Paper title: Biotechnology as a Part of Finnish Economy: National Growth Forecast
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Biotechnology as a Part of Finnish Economy: National Growth Forecast

Abstract
The foresight study is intended to offer important insights into biotechnological industry’s anticipated impacts on the Finnish economy. The impacts can be observed from two viewpoints. First, we present how public finance are linked with the development of scientific collaboration, business activities and growth potential of firms. Secondly, analysis is presented on how biotechnology firms affect the growth of the whole economy according to the firms’ sales expectations. The study focuses on the economy-wide impacts of converting expected potential into real economic growth.

Scientific collaboration between the biotechnology firms and research institutions seem to be high in two cases. First, a high share of public R&D funding implied intensive collaboration. Second, an experienced CEO in a relatively old and large company preferred collaboration, too. The high anticipated growth of biotechnology sales was related to the high R&D intensity generally. However, strict links were found between high growth prospects and high equity share of both private and public venture capital organizations without relatively high research intensity or commercialization ability.

The growth impacts were also estimated quantitatively. According to the firms’ sales expectations, the biotechnology sector adds 0.2 percentage units to the nominal GDP growth in 2002-2006, on annual average. The anticipated growth of biotechnology industry affects most strongly to the growth of production in chemical industry. The impact to other sectors is not remarkable but still clearly observable.

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1. INTRODUCTION

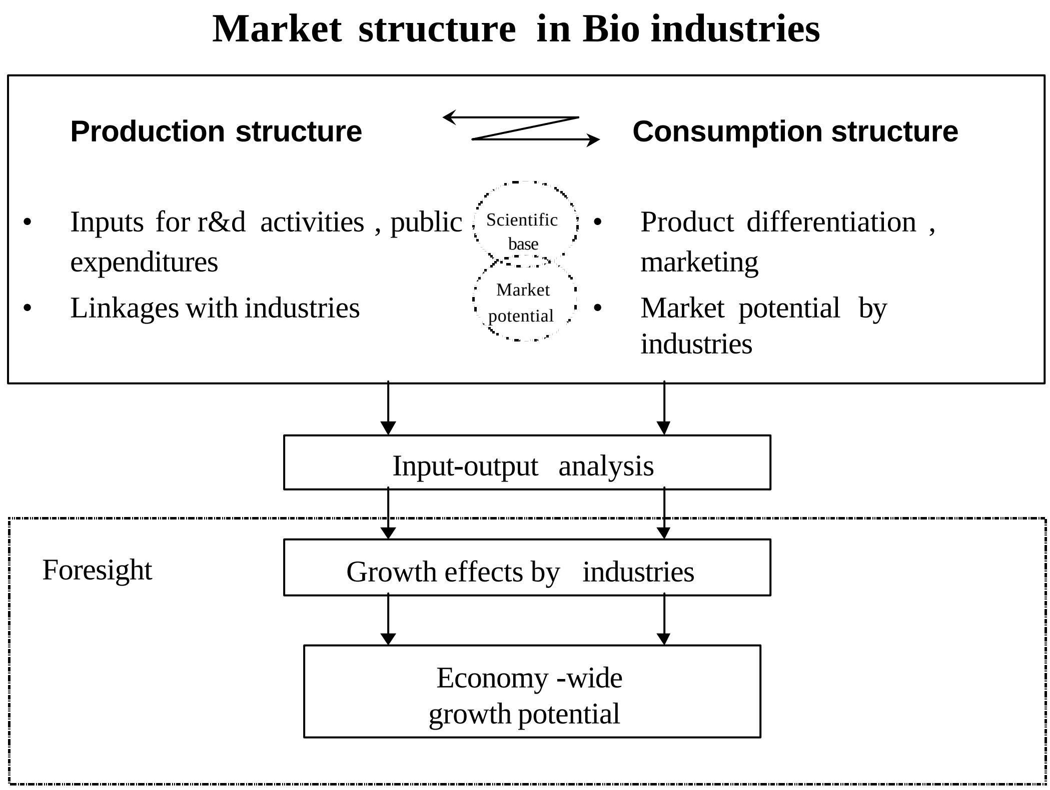
1.1 Background

There have been great expectations about the economic potential of biotechnology for a long time. New biotechnology is expected to become an important driving force in the economy after the era of information and communications technologies. In Finland, the number of dedicated biotechnology firms has grown rapidly in the 1990s and is estimated to be one tenth of the number of such firms in Europe. The public sector has expended a lot of resources in training and R&D in this field. Private investments and venture funding in the field have also grown decisively. The main application areas of biotechnology in Finland include pharmaceuticals, diagnostics, functional food, biomaterials, enzymes and food and chemistry businesses utilizing biotechnology as well as services related to these fields.

One of the special features of the new biotechnology is that as an industrial field it is not easy to define. Attention is usually paid to dedicated biotechnology firms, but they are not the only ones to make and commercialize biotechnological discoveries. Some established larger firms are also involved in biotechnology R&D and commercialization. The entire field is closely related to scientific research where many of the discoveries are made. The commercialization of the discoveries is, however, uncertain and the process is slow compared with, for example, information and communications technologies.

1.2 Aims

The aim of the study is to estimate econometric forecast for the economy-wide growth impacts of biotechnology industry in Finland. The methodological aim is to use survey data in forming both growth anticipations among the biotechnology industry and also inter-industrial growth effects. Utilization of survey data is necessary because of the classification problems in official statistics.



The study will examine firms’ interaction with research organizations and business activities and the financial structures of the Finnish biotechnology. To find the relations between public sector finance, academic research and biotechnology industry, we employ principal component analysis that compresses the data according to the variation among economic growth prospects and, for instance, different forms of public sector finance and cost of academic research collaboration (section 2). The relations of biotechnological industries with other sectors, those that use biotechnology in their processes and products and those that are suppliers to the dedicated biotechnology firms, are examined. We exploit input-output analysis to conduct growth contribution scenario for the Finnish economy as a whole (section 3). Finally, Section 4 concludes.

2. THE INTERDEPENDENCE OF BUSINESS PERFORMANCE AND THE SOURCES OF FINANCE

2.1 The growth prospects of the biotechnology firms

2.1.1 Growth expectations

Biotechnology firms seem to prospect high growth of demand in the markets related to their products. Particularly the global market potential appears to be enhancing. Table 1 presents the anticipated growth rates of sales of Finnish biotechnology industry.

Table 1. The annual growth rates of biotechnology product and service sales, the anticipations of Finnish biotechnology companies in five years.

Growth rate in %	Domestic sales	Exports	Entire sales
Pharmaceuticals	4 %	36 %	22 %
Diagnostics	4 %	17 %	14 %
Biomaterials	17 %	94 %	49 %
Food and feed	3 %	11 %	7 %
Industrial enzymes	7 %	5 %	5 %
Agriculture	21 %	24 %	23 %
Services	12 %	101 %	38 %
Other	6 %	19 %	18 %
Total	7 %	27 %	21 %

The table shows how the growth prospects vary among the branches biotechnology companies are related to. The biotechnology companies goods believe their sales will grow annually on average 21 percent during the next 5 years. The industrial enzymed related industry expects the most moderated growth, 5 percent. This is slightly surprising, when Finland is regarded as giant in mass and paper production.[1] On the other extreme, biomaterials production is anticipated to grow almost 50 percent in annual terms. Furthermore, the growth is principally expected to be realized in international markets, and not in Finland. While the figures seem relatively high, in the next chapter we ask, whether they make any sense.

2.1.2 The sensibility of growth anticipations

We utilize firms’ anticipations on their future sales growth rates in economy-wide forecasts. However, the use of firm level anticipations raises a question about the

[1] Laestadius (2000) argues also that this holds generally, biotechnological revolution has not yet reached the pulp and paper industry.

arbitrariness of announced growth rates. Are the figures only part of the firms' marketing principles?

Hermans (2002) analyzes empirically how theoretical knowledge management framework is connected to the market potential of Finnish biotechnology firms. In this context the theoretical framework intellectual capital (IC) is used to explain the anticipated growth of the sales of small and medium-sized biotechnology firms in Finland. The theory suggests that the interrelation of human capital, the firm's internal and external structures act as a driver for value creation in knowledge intensive business.

Hermans (2002) employed statistical factor analysis in order to construct interrelated IC factors. We used two of these factors in regression analysis as predictors of biotechnology firms' growth prospects. Some other dummy variables that cannot be used in factor analysis were also added to a regression model. According to the study, 40 percent of the variance of the anticipated growth of biotech turnover was explained systematically. There seem to be at least some systematic sense in the growth prospects. Thus, the estimate available appears to be a reasonable predictor for the future growth tendencies.

2.2 Ownership and other sources of finance

Some biotech firms are highly R&D intensive and their actual sales volumes are relatively low. Many firms have made negative profits due to that. But high growth prospects of the industry have encouraged investors to continue financing risky research activities that will create earnings in years to come. The most noticeable owners are individuals active in business (the largest share of equity investments among small companies), private venture capitalist companies (large and infant companies), public venture capitalists (adolescent companies), and other non-financial firms (middle-aged companies). The same sources of equity finance made the largest share of investments in highly R&D intensive firms (Hermans and Tahvanainen (2002).

In practice, great losses have been compensated by the investing part of the fund as equity and capital loans. This enables the positive equity in total balance sheet. This also offers a risk-sharing tool to an investor. However, the interest rates for capital loans are usually higher than the rates of conventional loan, there are often made contracts about an option to change capital loan to company's stocks on the expiration date of a capital loan. The capital loan instrument is much more common among the biotechnology firms than in the entire economy as a finance source (see Hermans and Tahvanainen 2002).

Table 2. The estimated distribution of the sources of finance in Finnish biotechnology firms. Sources: Hermans and Tahvanainen (2002).

	Equity	Capital loans	Debt	Total
A: All (N=72)				
%	55.6 %	24.8 %	19.6 %	100.0 %
(amount, mill.€)				387
B: Breakout by size of SME				
Small	30.5 %	46.1 %	23.4 %	100.0 %
(amount, mill.€)				47
Large	59.0 %	21.9 %	19.1 %	100.0 %
(amount, mill.€)				340
C: Breakout by age of SME				
Infant	54.1 %	35.0 %	10.8 %	100.0 %
(amount, mill.€)				214
Adolescent	57.3 %	19.6 %	23.2 %	100.0 %
(amount, mill.€)				88
Middle-aged	57.4 %	4.3 %	38.3 %	100.0 %
(amount, mill.€)				83
Old	n.a.	n.a.	n.a.	n.a.
(amount, mill.€)				n.a.

This view raises a question about the linkages between the different types of firms. What kind of linkages do exist between the sources of finance and the general features of biotech industry. We utilize variables available from the survey in answering the question mentioned above.

2.3 The principal components interrelated growth and business performance

2.3.1 Variables

Variables are selected by grouping them into two main parts. In the first group, there are 12 variables depicting present economic performance, innovation intensity, and the quality of the labor of the firms. These 8 variables measure economic performance and other present features of firms and the remaining 4 variables depict innovation capacity and activities. The second group consists of 12 variables, as well, presenting the sources of corporate finance. 7 variables measure private sources of finance and 5 variables public sector sources of finance and support. Direct expectations of the firms are taken into account by a single variable, “the anticipated growth rate of sales”. (See table below).

Table 3. The list of variables used in principal component analysis.

Name of group	Name of variable	Measure
Economic performance	Volume of commercial activities Volume of total activities Total turnover per persons employed Profitability Exports intensity Age of firm Solidity	Biotech turnover Number of personnel Total turnover per persons employed Profits per turnover Exports per sales Age in years Equity per (equity + debt)
Innovation activities and personnel skills	R&D intensity Commercialization ability Innovation intensity Business experience of CEO Skilled labor intensity	R&D costs per total costs Biotech turnover per (1+ patent applications + patents) Patent applications per R&D personnel Years in business life of CEO Research trained persons per total personnel
Private sources of finance	Influence of principal owner Individuals active in business as an owner Subsidiary effect Private venture capitalist as an owner Private capital loan intensity Debt from private financial institutions Trade credit intensity	Equity share of principal owner Equity share of individuals active in business Equity share of other non-financial firms Equity share of private venture capitalist Private capital loan share Debt share of private financial institutions Debt share of trade credit
Public sources of finance	Public venture capitalist as an owner Public capital loan intensity Public debt intensity Public R&D finance intensity Public R&D support usage	Equity share of public venture capitalist Public debt per total debt Public debt per total debt Public R&D support per R&D costs of a firm Share of public R&D support paid to academic institutions by firms
Expectations	Anticipated growth of sales	Anticipated annual growth rate of turnover in next 5 years

2.3.2 Method

There are not many empirical studies which cover the entire biotech sector in Finland. Therefore, we rely in this part, too, on the explorative approach. In other words, there is no theoretical framework behind the empirical investigation. We employ principal component analysis (PCA) as a statistical tool. This method is based on the idea not to have preconditions. PCA compresses the multitude of variables to a few components by exploiting the variation between cases. The variables are loaded with the component resulted from the analysis. Accordingly, our methodical goal is to find the components which link together the sources-of-finance and general-features variables from the data of biotech SMEs.

We chose PCA method instead of correlation method. The PCA method is a more powerful tool than simple correlation measures because PCA can partition common variances in data. Correlation tables measure the linkages (common variance) between variables. Due to the contradictions between different groups within data, the correlation method destroys sometimes part of the information a sample contains, which PCA takes into account.

2.3.3 Results

PCA method offered 9 principal components in order to explain the interconnectedness of the structures of financing sources and the general features of the small and medium-sized biotech companies. [2] PCA was performed with different numbers of variables. The results seemed relatively robust. Although the order of the components altered among the last ones, the most highly loaded variables remained the same strongly within the components. We also employed rotated principal component matrix solutions in order to ensure sufficient loadings within the last ordered components, too.

The PCA model explained 72 percent out of the total variation on data (Appendix 2, Table "Total variance explained"). The model explains over 50 percent of the variation on the original variables: the communalities of the single variables are in the range 0.55-0.90 (Appendix 2, Communalities).

The principal components obtained from the analysis can be divided into two fragments. The first fragment contains 3 general components reflecting the general features of the biotech firms. The second fragment is composed of 6 components related mainly to the sources of equity finance. Other forms of finance are also observed in this context. [3]

[2] The general idea of principal component analysis (PCA) is shortly expressed in appendix 1.
[3] The principal component statistics and component loading matrices are presented in appendix 2.

Table 4. General components of the Finnish small medium-sized biotech firms.

”R&D intensityand growth” component	”Public R&D funding” component	”Experienced CEO” component
- High R&D intensity - High growth prospects - High share of debt from public sector - Small company, low biotech turnover - Young - Low current commercialization ability - Low turnover per amount of labor	- High public R&D supports - Intensive research collaboration / High share of public R&D support paid to academic institutions -Low equity share of principal owners	- Long manager's business experience - Relatively old firm - High biotech turnover - Large amount of labor - High exports intensity - Intensive research collaboration / Large share of public R&D support paid to academic collaboration

General components describe the main features of the biotech companies. The features of the components are expressed with the help of adjectives, e.g. "A small and young company with high R&D intensity". The component structure can also be characterized by an opposite expression: "A large and old company with low R&D

The R&D intensity and growth component describes some features that have conventionally been regarded as common to the new biotech companies, particularly the linkage between R&D intensity and high future growth prospects. The component presents how R&D intensity is related to the company's age and size. High R&D intensity is loaded together with the company's low turnover and young age in the component. Simultaneously, low actual commercialization ability is linked with high growth prospects. In other words, the anticipated growth is not based on the already realized commercialization ability but on the ability in the future.

Public R&D support varies together with the Academic R&D collaboration within the "Public R&D funding" component. This is because the public authorities oblige the supported firm to collaborate with external research institutions. For example, TEKES often demands the existence of collaboration network before financing any research project. Within this component the equity share of the principal owners is negatively loaded with the amount of public R&D support. In other words, part of the publicly most supported companies is not controlled by influential owners with high shares of equity.

Management competence is measured simply by the CEO's business experience in years. The business experience of CEO seems to be a general feature within part of the sample and it is not related with the sources of finance. The experienced CEO works in a relatively old and large company with high exports intensity. The CEO also seems to notice the collaboration with academic research institutions.

Two components have high loadings with the equity share of other non-financial companies. These are called here subsidiary components. They show that the parent companies invest in the subsidiaries with the actualized growth of sales. The innovative subsidiaries component indicates that there are some other-firm-owned companies with relatively high biotech turnover and with high innovation intensity. May it be reminded that innovation intensity is the number of patents and patent applications per the number of personnel in R&D activities. Another "subsidiary firm" component simply relates the equity share of the parent company to the size of a subsidiary firm (measured both as in sales volume and the amount of personnel).

The lack of R&D intensity (within the "subsidiary" components) might be explained by the organizational division of activities in multi-functional corporations. R&D activities, sales, and production may be partially organized in separate foreign divisions within the consolidated company. This kind of internal division of activities could explain the seemingly low R&D intensity loadings. The "owners active in business" component is the mirror image of the large subsidiaries component above. There is a large personnel share of research trained staff.[4]

[4] Research trained staff contains the personnel that have a post-graduate degree diploma. That is to say, they have doctor's or licentiate's degrees.

Table 5. Owner-based components

”Innovative subsidiaries” component	”Large subsidiaries” component
- High equity share of principal owners - High equity share of other companies - High innovation intensity - High biotech turnover - High turnover per amount of labor - High debt share of trade credit - Low share of debt from public sector	- High equity share of other companies - Large amount of personnel - High biotech turnover - Low share of post-graduate personnel
”Owners active in business” component	**”Public sector VC* as an owner with high growth prospects” component**
- High equity share of individuals active in business - High share of personnel with a post-graduate degree - Small amount of personnel - Small biotech turnover	- High equity share of public sector venture capitalist - High anticipated growth rate of turnover - High solidity - High debt share of trade credit - High share of capital loans from public authorities - Relatively young companies - Small amount of personnel - Low equity share of principal owners - Low equity share of individuals active in business
”Private VC* company as an owner with high growth prospects” component	**”High R&D intensity and Private VC* company as an owner” component**
- High equity share of private venture capitalist companies - High anticipated growth rate of turnover - High share of debt from domestic financial institutions - Low equity share of principal owners - Low share of capital loans from public authorities	- High equity share of private venture capitalist companies - High R&D intensity - High share of public debt - Low current profitability - Low current exports intensity - Low commercialization ability

**VC stands for Venture Capitalist organization.*

Two components have high loadings with the equity share of private venture capital companies. These two components imply interesting relations to other financing instruments. The “private VC and high growth prospects” component presents how the equity share of private VC’s is varying jointly with the debt share of domestic and private financial institutions (e.g. banks). The “high R&D intensity and private VC” component shows how high private VC investments are related to a relatively high share of public debt. This may be due to the wide monitoring ability of private VCs or private and public debtors. PCA does not tell anything about the causality within the components.[5]

The “private VC and growth prospect” component raises some questions. Why are the growth prospects of the firms not related to any substantial activities (e.g. R&D intensity) or skill inventories (e.g. education of personnel)? Why is the anticipated growth of sales only related to the structures of financing sources? The search for an explanation is possibly two-sided. First, the private VCs can have knowledge and monitoring ability that cannot be revealed from the general quantitative data. The other side of the matter could be a strict demand of high growth rates which in turn produce counter-cyclically high revealed growth rates in expected earnings. Both of the two last mentioned components have some parallel loadings with equity share of private VCs and academic research collaboration. Simultaneously, the public sector R&D support seem to remain insignificant.

The “public sector VC and high growth prospects” component also points out the relation between the equity source and growth expectations. Furthermore, public VCs (mainly Sitra) seem to have invested in the young and small companies. They finance jointly by purchasing the equity and by offering capital loans. Due to this financing method the companies’ solvency ratios are high. This component reflects the negatively correlated relation between the public finance intensity and equity share of principal owners. The public sector has not been willing to finance companies with a high share of equity owned by individual entrepreneurs.

2.3.4 Discussion

The general view of the data expresses three bundles of characteristics. These bundles are not related to any specific ownership structures. First, some of the most R&D intensive firms seem to be recently established and the amount of their sales of biotechnology services or products is small. The R&D intensive firms announced that the more their costs contained R&D expenses, the higher were their growth prospects. Secondly, public R&D finance seems to be related to the spending on academic

[5] Darby and Zucker (2002) states that the proper science base increases the probability for the biotechnology company to go public.

research collaboration. This might be the result of preconditions of public sector R&D support decisions. Some public authorities demand firms to have external collaboration with academic institutions. Third, CEO's experience is related to some features of business activities. The experienced CEO works in matured companies with a large number of personnel and a large amount of sales. International trade relations also seem to be subject to the long business experience of CEO.

The general view implied strong links between the companies' intellectual capital and anticipated growth rates only in the "R&D intensity" component. Low realized commercialization ability of the young (but not necessarily small in personnel) company is related to high growth prospects. Ownership structure is also related in some parts to the high level of the anticipated growth rates of sales. Especially the companies that were owned or capital loan financed by private or public VCs announced high growth prospects in their sales volumes. Baysinger, Kosnik and Turk (1991) find the similar type of relationship among large public companies in the US. Accordingly, large equity share owned by institutional investors imply high R&D intensity. This raises the need of further research to investigate what kind of systematic explanations there are for the companies' growth expectations in the Finnish Biotech industry.

3. INPUT-OUTPUT MODEL

Econometric modeling procedure utilizes input-output analysis. We utilize input-output tables in order to estimate growth prospects covering the whole economy for the next five years.

3.1 The construction of the input-output model

We also utilize in this section a survey conducted by ETLA. The survey contains financial and business activity information on 84 Finnish biotechnology firms. A problem of aggregating the data arises due to the fact that there were 119 biotechnology firms active at the end of 2001. Furthermore, the sample seems to be slightly biased among the age groups. For example, the sample contains only 53 percent of the companies founded 1997-2001 and even 82 percent out of the older companies. In order to form plausible aggregations to depict the entire biotechnology field in Finland, we constructed weights according to the age groups of the firms. This to say, the weights are inverses of the percentage shares of the sample in different age groups.

Table 6. The count of biotechnology firms in the sample of ETLA survey and Total population.

	before 1991	1991-1996	1997-2001
The ETLA sample	25	34	25
The total population	29	43	47
Percentage share of sample	86 %	79 %	53 %

We established future sales figures according to the firms' announcements. The biotechnology firms expect successful growth potential in the next 5 years, in 2001-2006. Even the youngest firms expect some commercialization potential during the 5 years. The estimation of future sales was performed by weighting the biotechnology turnover of each firm.

A conventional input-output matrix was constructed in the following way.[6] The input-output production model presents interconnections between all the industrial and service branches.

(1)

$$x_i = \sum_{j=1}^{n} a_{ij} x_j + y_i = x = Ax + y = \begin{bmatrix} x_1 \\ x_2 \\ \cdots \\ \\ \\ \\ x_n \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & & \\ \cdots & & \cdots & \\ & & & \\ & & & \\ & & & \\ a_{n1} & & & a_{nn} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \cdots \\ \\ \\ \\ x_n \end{bmatrix} + \begin{bmatrix} y_1 \\ y_2 \\ \cdots \\ \\ \\ \\ y_n \end{bmatrix}$$

Coefficient a is counted as a dividence: $a_{ij} = \frac{x_{ij}}{x_j}$, in which x_j is the intermediary and final output produced by the industry. The term x_{ij} depicts how much the industry j uses the production of the industry i as an input.

Because $x = Ax + y \Leftrightarrow y = (I - A)x \Leftrightarrow x = (I - A)^{-1} x$. Therefore,

(2)

$$x_i = \sum_{i=1}^{n} b_{ij} y_i = x = (I - A)^{-1} y = \begin{bmatrix} x_1 \\ x_2 \\ \cdots \\ \\ \\ \\ x_n \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & & \\ \cdots & & \cdots & \\ & & & \\ & & & \\ & & & \\ b_{n1} & & & b_{nn} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ \cdots \\ \\ \\ \\ y_n \end{bmatrix},$$

when $[b_{ij}] = (I - A)^{-1}$. Presented in other way:

[6] See e.g. Forssell (1985) and Ciaschini (1989).

$$(3) \qquad (I-A)=\left[\begin{bmatrix} 1 & 0 & \cdots & & 0 \\ 0 & 1 & & & \\ \cdots & & \cdots & & \\ & & & & \\ 0 & & & & 1 \end{bmatrix} - \begin{bmatrix} a_{11} & a_{12} & \cdots & & a_{1n} \\ a_{21} & a_{22} & & & \\ \cdots & & \cdots & & \\ & & & & \\ a_{n1} & & & & a_{nn} \end{bmatrix}\right]^{-1}$$

$$= \begin{bmatrix} 1-a_{11} & -a_{12} & \cdots & & -a_{1n} \\ -a_{21} & 1-a_{22} & & & \\ \cdots & & \cdots & & \\ & & & & \\ -a_{n1} & & & & 1-a_{nn} \end{bmatrix}^{-1} = \begin{bmatrix} b_{11} & b_{12} & \cdots & & b_{1n} \\ b_{21} & b_{22} & & & \\ \cdots & & \cdots & & \\ & & & & \\ b_{n1} & & & & b_{nn} \end{bmatrix}$$

b_{ij} expresses how much the industry i needs to produce so that the industry j could produce one unit of final product j. Doing these matrix operations we are able to use coefficients of the inverse matrix when we estimate the effects of the growth in biotechnology industry in Finland.[7] The biotechnology firms were set to the industrial and service branches best fitting on their activities.

3.2 Forecast results

Table 7 presents the main results of the forecast procedure. The overall contribution of biotechnology business is slightly positive for the economic growth in Finland. Gross domestic product (GDP) is expected to grow 0.21 percentage units by the increase of biotechnology. The growth potential is distributed unequally to the economy. The chemical industry has the highest growth effects. If the firms' anticipations came true, the chemical industry would enhance its nominal production 3.1 percentage units in annual terms. Food and feed industry and electronics industry are not affected as

[7] Appendix 3 presents the coefficients of the 25 branch inverse matrix that was used in the forecasting procedure.

strongly as the case is in the production of chemicals. The annual growth contribution to their nominal production is estimated to be 0.3 percentage units.

Table 7. The anticipated nominal growth contributions of biotechnology sales in annual terms.

Branch	**Annual growth contribution, percentage units**
Agriculture	0.13 %
Forestry	0.05 %
Industrial production	0.55 %
Chemistry	*3.1 %*
Food and feed	*0.3 %*
Electronics	*0.3 %*
Construction	0.03 %
Services	0.10 %
GDP	**0.21 %**

The service sector forms the largest sector in the Finnish economy; the sector produces 63 percent of the GDP. Mirrored to this fact, the growth contribution of 0.1 % does not seem insignificant. In terms of euros, the contribution is 360 million euros during 2002-2006. There are also some impacts reflected to the other branches, agriculture, forestry and construction.

We held here anticipated exports as the only exogenous variable. This means that the increase in domestic production resulted from the input-output table. If at least part of the domestic production had been held as exogenous, the growth rates would have been slightly, not tremendously, higher.

One can argue whether the outcome of the forecast is reliable, or, how reliable it is. There are two main suspicions. The first is related to the great risk in developing new biotechnology innovations and particularly in converting them into commercially exploitable products. Second, there are doubts about the expected short time interval (here 5 years) for changing large losses to flourishing business.

4. CONCLUSIONS

The foresight study is intended to offer important insights into biotechnological industry's anticipated impacts on the Finnish economy. The impacts can be observed from two viewpoints. First, we present how public finance affects the development of scientific collaboration, business activities and the growth potential of firms. Secondly, analysis is presented on how private firms affect the growth of the whole economy. The study focuses on the economy-wide impacts of converting expected potential into real economic growth.

The linkages between finance and business prospects were searched by principal component analysis (PCA) among Finnish small and medium-sized biotechnology firms. The PCA method found three principal components not related to some specific class of owners. First, the "R&D intensity and growth" component describes some features that have conventionally been regarded as common to the new biotech companies, particularly the linkage between R&D intensity and high future growth prospects. These companies are also young and they do not yet have high sales volume. The second component stresses the role of public R&D support and academic R&D collaboration between the firms and research institutes. This is partially due to the workings of public authorities. They oblige the research collaboration for the firms they support. Third, there seem to exist firms with highly experienced CEOs. These firms are relatively large, in terms of turnover, personnel and export intensity. The firms see also the importance of research collaboration.

Several components related to ownership structures of the firms were found. The role of public and private venture capital organizations (VC) came up. There was a relation between the large ownership share of VCs and the high anticipated growth of turnover, but there was no R&D or commercialization based substance behind them. On the contrary, there was also a private VC related component that had high loadings with the R&D intensity but not with the anticipated growth. The VC related anticipated growth of sales raises a question about the monitoring ability of VCs. They have possibly some ability to monitor firms in ways that are not showing in the general data. Or, the firms owned by VCs must have higher growth prospects than others in order to get access for the finance.

The national growth forecast was based on the survey on the 84 Finnish biotechnology firms. The data was converted by age group weights to approximate the entire biotechnology industry in Finland (119 firms at the end of 2001). The growth prospects were estimated by firms' announcements about their growth in 2002-2006. These growth rates were related to official statistics. In this procedure we employed input-output analysis.

The high percentage growth prospects of the Finnish biotechnology industry remained relatively moderate as aggregated for the entire economy. The growth contribution for the Finnish nominal GDP growth was 0.2 percentage units annually. However, a noticeable impact on the chemical industry was seen. According to the anticipations, the biotechnology firms add 3.1 percentage units to the nominal growth of chemical production in Finland. The most of the biotechnology firms act in chemicals-related subindustries. The impact in other economic fields was not as substantial, but there was some positive contribution to other sectors, too.

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Appendix 1: Short expression of Principal Component Analysis (PCA).

PCA method forms as many linear combinations as there are variables (see e.g. Sharma 1996). However, we restrict the number of linear combinations to the number of components, p. The pth component is the last one the eigenvalue of which is more than one. Presenting formally:

(A1)
$$\begin{aligned} x_1 &= w_{11}x_1 + w_{12}x_2 + \dots + w_{1\,25}x_{25} \\ x_2 &= w_{21}x_1 + w_{22}x_2 + \dots + w_{2\,25}x_{25} \\ &\vdots \\ x_p &= w_{p1}x_1 + w_{p2}x_2 + \dots + w_{p\,25}x_{25} \end{aligned}$$

The components are uncorrelated within each other. The first component accounts the maximum variance in the data and the second one accounts the variance not captured****(oletko varma tästä capture-sanan käytöstä?)* by the first component, and so on.

It is necessary to restrict the growth of variance of a single component by fixing the scale of weights. Then there is no limitation to add new variables and compare the results. Formally speaking, the sum of the squares of the weights within a component always equals one:

(A2)
$$w_{i1}x_1 + w_{i2}x_2 + \dots + w_{i\,25}x_{25} = 1, \quad \mathrm{i} = 1, \dots p$$

and

(A3)
$$w_{i1}w_{j1} + w_{i2}w_{j2} + \dots + w_{i\,25}w_{j\,25} = 0, \quad \text{for all } i \neq j\,.$$

In other words, the new linear combinations are orthogonal to each other and they are uncorrelated with each other.

Appendix 2. Results on biotech data compression.

Communalities[a]

	Initial	Extraction
biotech turnover in meuros	1.000	.778
personnel	1.000	.539
total turnover per labor	1.000	.855
profitability (profits per turnover)	1.000	.691
innovation intensity (patent applications per r&d labor)	1.000	.758
commercialization ability (turnover per (1+patent applications+patents))	1.000	.657
post-graduated labor per total labor	1.000	.666
r&d costs per total costs	1.000	.627
public r&d support per r&d costs	1.000	.639
Solidity (equity+caploans per equity+debt)	1.000	.621
principal owner share of equity	1.000	.677
share of equity active in business	1.000	.902
Other firms' equity share	1.000	.788
public debt per total debt	1.000	.714
debt share of domestic private financial institutions	1.000	.854
debt share of trade credit	1.000	.758
exports per turnover	1.000	.546
Anticipated annual growth rate of turnover	1.000	.704
Manager's business experience in years	1.000	.779
Public venture capitalists' equity share	1.000	.747
equity share of private venture capitalist	1.000	.756
private capital loans per eq+cl	1.000	.805
public capital loans per eq+cl	1.000	.739
share of public r&d support used in university research	1.000	.799
age of firm	1.000	.628

Extraction Method: Principal Component Analysis

a. Only cases for which SME biotech firm = 1 are used in the analysis phase.

Appendix 2, continues.

Total Variance Explained[a]

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.409	17.635	17.635	4.409	17.635	17.635	2.641	10.565	10.565
2	2.721	10.883	28.518	2.721	10.883	28.518	2.569	10.277	20.841
3	2.215	8.861	37.379	2.215	8.861	37.379	2.106	8.423	29.265
4	1.881	7.524	44.903	1.881	7.524	44.903	2.073	8.293	37.558
5	1.797	7.188	52.091	1.797	7.188	52.091	1.938	7.752	45.310
6	1.544	6.174	58.265	1.544	6.174	58.265	1.883	7.532	52.842
7	1.262	5.049	63.314	1.262	5.049	63.314	1.806	7.225	60.066
8	1.116	4.464	67.777	1.116	4.464	67.777	1.648	6.590	66.656
9	1.084	4.336	72.113	1.084	4.336	72.113	1.364	5.457	72.113
10	.979	3.915	76.028						
11	.926	3.703	79.731						
12	.814	3.256	82.987						
13	.809	3.238	86.225						
14	.603	2.412	88.637						
15	.520	2.082	90.719						
16	.430	1.721	92.439						
17	.350	1.398	93.838						
18	.316	1.266	95.104						
19	.303	1.214	96.317						
20	.251	1.005	97.323						
21	.214	.858	98.180						
22	.154	.615	98.796						
23	.123	.491	99.287						
24	.110	.440	99.727						
25	6.833E-02	.273	100.000						

Extraction Method: Principal Component Analysis.

a. Only cases for which SME biotech firm = 1 are used in the analysis phase.

Appendix 2, continues.

Component Matrix[a,b]

	Component								
	1	2	3	4	5	6	7	8	9
total turnover per labor	.821	-1.87E-02	-.207	.178	.195	-.104	.189	-6.12E-02	.136
biotech turnover in meuros	.783	.251	-8.65E-03	.241	5.382E-02	-.134	.118	-6.72E-02	-5.98E-02
Other firms' equity share	.639	.398	-.179	-6.12E-02	-.293	-3.17E-03	-7.03E-02	.136	-.277
commercialization ability (turnover per (1+patent applications+patents))	.568	5.381E-02	-.287	-.370	.216	-.135	.139	5.111E-02	.158
age of firm	.554	2.465E-03	.373	-.222	6.283E-02	6.218E-02	-.275	7.393E-02	.210
r&d costs per total costs	-.523	.140	5.261E-02	.429	-.177	5.831E-03	-.188	.284	3.709E-04
principal owner share of equity	.508	-.372	-9.43E-02	.261	-.408	-.108	-1.10E-02	2.096E-02	-.154
exports per turnover	.505	-1.54E-02	.328	-.141	8.274E-02	.247	-2.79E-02	.110	.289
public debt per total debt	-.468	.361	-5.78E-02	1.078E-02	-.279	-.464	3.983E-02	5.759E-05	.256
share of equity active in business	-.259	-.764	.399	.199	3.910E-02	-1.20E-03	-5.76E-02	-5.00E-02	.211
post-graduated labor per total labor	-.218	-.639	-1.98E-02	.194	.342	-.132	-.176	-6.90E-02	3.801E-02
share of public r&d support used in university research	3.994E-02	.615	.483	.250	.125	.108	-.107	-.282	6.986E-02
personnel	.292	.436	.382	-9.64E-02	-2.19E-02	-8.88E-02	-.245	.184	-8.58E-02
debt share of domestic private financial institutions	-8.29E-02	-4.42E-02	.593	-.377	.229	.272	.320	-.139	-.321
Public venture capitalists' equity share	-.248	.288	-.537	-.198	.441	4.302E-02	.239	-4.74E-02	.139
innovation intensity (patent applications per r&d labor)	.341	-1.84E-03	4.606E-03	.577	-9.41E-02	2.949E-03	-4.20E-02	-.393	-.380
debt share of trade credit	.340	-.261	-.205	.408	.528	.165	-8.44E-02	.210	-9.07E-02
equity share of private venture capitalist	-.324	.157	.314	2.529E-04	.523	-.331	.109	.118	-.346
Solidity (equity+caploans per equity+debt)	-3.96E-02	.280	-.329	.365	.428	.229	-6.32E-02	-.175	.171
profitability (profits per turnover)	.366	-.345	5.412E-02	-.119	-.209	.587	.170	1.104E-02	5.749E-02
public capital loans per eq+cl	-.307	.172	-.419	2.455E-02	-.183	.541	-.279	.184	-1.47E-02
private capital loans per eq+cl	-4.06E-02	-3.37E-03	.119	.335	-.331	-6.90E-02	.696	-5.30E-02	.274
Anticipated annual growth rate of turnover	-.349	.143	-8.39E-04	.182	1.516E-02	.350	.433	.383	-.268
Manager's business experience in years	.190	.240	.387	.433	.151	-1.12E-02	5.713E-02	.494	.278
public r&d support per r&d costs	-.286	.405	.160	.135	-2.48E-02	.370	-5.80E-02	-.418	.186

Extraction Method: Principal Component Analysis.

a. 9 components extracted.

b. Only cases for which SME biotech firm = 1 are used in the analysis phase.

Appendix 2, continues.

Rotated Component Matrix[a,b]

	Component								
	1	2	3	4	5	6	7	8	9
r&d costs per total costs	-.673	-.119	-.297	-1.53E-02	-1.38E-02	.200	9.059E-02	-.151	3.932E-02
commercialization abilit (turnover per (1+patent applications+patents))	.633	.307	.124	-.124	.205	2.345E-02	-.287	-6.32E-02	-4.55E-02
total turnover per labor	.626	.190	.193	.400	.292	.236	-.213	-.159	.135
Anticipated annual growth rate of turnover	-.604	.153	.136	-9.16E-02	.221	6.637E-02	-.115	.354	.313
public capital loans per eq+cl	-.580	.203	.231	-.200	.258	-.171	9.172E-02	-.337	-.224
age of firm	.445	7.242E-02	.291	-2.52E-02	-.249	.428	8.671E-02	-4.11E-02	-.291
share of equity active in business	-7.52E-02	-.883	.157	1.830E-02	-.270	7.994E-02	-5.22E-02	2.082E-02	8.930E-02
Other firms' equity share	.162	.754	.117	.313	-9.81E-02	.109	-.145	-.154	-.126
post-graduated labor per total labor	2.676E-03	-.748	-5.74E-02	9.715E-02	.122	-7.80E-02	-.217	7.902E-03	-.161
profitability (profits per turnover)	5.042E-02	1.076E-03	.809	3.993E-02	-.101	-2.83E-02	-5.41E-02	-6.37E-02	.118
public debt per total deb	-.152	9.627E-02	-.651	-.298	-.149	-5.69E-02	.157	-.216	.270
exports per turnover	.361	5.445E-02	.446	-7.53E-02	-9.50E-02	.432	9.635E-02	-3.92E-03	-5.57E-02
innovation intensity (patent applications per r&d labor)	3.521E-03	3.457E-02	1.955E-02	.853	3.766E-02	-5.39E-02	.152	-2.21E-02	3.425E-02
principal owner share of equity	.117	1.957E-02	.223	.543	-.282	8.420E-03	-.360	-.311	.111
biotech turnover in meuros	.470	.399	6.396E-02	.519	.114	.316	-3.99E-02	-4.54E-02	9.010E-02
Solidity (equity+caploan per equity+debt)	-3.73E-02	-1.74E-02	-5.58E-02	.111	.705	5.504E-02	.291	-.127	-5.19E-02
Public venture capitalists equity share	7.193E-02	.154	-.180	-.386	.674	-.273	-2.44E-03	6.559E-02	5.424E-02
debt share of trade credi	5.045E-02	-.219	.220	.365	.545	.296	-.315	2.089E-02	-.203
Manager's business experience in years	-8.93E-02	1.969E-02	-4.09E-02	3.927E-02	8.321E-02	.853	2.364E-02	2.375E-02	.180
personnel	.103	.387	-9.42E-02	3.066E-02	-.253	.440	.161	.126	-.265
public r&d support per r&d costs	-.184	3.003E-02	2.930E-02	-5.58E-02	.127	-6.58E-02	.758	-1.57E-02	6.471E-02
share of public r&d support used in university research	1.857E-02	.185	-.151	.169	1.990E-02	.362	.738	.192	-2.38E-02
debt share of domestic private financial institutions	5.752E-02	-5.00E-02	.306	-.133	-.218	-6.09E-02	.206	.802	1.006E-02
equity share of private venture capitalist	-8.05E-02	-.119	-.474	-4.17E-02	.104	.145	-4.44E-02	.680	-.115
private capital loans per eq+cl	-3.07E-02	-3.28E-02	6.537E-03	7.767E-02	-7.35E-02	7.612E-02	6.021E-02	-3.61E-02	.884

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 22 iterations.

b. Only cases for which SME biotech firm = 1 are used in the analysis phase.

Appendix 2, continues.

Component Transformation Matrix[a]

Component	1	2	3	4	5	6	7	8	9
1	.630	.353	.379	.427	-.028	.306	-.186	-.136	-.073
2	-.074	.739	-.348	-.103	.196	.211	.479	.058	.001
3	.032	-.231	.069	.014	-.570	.491	.372	.486	.030
4	-.362	-.247	-.155	.665	.283	.355	.110	-.218	.277
5	.281	-.295	-.102	-.087	.673	.199	-.015	.477	-.308
6	-.363	.070	.824	-.083	.254	-.026	.321	.026	-.084
7	.106	.124	.117	-.066	.152	-.117	-.165	.407	.852
8	-.379	.175	.042	-.318	-.004	.580	-.620	-.002	-.047
9	.316	-.277	.030	-.495	.121	.323	.266	-.548	.296

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Only cases for which SME biotech firm = 1 are used in the analysis phase.

Appendix 3. Input-output inverse matrix with coefficients by 25 branches.

	Agriculture	Forestry	Mining	Food	Textiles	Wood	Paper	Graphic	Oil	Chemicals	Plastics	Non-met	BasMetal	Machinery	Electronics	Vehicles	Other ind	Energy	Construction	Wholesale	Hotels	Infrastr	Residential	Public sector	Other serv
Agriculture	1.134	0.001	0.006	0.419	0.005	0.003	0.006	0.006	0.002	0.006	0.004	0.004	0.003	0.004	0.003	0.003	0.003	0.004	0.003	0.007	0.106	0.004	0.002	0.008	0.005
Forestry	0.004	1.023	0.005	0.007	0.003	0.368	0.108	0.017	0.002	0.006	0.006	0.009	0.004	0.003	0.002	0.003	0.054	0.010	0.027	0.003	0.004	0.004	0.005	0.002	0.002
Mining	0.009	0.000	1.023	0.007	0.003	0.003	0.014	0.003	0.002	0.017	0.004	0.038	0.021	0.004	0.002	0.004	0.003	0.040	0.024	0.002	0.003	0.003	0.005	0.001	0.001
Food	0.139	0.002	0.018	1.325	0.011	0.009	0.019	0.018	0.006	0.019	0.012	0.011	0.010	0.011	0.008	0.010	0.009	0.011	0.008	0.020	0.313	0.012	0.005	0.022	0.016
Textiles	0.007	0.001	0.006	0.004	1.119	0.002	0.002	0.002	0.001	0.002	0.002	0.007	0.002	0.003	0.002	0.005	0.002	0.002	0.007	0.002	0.003	0.002	0.001	0.001	0.002
Wood	0.006	0.001	0.008	0.007	0.004	1.108	0.040	0.009	0.002	0.007	0.007	0.015	0.006	0.006	0.003	0.005	0.148	0.013	0.079	0.003	0.005	0.008	0.010	0.002	0.003
Paper	0.025	0.002	0.034	0.064	0.026	0.030	1.283	0.196	0.017	0.050	0.046	0.040	0.024	0.020	0.017	0.018	0.035	0.078	0.016	0.023	0.027	0.013	0.022	0.019	0.020
Graphic	0.012	0.002	0.013	0.030	0.014	0.008	0.009	1.036	0.006	0.012	0.010	0.012	0.007	0.012	0.011	0.010	0.017	0.005	0.007	0.029	0.023	0.015	0.006	0.046	0.031
Oil	0.016	0.007	0.019	0.012	0.005	0.009	0.010	0.006	1.076	0.025	0.008	0.015	0.034	0.007	0.004	0.006	0.007	0.012	0.008	0.009	0.006	0.023	0.008	0.005	0.005
Chemicals	0.074	0.002	0.032	0.038	0.034	0.023	0.050	0.021	0.011	1.135	0.109	0.026	0.014	0.014	0.008	0.015	0.034	0.012	0.026	0.009	0.013	0.006	0.006	0.005	0.008
Plastics	0.017	0.001	0.007	0.021	0.018	0.004	0.006	0.004	0.005	0.012	1.030	0.013	0.004	0.007	0.009	0.011	0.018	0.012	0.021	0.017	0.008	0.007	0.004	0.002	0.005
Non-met	0.005	0.001	0.008	0.008	0.004	0.008	0.004	0.003	0.001	0.006	0.005	1.096	0.004	0.004	0.002	0.010	0.007	0.003	0.078	0.004	0.005	0.008	0.008	0.002	0.002
BasMetal	0.008	0.001	0.018	0.011	0.006	0.009	0.013	0.006	0.006	0.012	0.013	0.026	1.490	0.128	0.025	0.075	0.013	0.026	0.027	0.005	0.006	0.006	0.007	0.004	0.003
Machinery	0.034	0.002	0.074	0.032	0.012	0.023	0.024	0.015	0.012	0.022	0.018	0.052	0.017	1.168	0.017	0.124	0.043	0.034	0.105	0.008	0.014	0.021	0.016	0.010	0.005
Electronics	0.008	0.002	0.017	0.010	0.008	0.007	0.009	0.010	0.006	0.008	0.009	0.010	0.008	0.028	1.227	0.024	0.014	0.016	0.022	0.014	0.009	0.017	0.006	0.011	0.016
Vehicles	0.003	0.000	0.013	0.003	0.004	0.003	0.003	0.003	0.001	0.002	0.003	0.004	0.003	0.012	0.003	1.062	0.003	0.003	0.016	0.002	0.002	0.015	0.002	0.001	0.001
Other ind	0.001	0.000	0.002	0.001	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.006	1.053	0.001	0.010	0.003	0.002	0.002	0.001	0.002	0.004
Energy	0.050	0.002	0.052	0.048	0.025	0.040	0.127	0.037	0.047	0.069	0.039	0.046	0.076	0.026	0.014	0.025	0.032	1.344	0.025	0.025	0.026	0.015	0.077	0.022	0.020
Construction	0.026	0.008	0.038	0.026	0.010	0.020	0.024	0.020	0.009	0.016	0.014	0.024	0.013	0.014	0.007	0.015	0.014	0.019	1.030	0.016	0.034	0.086	0.103	0.009	0.011
Wholesale	0.103	0.030	0.033	0.054	0.016	0.025	0.019	0.028	0.036	0.021	0.018	0.020	0.034	0.025	0.020	0.025	0.018	0.016	0.108	1.077	0.076	0.058	0.024	0.051	0.071
Hotels	0.003	0.003	0.009	0.007	0.006	0.006	0.007	0.027	0.004	0.006	0.009	0.007	0.007	0.008	0.006	0.006	0.006	0.006	0.004	0.007	1.007	0.010	0.002	0.008	0.008
Infrastr	0.057	0.011	0.191	0.124	0.058	0.113	0.105	0.119	0.040	0.078	0.064	0.124	0.090	0.059	0.035	0.048	0.073	0.051	0.070	0.107	0.049	1.099	0.017	0.045	0.056
Residential	0.010	0.002	0.009	0.015	0.019	0.008	0.006	0.019	0.008	0.007	0.012	0.011	0.008	0.012	0.013	0.010	0.019	0.005	0.009	0.052	0.116	0.016	1.153	0.006	0.019
Public sector	0.006	0.001	0.012	0.012	0.011	0.007	0.008	0.015	0.008	0.009	0.012	0.010	0.010	0.014	0.015	0.011	0.010	0.009	0.006	0.022	0.023	0.006	0.004	1.062	0.024
Other serv	0.067	0.005	0.176	0.106	0.093	0.050	0.059	0.228	0.042	0.065	0.072	0.078	0.064	0.115	0.080	0.131	0.077	0.057	0.048	0.086	0.158	0.052	0.085	0.083	1.102

See equation 3.