5). Although sales and marketing still tends to be the big money-earner, the shift in labour specialisation has resulted in an interdependency between two types of organisations, particularly exemplified by the U.S. example: small, dedicated biotech firms (DBFs) with proprietary technology platforms engaged in drug discovery (and occasionally development) and on the other end, mid-size to large pharmaceutical companies with many more functions vertically integrated and significantly more revenue-rich than the smaller DBFs.

This "new way" of developing drugs has been one key factor that has given the small companies a possibility to enter the field previously dominated by large players. The new integration of different disciplines and the increasing importance of publicly generated scientific knowledge have increased the need for the Big Pharma to collaborate with universities and small start-ups or specialized companies. This new increasing interdependence between small discovery companies and large MNCs suits both parts. The small companies get resources, tools and a distribution channel as the big companies can increase their R&D productivity, spread their risks related to expensive R&D and have access to new knowledge and new innovations.

From a spatial point of view the knowledge value chain is increasingly both local and global. Early phases like research and early exploitation of new discoveries are highly regionalised. Typically small companies are spin-offs from university or industry with a single product they want to bring to the market. This case applies also to Turku. These companies tend to locate near their knowledge base, which in this case are the local

universities and existing mid-size companies. The later development, distribution and marketing are highly globalised especially in pharmaceuticals but increasingly also in other fields like diagnostics and nutriceuticals.

To sum it up, the emergence of new technologies and tools have changed the industry structure, increased the role of universities and R&D-institutions as sources of knowledge and opened up new possibilities for small start-up companies with specialised know-how. In Turku, these changes have been quite visible. Facing increasing global competition, the local mid-sized company Orion has moved increasingly from manufacturing and distribution to R&D and at the same time cut down the number of drugs in the pipeline. A few of these R&D-programs have since continued as independent DBFs. Also the co-operation between the universities and firms has increased drastically and the number of new specialised start-ups using modern biotechnology has grown significantly.

Economic factors behind the transition

Economic factors are closely related to technological change as the changes in technology have affected the way especially the pharmaceutical industry is reorganising itself. Economic factors affecting the development process are not limited to those affecting a particular industry but also general economic fluctuations can have big impact on the competitiveness of firms and the policy made by supranational, national and local policymakers.

The main economic opportunity for new small companies comes from the problems encountered by the global pharmaceutical companies. The recent economic changes in the pharmaceutical industry can be summarised as:

- Impact of losses in patents has deteriorated the profits. Large pharmaceuticals are hard pressed to find new patentable “blockbusters” (Bureth 2002)
- There has also been a gradual decrease in the productivity in pharmaceutical R&D processes. This has been partly explained by the fact that the traditional methods like ‘random screening’ need more and more molecule candidates to be successful, which has increased expenditure. Other explanation has been the skills – old pharmaceutical R&D skills have been focused on chemistry based expertise and is there has been a lot of problems in turning these skills to more biology based.

– There has also been a tremendous increase in R&D costs at the same time as market shares have dropped. The average cost of a new drug has been estimated to be over 800 million dollars and fewer and fewer drugs are able to cover their development costs (DiMasi et al 2003).

As there are not enough blockbuster drugs in the pipeline, the development cost have gone up and the R&D productivity down, there has been a need to reorganise the whole development process. The outsourcing of R&D and services has become more common. In fact, interaction and different kinds of co-operative agreements are more common in biotechnology industries than in any other field (Hagedoorn, 1993). Companies sell different specialised services and intellectual property to other companies that further develop innovations. This has opened up many new opportunities for small and medium sized companies. Many of the new companies in Finland do not produce end products but usually intermediate products and services used by other members of the industry (Brännback et al 2001b, 24).

From the SME point of view the most important economic factor, however, has been the development of venture capital (VC) markets in Finland during the 90s. This factor has been especially important for biotechnology firms since in biotechnology the R&D costs are very high and the typical time to markets for a product can be very long (10-12 years in drug development). For many of the local company executives, the increased availability of VC in the mid 90s was one of the key factors that enabled the companies to grow. In Finland, in contrast to US, private VC has not played such a big part. The domestic private VC sector is still not very big and only a few foreign VCs have so far come to Finland. Therefore the public funded organisations and funds like Sitra have played a very big role in substituting the lack of foreign private VC.

The more global economic factor for the whole life sciences is the steadily growing markets. Most of the markets are in the developed countries, where population is aging at the same time when the general income levels are steadily growing. In drugs, for example, the global market in 1999 was $350 billion, which was 11% more than a year before. The same applies to related fields like diagnostics. It has been estimated that by 2010, global markets, including sectors where life sciences and biotechnology constitute a major portion of new technology applied, could amount to over EUR 2,000 billion (Commission of the European Communities 2002). At the same time the USA and

Japan alone cover more than 50% of all markets. This means that while profits from individual products are decreasing, the whole market is growing fast.

One general economic element affecting the growth environment has also been the severe economic recession in Finland in the early 1990s. As a result thousands of companies and jobs were lost. The recession caused many structural changes both in companies but also public sector. Especially the public sector was activated to generate new jobs and in Finland, an innovation oriented approach was chosen. This meant increasing support for both public research and private firm and job generation.

Partly as a result of the economic downturn the local government was also activated. The recession hit Turku harder than many other cities. The local industry had succeeded fairly well previously and thus there had been no real need for local activism in economic development. During the recession, many of the local industries had to face a serious restructuring, leaving Turku with a very high and persistent problem of unemployment. At the same time in many other Finnish university cities, the rise of ICT industry and especially Nokia provided a new path for success. However, Turku did not have a lot of education and research in ICT and the industry was also quite small. Something else had to be found and biotechnology is a very strong candidate for a new growth industry and policy initiatives were directed to support research and business in this area.

Institutions – the changes in the innovation environment

The local development of the biotechnology industry in Turku probably would not have happened in the current magnitude, had it not been the change especially in the national policy environment. Compared with some major biotechnology countries like the USA and the UK, the Finnish national innovation system is highly integrated but state led. The national innovation system plays a big role in the development of biotechnology industry in Finland. Most of the financing for the universities and the companies come from public sources and there are several dedicated programs at the national level to support biotechnology. Some sources even see that biotechnology will be the fourth pillar of the Finnish industry in the future.

The Finnish model for supporting biotechnology can be described as ‘Science-led strategy from above’ (Cooke 2002, 24). In Finland the national innovation system has played a significant role in the development of the industry. It has important components supporting science based and resource intensive business, like Academy of

Finland funding basic research, TEKES applied research, development and knowledge transfer, Sitra providing funding and VTT conducting research. There are also public programs like Centres of Expertise co-ordinating and focusing resources in key industries in each region.

The national innovation system in Biotechnology covers several institutions and organizations, many of which are located in Helsinki region. The most important of them are the ministries, the Academy of Finland and the Finnish Technology Agency TEKES. The biggest public sources of finance for biotechnology are the Ministry of Education, the Academy of Finland, the Ministry of Trade and Industry and TEKES.

In the late 1980s, the ministry of education started the first research programme on biotechnology. Since then the amount public funding in the form of different research and technology programs, Centre of Excellence funding for universities and public VC has increased tremendously. The Finnish government has had a determined strategy to increase the amount R&D expenditures and has also channelled more and more public funding to support R&D activities.

Biotechnology has been one of the key areas of public funding and institutional support. Biosciences cover roughly 40% in the national R&D budget. TEKES, the national technology agency has invested some $90 million in biotechnology, which accounts for 27% of the total investments. The Ministry Education has set new Centres of Excellence to universities and in 2000, nine of the 26 top units were in the field of Biotechnology.

The impact of the changes in the national science and technology policy has been very remarkable also in Turku. The new dedicated university research units have received a lot of public funding; local actors have been active in the development programs. Also the public VC has played a big part in the growth of the new firms. However, in Turku the national institutions can be seen more to be in a position of resources for local activity rather than activators themselves. As it comes to visibility in the national policies, Turku remained quite invisible (compared with e.g. Helsinki) until the late 80's. During that time (1987) the Ministry of Education launched a new research programme on biotechnology. In the first drafts were very Helsinki centred despite the fact that Turku was not much smaller in terms of biotechnology related activities. This 'injustice' raised local activity among the research community (Bruun et al 2001). This situation leading to local informal initiatives to increase the visibility of

Turku in terms of biotech activities can be seen as one of the turning points in recognising the opportunities to develop a local concentration of biotechnology.

Local opportunities - the development of Biotechnology industry in Turku

In addition to many external factors that have provided opportunities for the local industry to emerge and grow, local elements have also been crucial. The long-time development of the local knowledge base in biotechnology related fields, close interaction between knowledge providers and users but also local institutional innovations have all provided the local biotech activities a good breeding ground.

First of all, the existing local capabilities have not appeared only lately, but have been accumulated over time. The current fast growth in terms of new companies has mainly happened during the last ten years, but the roots of the industry are much older. The first drug companies (Leiras and Farmos) were established in the 1940s. Also Wallac (nowadays part of the PerkinElmer group) was born during that time. These mid sized companies established the tradition of co-operation to some university groups and departments during the time when it was not that common in Finland. A good example of this is the diagnostic company Wallac that had a need for co-operation with the universities already in the 60s. They also had this need to make sure the availability of professional employees and the technology centre provided a good opportunity.

These older and bigger companies have been a valuable asset for the concentration to build on. The bigger companies have had an influence that in the long run specialised expertise in business and development activities has been accumulated in the region. This is clearly illustrated by the fact that many key people in the smaller companies in Turku and even in the universities have been working at some point in the bigger companies. Bigger companies have also acted as a pool for the workforce as for many special services. In the case of Turku it seems, though, that the use of local services is small among the bigger companies. One important thing in the case of bigger companies in the region is that they have, in many cases acted as a pool for new start-ups. Many ideas have been exported even by individual workers leaving the company but in some cases also by a dedicated spin-out strategy of the bigger company.

Also the scientific knowledge base has not been developed overnight. Instead, many of the strong fields are based on studies started as early as in the 60s or 70s. In Turku, the level of scientific research in the biotechnology related fields has been of high level

with many research groups near the top of the world in their related fields. This has been a very important resource for the growth of biotech industry. It has been noted in several studies that in biotech, the performance the strength and width of the scientific base is perhaps the single most factor affecting the development of the industry (Breschi et al 2001).

One of the important factors for new start-ups has been the strong academic linking to US. When the molecular biology revolution occurred in the 1970s, many PhDs and doctors from Turku did their postdoctoral research work in some of the best laboratories. During they stay they witnessed firsthand the birth of commercialised biotechnology and the many pathways through which academics became involved in the business of medicinal biotech. This appears to have been particularly important for a few lead researchers who subsequently came back to Turku and became intricately involved in the setting up of both the Centre for Biotechnology, as well as a few start-ups which have been very promising.

From a policy and resource point of view, one important factor in the rise of biotechnology has been that the low critical mass in IT-related skills and industry. This has led to the need for a concerted effort to foster its life-sciences research and commercialisation. The absence of engineering departments in the Turku city area (except for Chemical engineering at the Åbo Akademi which has been relevant to biotech) is often stated by academics, policy makers and entrepreneurs alike as the reason why no IT-boom occurred in Turku, unlike in many other Finnish cities.

In addition to the long term development of capabilities, the developments in the local innovation environment during the past 15 years have been very important for the dynamics of the biotechnology industry. In general, this development can be seen as a modification of behaviour of key agents: local actors in business and academia, university administration and city government.

The first change can be seen as happening in the local innovation network. The first seed can be seen from the late 80s. The first dedicated project for improving biotechnology research the South-West Finland Biotechnology project (SWB) started in the mid 80s. In addition to some scientific results, this can be seen as the first time when biotechnology was introduced as potential growth area. Approximately at the same time (1986) a Foundation of New Technology (FNT) was established. This was a very informal organisation, consisting of around 30 key people mainly from industry and

academia and originally intended to discuss about plans to establish first technology park idea the Data-City (Bruun et al 2001). This was the first bigger forum where key people could be brought in to the development process.

The technology centre was the physical forum for building a cluster. What is interesting, that in Turku the city of Turku was not the initiator in starting a technology park. Of the 7 technology parks running in Finland in 1989 five were a result of the city government working centrally in the development process (Höyssä 2001, 29). Instead in Turku, the main initiators for new technology park initiatives, Data-City and later Bio-City, were individual actors from academia and different business, most notably construction. On the other hand, the technology centre being strongly associated with real estate business put even more distance towards the city administration.

Technology centre BioCity was the second stage of the local technology park concept. It was started in 1989 after a relatively successful ICT related DataCity. The successful forming of BioCity can be seen as a combination of different needs that were joined for a common platform. The real estate business saw a business opportunity in a new kind of a 'technology concept', some industry people saw an opportunity to get more contacts and influence in the co-operation with the universities and the university people saw an opportunity to get better resources for their research and education activities. Earlier positive experiences in starting an ICT related activity in the form of DataCity gave the actors more confidence for pursuing same kind of activities related to biotechnology. The universities saw that co-operation between them could work and the local decision makers were more aware of the new opportunities.

The BioCity concept has been very important for the cluster in many ways. BioCity was not only a building for new companies to operate but also bigger concept. The original idea was to provide synergy between industry and academia by gathering a critical mass of researchers in different fields and technical resources together with each other and the companies (Bruun et al 2001). This was made by establishing new facilities and labs that were jointly administrated by two universities, the University of Turku and Åbo Akademi. From the universities point of view, however, this new kind of organisational innovation came not so much from a shared vision but from lack of resources which made the administration look for new ways of co-operation. Nowadays the whole BioCity Turku research community consists of over 50 research groups with over 500 people working in different fields.

The recession in Finland and in Turku in the early 90s activated more local actors and also the city government to look for new future industries to concentrate on. Compared with other mid-sized cities like Oulu, Tampere and Jyväskylä, Turku became active in the local economic development quite late. This has been partly a consequence of the local industrial structure – the impacts of economic restructuring in the 70s and 80s were not as severe as in many other cities. The collapse of the Russian markets that was important for many local industries and the recession made also the local authorities to pay more attention to economic development issues. Since then, the city of Turku has been very active in promoting new industries and particularly biotechnology. The city has invested especially in infrastructure.

Local authorities, alongside other actors, have also been active in supporting the national Centre of Expertise programme – a program which in Turku has brought new resources in organising co-operation especially biotechnology related areas. In general, all the local actors have been very active in using the opportunities provided by the national science and technology policy and regional policy. One element that shouldn't be underestimated has also been the use of biotechnology as a spearhead branch in city marketing.

To sum it up the local factors in Turku have been important in the process of building capacity. The most important local actors have been:

- Older Mid-size companies => early co-operation with the universities, employment base, spin-offs
- Local active key players in industry, research and real estate business => creating vision for development, activating local players, lobbying, acquiring resources
- High level university research
- City of Turku => Building infrastructure and supporting development in the late 90s

Conclusions

The aim of this paper was to analyse the different aspects that have been affecting the birth and growth of biotechnology industry in Turku. The main argument was that instead of just looking at one factor, such as opportunities provided by technological change, the logic of spatial concentration of firms or public policy intervention, there is a need to see these different aspects as all being important for the successful development of a locally clustered industry. The study was based on assumption that the dynamics of the development process determine the way industry develops in a certain

location. The paper aims to show the way these different external and local factors are related to each other, affecting each other during the process.

The driving local organisations and actors behind Turku's upward trajectory in biotechnology have been its historical tradition in medicine, biology and chemistry that has formed a strong local science base. These, with intersections with the pharmaceutical and diagnostic firms have been driving the gradual economic success of Turku firms. Overall, because of the long-term relationships with university researchers established by mid-size pharmaceutical companies within Finland, both domestic and foreign, the industry-academic connections function relatively well. In addition, there has been an organisational proliferation of "new" types- hybrid research organisations heralding new forms of inter-university co-operation as well as new intersections with the private sector. In general it seems that knowledge transfer as well as knowledge spill-over effects have been in a quite important role for the development and spatial concentration of the cluster.

The other remarkable local factor has been the activation of local development around biotechnology in the late 80s and early 90s. These coalitions have had a very big impact on launching a biotechnology related science park, forming new institutions to support biotechnology, mobilising local resources as well as lobbying for national resources. What has been remarkable in the birth of this local 'development network' is the almost total absence of public actors in the early stages of the process. Instead, the local activism has bread from various interest groups driving their own agenda inside a shared framework.

In this paper, I argue that the local science base, long traditions in university-industry co-operation and strong policy networks have not been enough for a new biotechnology industry to emerge and grow in Turku. The success has also required favourable external conditions that have enabled the local capabilities to be converted to industrial activities.

The technological evolution especially in biology and ICT has especially changed the pharmaceutical industry structure. The role of universities and dedicated R&D organisations has increased in generating new knowledge. This has meant both increasing co-operation between industry and academia, and the increasing commercialisation of university research in the form of patents but also new-start up firms.

Technological change, legislation (especially IPR) and the increasing cost of drug design has also chanced the economic conditions around life sciences. The problems faced by large multinationals have forced them to change their behaviour, which in turn has opened up new possibilities for specialised R&D and service companies. Especially in Turku one economic factor has been the increasing financing for biotechnology firms in the form of VC in the 90s. Without this change the growth probably would not have been possible at least in biopharmaceuticals, which is the biggest sub-sector in Turku.

Also the changes especially in the national Science and Technology policy and the national innovation system have been very important source for new resources. The amount of public funding to R&D has increased tremendously from the late 80s and this funding has been channelled in many ways to academic research, commercial R&D and public venture capital. This has been especially true in new emerging and growing fields like ICT and biotechnology, which have got a lion's share of all public R&D funding. National organisations like the ministries, TEKES, Academy of Finland and Sitra have therefore had a very big impact also in the development of biotechnology industry in Turku as the local resources have been quite limited.

If looking at the general critical factors for the cluster development, Turku fits quite well with the general picture found elsewhere. In the British study of Biotechnology Clusters (Biotechnology Clusters, 1999), several factors were identified that affect the development of biotechnology industry in a given location. If looking at the Turku case in this light, we can conclude that many of these factors have also been present in Turku. Below are the different factors and an evaluation of their significance in the case of Turku:

i.) Strong science base => In the recent international evaluation the science base in Turku was found of high level.
ii.) Entrepreneurial culture => A lot of new companies have been born. The general culture still not very entrepreneurial.
iii.) Growing company base => Company base has grown rapidly in many fields in the last part of the 90s, not many new DBFs in the past few years
iv.) Ability to attract key staff => So far the local and other Finnish universities have been able to provide staff. According to many companies a key problem in the future, especially for foreigners Turku too small and not very attractive.
v.) Availability of finance => Lack of MNCs and international VC. Domestic VC (especially public) has substituted international VC in the 90s. Recently VC money has been tighter and there have been big problems in attracting financing. Remote location and the lack of Finnish private VC a challenge.

vi.) Premises and infrastructure => Good infrastructure. Public sector (especially the City) very active in supporting building new infrastructure recently. University funding has been very tight.
vii.) Business support services and large companies in related industries => Few larger companies that use local services. Many specialised services in Helsinki and abroad. Some good local services but the number is still quite small.
viii.) Skilled workforce => A Good level of education in the local universities. The long tradition in pharmaceuticals and diagnostics provides experienced people though not enough for specialised jobs. Especially lack of business expertise related to biotechnology and internationalisation. Small city size has a negative impact on the general functionality of the labour market.
ix.) Effective networks => Local networks working effectively and have been born voluntarily around issues, not formality. Global networks are quite wide.
x.) Supportive policy environment => National policy very important in providing financing both for research and commercial development. Local policy more important recently in supporting infrastructure. University policy and structures not hindering but not helping either.

All in all, it can be concluded that the success story in Turku has so far been based on a combination of several factors related to the long term accumulation of biotech related capabilities, technological transition, economic factors and institutional factors. The opportunities provided by these external factors have not been enough, however, but strong local development activities have also been crucial in capitalising the opportunities rising from the changes in the external environment.

If looking at the future challenges for the biotechnology industry in Turku, there are several factors that might prove problematic. First, the current success has so far been based on a science based approach. In Turku, the industry consists mainly of R&D industry related to research and development. This strategy is very risky and at the same time requires strong resources for continuing especially at the initial stage when there are now revenues from existing products or intellectual property. This danger is already evident as the global recession has cut down the financing for new start-ups in Turku and many of them have had to cut down their activities and personnel.

To escape this trap seems difficult as there seems to be very little possibilities to build the whole value chain in a small region, where there is not so much variety in terms of skills, capabilities and firm-size. At the same time, the expectations especially among the policymakers are waiting for biotechnology to produce more jobs especially in manufacturing but it is unlikely that biotechnology will ever become a major

employer. Biotechnology cannot be new Nokia, because of the differences in the industries and opportunities. This is something that is a challenge to local policy making. Biotech is risky, expensive, does not employ unemployed people with low education and it is also fairly unlikely that biotechnology will ever bring any bigger production plants to the region.

From spatial point of view there is also the question of size and critical mass in the future. Some of the late studies have shown that biotechnology is increasingly concentrated (at least in US) in few so megacentres. Turku is already facing serious competitions from the Finnish capital region Helsinki but also from other big regions in Europe and in US. It also seems to be difficult to get international companies, personnel and private VC to the region and therefore, despite dense international connections, the local cluster probably has to rely mainly on local human and financial resources also in the future.

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