International mega-trends and growth prospects of the Finnish biotechnology industry: Recent economic research and policy implications

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Abstract

The aim of this paper is to describe recent economic growth forecasts of the Finnish biotechnology industry and provide analysis of the international and industry-specific factors behind these forecasts. The new economic geography of the European regions suggests that spatial agglomeration of economic activities will be strengthened internationally if European integration deepens. In addition to that, the Finnish pharmaceutical industry has enjoyed high regulatory protection and it has achieved similar price mark-ups during the 1970s–1990s to its counterpart in the USA. According to the analysis of small and medium-sized Finnish biotechnology companies, it seems that the most promising biotechnology companies have a well-balanced combination of intellectual capital. Despite expectations of rapid growth, it will take decades rather than years for the biotechnology industry to catch up with the three industrial pillars, the forestry, machinery and electronics industries. To fulfil the expectations, there is a need to build collaboration and financing networks between the biotechnology industry and traditional industries, such as forestry, electronics and pharmaceuticals. Most of the current Finnish biotechnology companies are related to healthcare activities. The Finnish biotechnology industry could offer solutions to the cost crisis in healthcare while at the same time spurring development of an internationally competitive industrial cluster.

Keywords: *spatial agglomeration, price–cost margins, capital structure, intangible assets, input–output analysis*

INTRODUCTION

Background and objectives

The objective of this paper is to present an overview of and policy implications on the international mega-trends and the growth prospects of the biotechnology industry in Finland (see Hermans[1]). The present paper analyses Finland's biotechnology industry from the five viewpoints of international and regional integration,[2] the market structure of the pharmaceutical industry,[3] capital and ownership structures of bio-pharmaceutical companies[4,5] as well as companies' intangible assets and growth expectations[6] and discusses the results of a forecasting model based on the companies' growth expectations and the probability of their success.[7]

An overview of the innovation policy of Finland from the perspective of the biotechnology industry is given first. The biotechnology industry plays a special role in Finnish growth and innovation policy. This special role has shaped the questions addressed in these five studies and the way in which the research was carried out.

Because biotechnology has played a significant role in Finnish innovation policy, certain conclusions are drawn regarding each of the five research areas, both from the viewpoint of firms'

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Out of a total 120 Finnish bitechnology companies, 84 participated in the survey

strategies as well as business and innovation policy. Hermans and Kulvik[7] discuss the potential of the biotechnology industry to grow into one of Finland's main manufacturing industries or growth clusters, comparing it with the healthcare sector, and the forestry, machinery and electronic industries. (See also Hermans and Ylä-Anttila.[8])

Definitions

The biotechnology industry does not exist as an individual branch in any official statistical classification. A single definition was agreed upon at an Organization for Economic Cooperation and Development (OECD) ad hoc meeting held in Finland in May 2002. According to the definition, biotechnology is: 'The application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services.' In addition, a list-based definition specifies biotechnology processes in more detail.

Companies can develop biotechnology processes or they can apply biotechnology processes in their production. The former can be called biotechnology research companies and the latter biotechnology-using firms. An individual company can be classified as belonging simultaneously to both categories. In this case the company can be called an integrated firm (see Nilsson[9]).

The research behind the present study employs the biotechnology-related data drawn from the ETLA (the Research Institute of the Finnish Economy) survey. The ETLA survey was conducted at the beginning of 2002 and covers 84 companies. The first descriptive analysis of the ETLA biotechnology survey was carried out by Hermans and Luukkonen.[10] There were approximately 120 biotechnology companies in Finland at the end of 2001. Thus, the coverage of the data seems sufficient. The problem of how to define biotechnology companies was solved by choosing the firms in the database of the Finnish Bioindustries Federation to represent the population of Finnish biotechnology companies.

The Finnish Bioindustries Federation classified its member companies into seven categories. In the ETLA survey an individual company could classify itself simultaneously in several categories. Figure 1 depicts in which categories the biotechnology companies consider themselves to be. Most of the companies are involved in the businesses of pharmaceuticals and diagnostics.

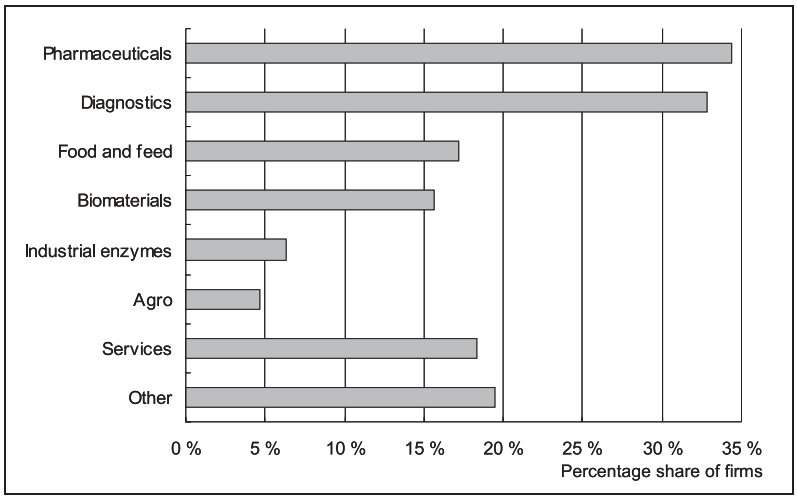

Figure 1: Activities of the biotechnology companies in the ETLA survey by sector

INNOVATION SYSTEM AND CURRENT STATE OF THE BIOTECHNOLOGY INDUSTRY

The following discussion on the current situation of the Finnish innovation system is partially based on Hermans and Ylä-Anttila research.[8] During the 1990s there was a clear shift of emphasis in innovation and industrial policies. While policies in the 1980s can be characterised by picking the winner's approach, policies adopted in the 1990s can be described as providing or enabling policies. The emphasis moved towards indirect measures in influencing firm behaviour, avoiding direct interventions in the product market, promoting competition, and providing a stable macroeconomic environment. In 1990 the concept of a national innovation

Industrial policy in Finland changed from the 1980s steering to 1990s supporting measures

system as a basic category of science and technology policy was introduced to accentuate the systemic nature of innovation.

The roots of Finland's current innovation policy date back to the 1970s and 1980s, when the decisions to increase science and technological investment were made. For more on the background and development of science and technology policy, see Lemola,[11] Georghiou *et al.*[12] and Ylä-Anttila and Lemola.[13] The basic pillars of research policy were built partly in the 1960s, but mostly in the 1970s and 1980s and the first programmes for applied research were started. The goal was to lift the technological level of Finnish industries and to reduce the dependence on raw material-driven production and exports. The one-sided structure of exports was regarded as a problem – the intermittent problems with deep imbalances in the economy were due largely to strong cyclical fluctuations in the export industry.

Heavy investments in ICT

The 1990s can be called a decade of the national innovations system

Even at the end of the 1970s Finland's research and development (R&D) expenditure relative to gross domestic product (GDP) was one of the lowest in the industrialised countries. The 1980s was a decade for systematic and goal-oriented technology policy. One of the key vehicles for implementing this policy was the National Technology Agency of Finland, Tekes, established in 1983. Regional science parks and technological centres were established to support the dissemination of research findings and utilisation of regionally generated information. The R&D expenditure grew in real terms at a rate of about 10 per cent per annum, which was one of the fastest in the OECD countries.

The main tools for implementing technology policy were technology programmes, which fostered the implementation of a strategic innovation policy, thus making use of the small country's scarce resources. According to this policy, heavy investments were made in information and communication technology (ICT) in several technology programmes that had been initiated before the founding of Tekes. The huge success of Nokia and the ICT cluster that emerged around it was a sign of the successful policy choice, even though the policy naturally accounted for only part of the success.[14]

The 1990s can be called a decade of the national innovation system in terms of innovation of science and technology policy. Innovation activities started to be seen more and more as a key product of dialogue and interaction between different actors – companies, research institutes, financiers of innovative activities and other policy makers.

The structural change that occurred in the Finnish economy in the 1990s was relatively swift from an international perspective as well as relative to Finland's own economic history. The transformation toward a competence-driven economy had continued for several decades already, but it accelerated considerably in the 1990s and strengthened the structural change. Technology policy played an important role even though most of the development was company driven.[13] Economic integration and the opening of the economy to international competition spawned a competence-driven phase of growth. The innovation intensive sectors benefited more than other sectors from the new markets. Productivity and capital efficiency increased considerably.

Changes in technology and business policy and innovation policy inevitably have an impact also on the biotechnology sector. The impacts are clearly apparent in at least two respects. First, since it was possible to use policy to foster the success of the ICT sector, it was deemed possible to do the same thing in the biotechnology sector. The R&D investments of the companies in the ICT sector – mainly Nokia – rose sharply in the 1990s and the early 2000s.[15] As regards research activities Finland has specialised more in the ICT sector than any other country in the world. Public investment was

Could the ICT policy success be repeated in biotechnology?

especially important in the 1980s and 1990s during the recession. By the end of the decade, research activity became more company-oriented, even though the ICT sector's share of public research funds was still substantial. Public investment in the ICT sector had spawned a considerable increase in private investment: the ICT sector seemed to be an example of a successful strategy of innovation policy, so it could be worthwhile to search for another sector with new potential – biotechnology.

Secondly, the founding of regional competence centres has had a positive impact on the biotechnology sector and on investment in companies in this sector. Most of the companies in this sector are located in five of the science and technology parks located around Finland (see Figure 2). From the standpoint of the biotechnology and bioresearch, the situation is problematic: it is difficult to find a sufficient critical mass. Furthermore, Kafatos *et al.*[16] pointed out that there is little cooperation between the regional biotechnology centres in Finland.

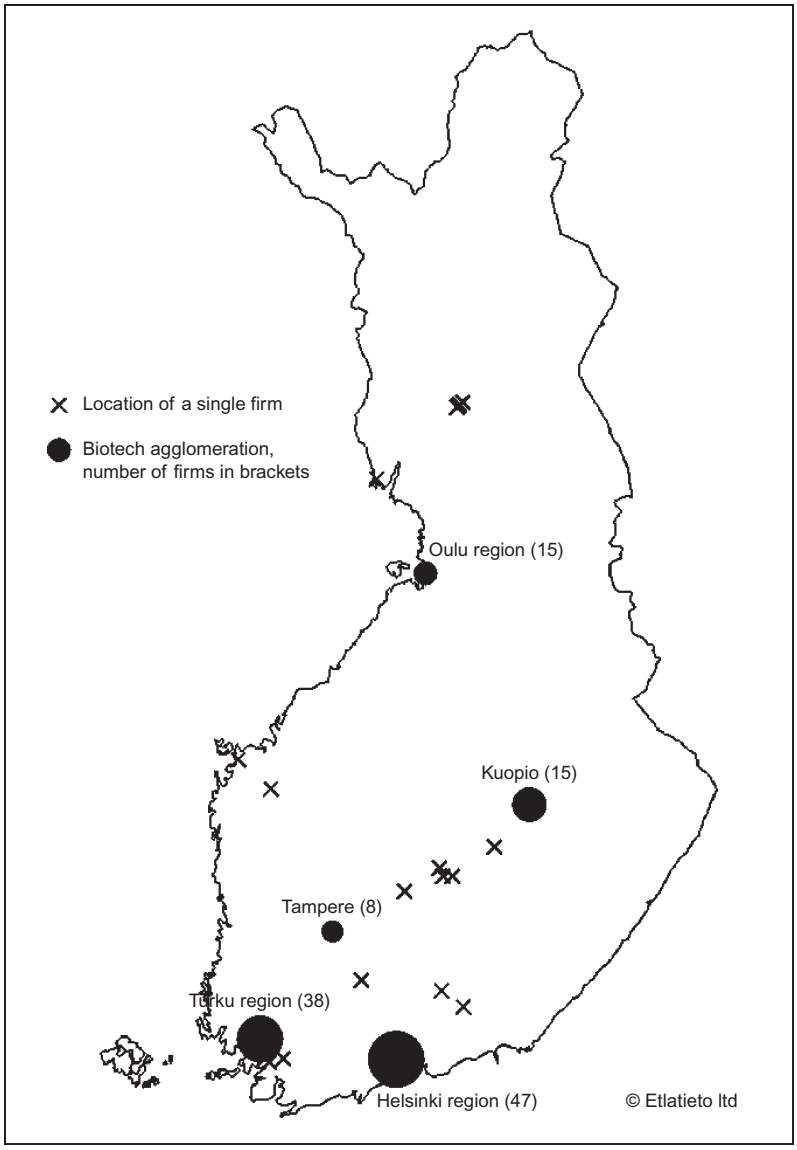

Figure 2: Location of the Finnish biotechnology companies in 2003

The differences between the biotechnology and ICT sectors from the standpoint of the functioning of the innovation system and technology policy are significant, as Luukkonen and Palmberg[17] demonstrate. Biotechnology is not closely affiliated with existing sectors that are currently strong in Finland – the sector has no strong manufacturers or growth engines. The Finnish biotechnology sector has concentrated – as in several other countries – on biopharmaceuticals. The significance of the pharmaceutical sector in Finland's industrial structure has nevertheless been relatively small compared with many other countries. There is relatively little biotechnology research and manufacturing activity related to the large traditional processing industries, such as the forest and chemical industry.

The research and manufacturing activity related to biomedicine – or biotechnology in general – has been chosen as a focal point of business and technology policy in almost all developed countries. Competition in the sector is thus keen and demands high investments. The risks related to the public financing of innovation policy and biotechnology are great.

Finland's biotechnology sector is currently quite small. In 2001 the value added by the entire biotechnology sector was about €500m (Table 1). This figure includes an estimate for biotechnology-related production of large multi-sector enterprises. The total value added of small and medium-sized biotechnology enterprises was less than €100m in 2001.

Table 1: Biotechnology industry in Finnish enterprise sector

	Biotechnology industry SMEs (€m)	Total biotechnology industry* (incl. multi-sector firms) (€m)	Total enterprise sector (€m)	Biotechnology industry's share of enterprise sector – SMEs (%)	Total biotechnology industry's share of enterprise sector* (incl. multi-sector firms) (%)
Number of companies	110	130	225,000	0.05	0.06
Sales revenues	200	1,400	272,000	0.1	0.5
Value added	90	500	88,000	0.1	0.6
Employees	2,000	14,000	1,319,000	0.2	1.1
Exports	120	600	54,000	0.2	1.1
R&D expenditures	162	300	3,300	4.9	9.1

Total value added for the biotechnology sector in 2001 was €500m

* Sales revenues and exports of multi-sector companies are estimated for biotechnology production and employment and for employment as a whole.
Sales revenues, value added, exports and R&D expenditures are based on figures provided by enterprises regarding extent of biotechnology activities.
Source: Based on data for 2001 (ETLA, Statistics Finland).

The situation of the biotechnology industry is illustrated by the fact that the R&D expenditures of the small and medium-sized enterprises (SMEs) are considerably higher (approximately 40 per cent) than their value added. The research investments have for the time being generated very little production. The research investments of SMEs are funded primarily by the government. Since the public financing of the biotechnology sector's research has been about €400m since the beginning of the 1990s (Figure 3), the average financing per SME has been €3–4m. This sum includes both direct funding to the SMEs and also funding to universities and research institutions that companies can utilise indirectly.

Even though public financing has not

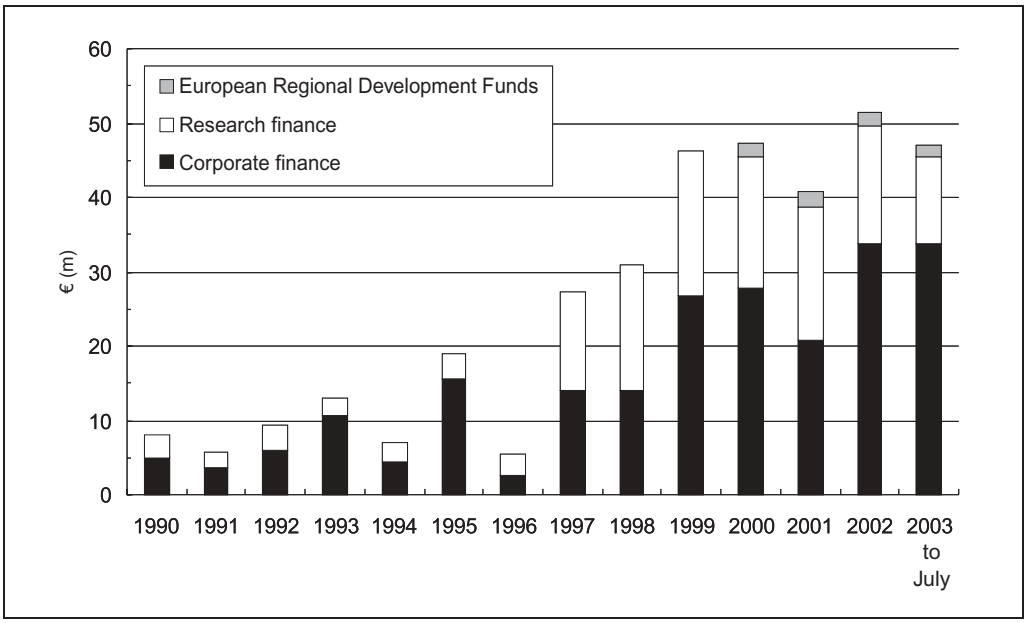

Figure 3: Biotechnology-related funding from Tekes, the National Technology Agency of Finland, 1990–2003 (€m in 2002 prices)

been comparatively high, relative to the size of the economy and the number of active enterprises it has been of significant magnitude.

A growth forecast combining companies' sales forecast, current sales revenues and the bankruptcy risk

GROWTH PROSPECTS OF BIOTECHNOLOGY SECTOR

Forecast growth and other sectors

Hermans and Kulvik[7] compiled an economic growth forecast where the probability distribution is formed from the companies' sales growth forecast and their current sales revenues. The model also incorporates the bankruptcy risk. The modelling technique is based on the sectoral input–output method utilising the purchase and sales volumes announced by companies in the respective sectors.

In year 2006 a forecast value added €850–1200m, corresponding to an annual growth of 10–18 per cent

According to the forecast model based on the data from the year 2001, the biotechnology cluster is able to produce €850–1200m worth of value added with a probability of 90 per cent in the year 2006. In the year 2001 the entire biotechnology sector's value added was about €500m, meaning that annual growth of the entire cluster would be 10–18 per cent. Despite this, the value added will remain relatively low because the biotechnology companies use a high amount of funds for purchasing services and goods from outside the firm. According to the forecasting model, by 2006 the biotechnology cluster's contribution to annual GDP growth will be about 0.05–0.09 percentage points.

The forestry, machinery and electronics industries are the three main pillars of the Finnish economy

In order to put the growth possibilities of the biotechnology sector into perspective, we can ask when Finland's currently strong sectors – the forestry, machinery and electronics industries – were in the same situation (Figure 4). The forecast growth of the Finnish biotechnology industry is not strictly comparable with the forestry, machinery or electronics industries. There are obviously many differences in the necessity of international collaboration in research and in business. However, it is interesting to see how long it has taken, in these mature industrial sectors, to grow to the position where they are today. This can be contrasted to the Finnish biotech industry.

In year 2000 prices, the value of forest industry production was €0.5bn in the early 1950s. The electronics industry reached that level in the mid-1970s. If the biotechnology sector achieved the same growth as that of the electronics industry fuelled by Nokia, it would reach the position of the 'fourth pillar' of industry in about 30 years. If the life cycle of the biotechnology industry as an independent

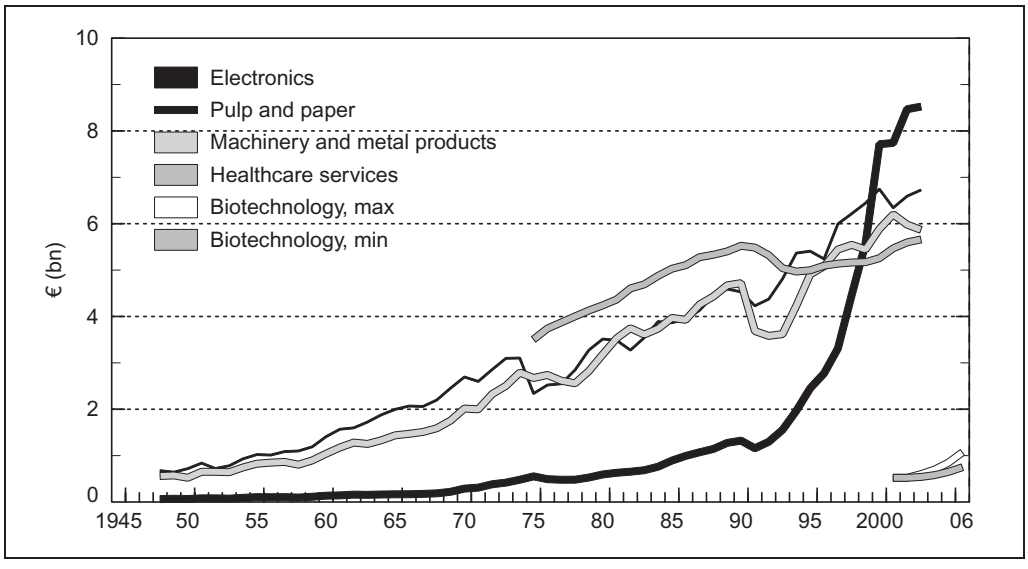

Figure 4: Production by sector 1970–2002 (€bn in 2000 prices)[18]

For the main pillars it took 25–50 years to reach their present position, for biotechnology sector it would take 15–30 years

sector is comparable to that of the forest industry, it would take 50 years. If a long-term growth rate of production of the biotechnology sector is sustained at the same level as in the forecast period 2001–2006, it would take 15–30 years to reach the same production level as the electronics or pulp and paper industry has today.

The healthcare sector offers a domestic market potential for biotechnological applications

The healthcare sector's domestic service production was at relatively high level compared even with highly export-oriented industries unto the economic slump during the beginning of 1990s (Figure 4). Since the depression, the growth rates of healthcare service production has been moderate. However, the massive healthcare sector has reached a major crossroads owing to the ageing of the population and advances made in medical science. On the one hand, the ageing population and the medical ability to diagnose and treat more illnesses than before increase the cost pressures on healthcare. On the other hand, biotechnology applications are expected to spawn cost savings over the long term by, for example, making time-consuming diagnostic methods more efficient and facilitating targeted therapy. Below are some policy implications on how the Finnish biotechnology industry could offer solutions to control for a cost crisis in healthcare while at the same time spurring development of an internationally competitive industrial cluster.

The Finnish biotechnology industry could offer solutions to control cost crisis in healthcare

Healthcare cost crisis and growth potential of biotechnology

As seen above, biotechnology is often linked with drug development and various types of healthcare applications such as diagnostics and biomaterials (Figure 1). Almost 60 per cent of the small and medium-sized biotechnology companies indicate that they operate in the pharmaceutical industry or have ties with clients in the pharmaceutical industry. Fields linked indirectly with healthcare include functional foodstuffs, enzymes and assorted research services. However, the Finnish pharmaceutical industry and other healthcare-related industries are nevertheless relatively small on a global scale.

Inaccurate diagnoses or a lack of appropriate treatment lead to a wasteful use of personnel resources and medication. In other words, if the illness is not known or it cannot be treated, the patient has to undergo time-consuming procedures and the treatment may have to be changed numerous times. The patient may have to be institutionalised owing to inefficient treatment. If more efficient ways can be found to make diagnoses and treat patients that would otherwise need long-term care, relatively expensive methods can generate cost savings by shortening the duration of treatment times (see the Appendix; Hermans and Kulvik[18]).

There is an increase in cost pressures on healthcare because of the ageing of the population and the medical ability to diagnose and treat more illnesses than before. However, if the biotechnology industry can develop new biotechnological applications, which make time-consuming diagnostic methods significantly more efficient and which facilitate targeted therapies, some cost savings can be spawned by reducing the need for long-term patient care owing to inaccurate treatments. If in such cases, the long-term savings are higher than the increase in the direct costs of acute healthcare, and the adoption of new technologies can even be expected to induce savings in the total healthcare expenditures. This, however, preconceives an integration of healthcare policies over the acute and long-term care planning.

In Finland there are several types of diseases that are significant from a public healthcare perspective, the treatment of which have considerable macroeconomic effects. The macroeconomic effects can entail costs other than those stemming directly from healthcare. For example, worker absenteeism and premature

pensions affect the productivity of various industries.

Finns' major illnesses have steered the allocation of domestic research resources producing centres of expertise

Illnesses significant from a public healthcare perspective have steered the allocation of domestic research resources, which has spawned internationally significant areas of expertise in medical science and related fields. The research knowledge and demand for its commercial applications arising from these kinds of public healthcare needs enable the domestic market to be used as a commercial test market. Finnish end-users of healthcare products represent the top experts in their fields; this test market promotes the product development of biotechnology companies and development of service concepts as well as preparing companies' products and services to compete on international markets.

CONCLUSIONS

Policy implications

Finland's biotechnology industry has comparative advantages in specific niches with substantial market potential

A small open economy cannot do everything itself. From the standpoint of innovation intensity, the safeguarding of sufficient critical mass is of profound importance if the emergence of a biotechnology industry is deemed worthy in Finland. In order to foster the success of biopharmaceutical companies, a business concept ranging 'from services to development of own drugs' must be developed, which will also spawn profitable business activities in the pharmaceutical sector. The protection of intellectual property rights and utilization of business expertise right from the onset of the research projects will help biotechnology companies receive financing and launch successful business activities.

Sufficient innovation inventiveness and critical mass must be defined and obtained

Industrial history shows us that if a region or a country has no previous industrial traditions in a certain sector, successful businesses and new growth emerge slowly or only seldom. Finland has pinned high hopes on biotechnology as a source of new research-intensive growth. Almost all industrialised countries have the same goal, and many of them already have long traditions in this sector, unlike the short history in Finland. The biotechnology sector's volume of production measured by value added is about €500m. The growth of the biotechnology companies can be facilitated by directing resources to niches where Finland has comparative advantages and where the commercial applications have substantial market potential in the future.

The following discusses five implications broadly derived from the viewpoints above.

Market structure and regional concentration

The significant relation between innovation intensity and location of economic activities derived by Hermans[2] raises some issues on policy implications. The emerging knowledge-based industries (such as the biotechnology industry), which can guide the formation of new spatial agglomerations in the future. According to List's traditional infant industry argument (see, eg, Krueger and Tuncer[19] for seminal empirics and Symposium on infant industries[20] for more recent discussion), the temporary governmental protection of a new emerging industry displaying considerable market potential can be justified especially within small peripheral economies, which lack economies of scale in their production activities.

Implication 1: Sufficient innovation intensiveness and critical mass must be obtained and defined in the individual biotechnology competence segments in the future if Finland wants to have an economy based on knowledge, instead of, for example, wage cost advantages. The extent to which the infant industry argument should be applied to the biotechnology industry need to be investigated in order to secure the viability of the geographical periphery, such as Finland.

The price–cost structure in the pharmaceutical industry

The price–cost structure[3] in a small economy with price controls, seems to be the same as in a large economy without price controls. The Finnish regulatory environment concerning drug development and pharmaceutical markets has recently changed: international trade barriers have decreased and there is also a harmonisation process in patent regulation within EU. This indicates that the Finnish pharmaceutical industry will probably not be able to earn as high margins as previously. In order to bolster up the profitability of the pharmaceutical industry, companies outsource their research and development because of the considerable risk associated with these activities.

A clear synergy potential between large Finnish pharmaceutical companies and small biotechnologically advanced companies

Implication 2: In the near future it will be possible to operate profitably as a small entrepreneur in certain niches in the pharmaceutical sector. Some large Finnish pharmaceutical companies could strengthen their position in global markets by collaborating with small and technologically advanced Finnish biotechnology companies. The kind of collaboration could offer synergy in the combination of most modern technology of small biotechnology companies and resources and logistics of a large pharmaceutical company.

The investigation of financial sources and business strategy of biopharmaceutical companies

For a value creation perspective, positive cash flows are crucial in the start-up phase

Hermans[4,5] confirmed that the main sources of financing for young companies are the persons working at the company, private venture capitalists and the public sector. The growth expectations of young companies point far into the future. The older biopharmaceutical companies owned by other firms have already been able to generate revenues, which is indicative of the pharmaceutical industry's new strategy of outsourcing R&D activities.

A balanced management of a company's intellectual captial requires introduction of business expertise at an early stage

Implication 3: The equity financing of biopharmaceutical companies in the start-up phase is based on the premise that the investors presume they can exit at a later stage. In the current situation in the international financial markets the most common way to exit is via an acquisition or other type of restructuring – in the future also via an initial public offering. The company is an attractive target for acquisition and its value will simultaneously grow when the company has begun to produce considerable amounts of revenues or its product development has proceeded far enough. This calls for dynamic corporate strategies, in which positive cash flows can be generated even at the start-up phase of the company in order to finance the later development phases of the company's products.

The analysis of intangible assets and growth potential of Finnish small and medium-sized biotechnology companies

Hermans and Kauranen[6] conclude that when a company's intellectual capital (human capital, structural capital and relational capital) are balanced and soundly managed, the company's present value is relatively high (see also Hermans and Kulvik[21]). Then potential investors or buyers of the company are able to make a strategically justified estimate of the company's future earnings expectations and the present value. Financing paves the way for the company to turn its innovations into commercial products.

Implication 4: The management of biotechnology companies' intangible assets and competencies is an important measure of future earnings expectations and therefore the company's present value. Thus the integration of business expertise from the start as a part of the technological development occurring in the network of biopharmaceutical companies helps determine whether the company's business strategy is based on development of the market potential of products, not just technological competencies. In practice, the biotechnology industry could utilise the business skills of the managers of other

sectors, such as information and communication technology cluster, in which Finland holds a fairly experienced management (see also Tahvanainen[22]).

The growth forecast for the biotechnology industry

Hermans and Kulvik[7] present the SMEs in the biotechnology industry as a sector of its own. Growth impacts of the biotechnology industry extend to many sectors, foremost the chemical industry, which includes also the pharmaceutical sector.

The Finnish biotechnology industry can create a sustainable comparative advantage

Implication 5: The biotechnology industry as a distinct sector will not become one of the main pillars of the Finnish economy for at least a decade, even if the growth is swift. It is likely that the Finnish economy's new engine of growth will emerge from a combination of already existing expertise in old sectors with the technological leaps in new sectors. In this case, biotechnology may play a significant role. To fulfil the anticipations, there is a need for the creation of a critical mass of factors of production and comparative advantage by building collaboration and financing networks between the biotechnology industry and traditional industries, such as the forestry, electronics and pharmaceutical industries.

Topics for further research

Further research is needed to evaluate which potential niches the biotechnology sector should seek to fill when developing products with commercial potential. When seeking to identify these niches, it is important to keep in mind that the competence base must be sufficiently large to generate the critical mass necessary for spawning products and services with sufficiently large market potential. We can look at the prerequisites for turning research into commercial products from the standpoint of the competence base underlying this critical mass: knowledge-intensive entrepreneurship, financing possibilities and international market potential.

- By distinguishing the main incentives and barriers regarding entrepreneurship in a research segment with a deep competence base. In addition, by investigating the distribution of key research areas and biotechnology companies that have already emerged, we can seek to find niches that not only have a considerable competence base but also a 'commercialisation gap'.

- By analysing the preferences of financiers investing in biotechnology companies, which are then compared with the distribution of the competence base of biotechnology research. This reveals to what degree the financiers have been able to utilise the Finnish competence base.

- By analysing and comparing the international market potential to Finland's competence base. This topic offers analysis on what kind of market potential can be related to the Finnish competence base.

This type of further research would be beneficial for planners of general technology policies and stakeholders in various sub-sectors of the biotechnology industry. Technology policy experts can benefit from the research results when gauging use of alternative types of support in light of the principle of comparative advantage based on international trade analysis. In Finland substantial amounts of state aid are directed to the biotechnology sector. The private and public investment activity is rather modest by international standards. Resources should thus be allocated prudently.

Biotechnology research can be applied in many diverse areas. There is a danger that when making financing decisions the authorities are unable to 'see the forest for the trees'. Therefore, start-ups that base their activities on isolated top-notch research fields may end up without financing. A reason can be the lack of a viable business plan even if the segment has considerable market potential.

Further research should offer such new information about the biotechnology sector that would assist public and private financiers in better understanding the biotechnology sector and its companies. A proper understanding of which domestic top-notch research fields might offer applications with the highest market potential is necessary for making sound decisions when steering scarce resources.

APPENDIX
Case study: Use of biotechnology in treating strokes – more efficient treatment leads to savings[23–25]

Stroke is the most common type of blood-circulation-disturbance in the brain. The acute phase requires several days of intensive surveillance, which has led to an increse in treatment costs. In 1999 about 6 per cent of total healthcare expenses were related to treatment of strokes. The treatment of patients suffering from brain circulation disorders takes an average of 2.5 years, which in Helsinki costs about €100,000.[26] Fogelhom *et al.*[27] estimate that the ageing of the population means that the need for acute treatment will double by the year 2030.

The nuerological policlinic of the Helsinki University Central Hospital (HUCH) has started to treat stroke patients with so-called trombolytic therapy, where a doctor tries to remove a blood clot by dissolving it. Alteplase, a drug produced in hamster ovarian cells by the aid of recombinant DNA technique, is the most widely used thrombolytic agent. Despite the favourable results obtained by the thrombolysis, it has two drawbacks. First, the medication is relatively expensive- one dose costs over €1,000. Secondly, the trombolysis must be started quickly- three or four hours following the onset of symptoms.

In 2002 about 8 per cent of the stroke patients coming to the HUCH neurological clinic received the solvent treatment with good results. About 60 per cent of the patients receiving thromobolysis recovered. The total cost savings with respect to the recovered patients were about €84,000 per patient, which represents over 80 percent of the non-recovering patients' total costs.[28]

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