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AGGLOMERATION AND SPECIALISATION PATTERNS OF FINNISH BIOTECHNOLOGY – On the Search for an Economic Rationale of a Dispersed Industry Structure

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ABSTRACT: This study sets out to inspect empirically whether existing theory in Geographical Economics (GE) is able to provide a rationale for the controversial and much debated structure of the highly knowledge- and research-intensive biotechnology industry in Finland. In addition to providing evidence of GE in action, we integrate the effects that active public technology policy might have on geographic structures of industries into our analysis as a novel discourse. The results provide evidence of a theory based rationale that is able to deepen our understanding of the roles that different regions have enacted in the development of the case industry. Simultaneously, however, the rationale also reveals several challenges that different types of regions still have to overcome in order to steer on a track of sustainable economic development in the future. Based on the results we argue that public sector funding has enabled certain regions to develop in ways that otherwise would not be sustainable.

KEYWORDS: Geographical economics, regional agglomeration, regional specialisation, regional integration

1 Introduction

1.1 Objectives and Empirical Setting

This study sets out to inspect empirically whether existing theory in Geographical Economics (GE) is able to provide a rationale for the controversial and much debated structure of the highly knowledge- and research-intensive biotechnology industry in Finland. In contrast to its extensive theoretical contributions the GE literature seems to suffer from scarce empirical research. In addition to providing evidence of GE in action, we integrate the effects that active public technology policy might have on geographic structures of industries into our analysis as a novel discourse. Very active public innovation policies characteristic of most of the Scandinavian economies enable us to analyse its interaction with the studied GE framework.

While variables proxying the traditional phenomena of GE will be mainly derived from theoretical discourses by Krugman (1991a), Krugman and Venables (1996), Brezis and Krugman (1997), as well as Duranton and Puga (2001), the distribution of corporate financing from different public and private institutions function as an expression of implemented technology policy.

Our empirical focus on biotechnology is grounded in the above-cited discourses that award a vital role to the intra-industry trade of intermediate inputs in determining geographical location. With knowledge being a critical value-driver and a disproportionately central input in the business of biotechnology as a knowledge-intensive business, we expect the industry to react especially sensitively to the effects of intra-industry trade of knowledge that we capture by observing R&D collaboration patterns in our data. Thus, we expect the biotechnology industry to provide us with a formidable testing-ground for the GE literature.

Once a rationale for the geographic structure of our case industry has been established, we will be able to discuss its economic justification. In pursuing this objective, we particularly aim to identify conditions under which knowledge-intensive businesses can be expected to thrive in locations of dense agglomeration, on the one hand, and in significantly smaller geographical peripheries on the other. The results will enable us to form implications that can be applied in public innovation policy design.

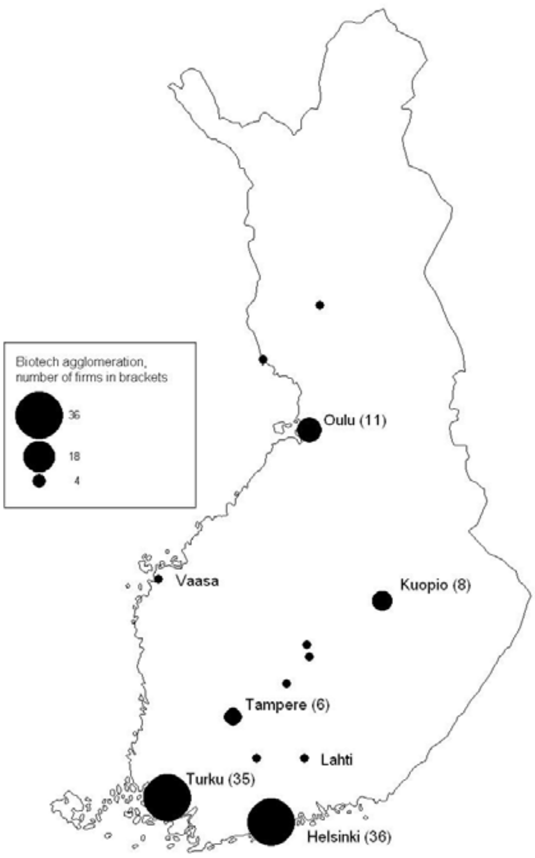
Our analysis is based on data retrieved from a population of 111 Finnish small and medium sized companies active in various sectors of the biotechnology industry. This population-wide data encompasses information on company size and location. To answer our research agenda we additionally employ a more detailed subsample of 62 companies encompassing a much broader scope of data. An overview of the data is provided in Hermans, Kulvik and Tahvanainen (2006). The Finnish biotechnology industry is chosen for its pronouncedly dispersed and multi-centred geographical structure that enables us to observe firms in very dissimilar locations and conditions within the same sample (Hermans and Tahvanainen, 2006). Moreover, the quality of firm level data and precise information on firm co-ordinates necessary to construct measures for spatial agglomeration speak in favour of reverting to Finnish data sets.

To enrich the background of our empirical setting, Section 1.2 proceeds with a brief discourse on the key aspects of the geographical structure of the sample industry. Section 2 encompasses the treatment of literature that this study leans on, and proposes estimates for the industry structure that we expect to confirm by means of a principal component analysis (PCA) in Section 3. Preceding the PCA, however, Section 3 also provides extensive descriptive results highlighting the relevant specificities of the underlying data regarding the phenomena of agglomeration, specialisation and public funding. In Section 4 we deliver the results of the analysis and discuss them. Section 5 provides conclusions pointing out potential public policy impacts and prospective avenues for complementary research.

1.2 Background – The Finnish Biotechnology Industry on the Map

Finland's small and medium sized biotechnology industry is agglomerated around several geographically dispersed locations. These are the Helsinki, Turku, Tampere, Kuopio and Oulu regions, of which the Helsinki and Turku regions alone account for two thirds of the industry's ca. 120 firms including large biotechnology companies. All five regions boast universities active in biotechnological research. Figure 1.1 shows their geographical distribution.

Figure 1.1 Geographical Distribution of Finnish Biotechnology SMEs



There is an obvious discrepancy between the relatively small size of the country, that of the resident biotechnology industry and the relatively large number of agglomerated hubs. These hubs also all feature biotechnology centres providing facilities and services to the resident companies. These centres are the outcome of the national innovation policy of the early 1990s that focused strongly on regional development. A decade later criticism has been heard of the establishment and maintenance of five separate hubs as being inefficient in the sense that the industry is dispersed across the country impeding the formation of a critical mass needed to spur the industry's so far modest internally generated growth (e.g. Kafatos et al. 2002).

To make the discrepancy more plastic and tangible, we can compare the ratio of country/industry size and the number of established hubs to that of the USA, the world leader in biotechnology. In raw numbers, the USA has a surface area 30 times larger than that of Finland, a GDP 74 times larger than the Finnish equivalent[1], and a biotechnology industry ten times the size of Finnish biotechnology measured by the number of firms. In terms of total sales the US biotechnology industry outweighs the Finnish by a factor of 118 (Nationmaster, 2006). Given these numbers, the USA has only two major and seven minor regions of agglomeration in the biotechnology industry with the former being Boston and the San Francisco Bay Area. Resources are more concentrated and single hubs constitute by far larger units than those in Finland. A critical mass of companies forming a self-nourishing cluster can be envisioned with ease in this setting. In the light of the figures the criticism of the multi-centred structure of Finnish biotechnology seems reasonable at first glance.

While it is argued to be a disadvantage for the competitiveness of the Finnish biotechnology industry, the spatial dispersion together with emerging regional patterns of specialisation discussed further below provide a fascinating opportunity for testing GE based theories that, although fragmented in their foci, deal in-depth with these phenomena. In this study we will draw from a broad range of approaches present in the contemporary GE literature in an attempt to capture the rationale of the industry structure under study in all its facets.

1.3 Approach

One potential approach for the analysis is first to explore the reasons behind the spatial structure of industrial activities as driven by market structure. Agglomeration and specialisation are two key dimensions thereof. Once we are able to establish an economic rationale for the phenomena of agglomeration and specialisation, we are able to argue whether our sample industry's geographical structure is economically justifiable in the light of these results.

The Geographical Economics literature to be reviewed shortly suggests several economic drivers behind the agglomeration and specialisation of industries that have to be integrated into the analysis. These drivers, based on the assumption of a monopolistically competitive market structure, comprise regional labour pooling and knowledge spillovers, intra-industry linkages, transaction costs, regional market size, the degree of regional specialisation and the degree of integration between regions. Taking these drivers into account, firms choose their respective locations in an attempt to maximise their profits. In a fully dynamic setting, so the literature argues, the industry will find an equilibrium in which the empirical observer should be looking at a geographical structure that features diversified, densely agglomerated but innovative centres co-existing with peripheral, small but highly specialised hubs.

In order to test whether the GE based theories are able to explain the spatial structure of the industry under study in this paper we need to analyse the interaction of the above-mentioned drivers and examine to what extent these interactions correlate with the phenomena of agglomeration and specialisation in our data. To this end we will revert to a principal component analysis detailed in Section 3.

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1 The USA spends 0.77 % of GDP on R&D compared to 0.93 % in Finland.

From the perspective of the policy maker there are two questions that need to be addressed in detail. First, given that supernormal profits will not be sustained in the long-run due to free entrance as well as uninhibited mobility of companies and labour between regions, what is the penalty for not locating in or close to either type of hub? And second, how does the Scandinavian type of active regional innovation policy as a major provider of financing affect the formation of the hubs as predicted by theory? By freezing the industry's movement towards its equilibrium distribution using a static cross-sectional data set we should be able to empirically observe differences in the typology of firms that already reap the theory-predicted benefits of locating in agglomerated or specialised regions, on the one hand, and those that are established in more peripheral or unspecialised regions, on the other. That should give us the tools to answer to the first question. Complementarily to the purely Geographical Economics-based framework we will also test how active public policy affects the location decision in the sample by using public funding provided to companies in different regions as a measure. This should give us the answer to question number two. We will return to the detailed discussion of our approach later. Now we proceed with the theoretical background of the study.

2 Theoretical background – The Geographical Economics Literature

To be able to establish an economic rationale for the geographical structure of a given industry we first need to understand the economic rationale behind the underlying drivers of the structure.

In building a comprehensive framework that provides such a rationale we are able to revert to extensive existing literature. Krugman (1991a) serves as a suitable starting point that we will extend by complementing it with aspects presented in other recognised theoretical works in the field of Geographical Economics (GE).[2] We begin by reviewing studies related to the drivers of spatial agglomeration in the next sub-section. In the subsequent sub-section we will turn to literature dealing with drivers of regional specialisation. With this said, agglomeration and specialisation will be the two main aspects used in explaining the geographical structure of the Finnish biotechnology industry. As already mentioned above, a third but not minor aspect will be the influence of public financing flowing into the different geographic regions of the industry. We do not provide an explicit theoretical foundation for its role but content ourselves with its purely empirical analysis.

2.1 Spatial agglomeration

Krugman (1991a) sets out to compose a model that provides the economics for the phenomenon of agglomeration of manufacturing in particular regions of countries. In building his model Krugman splits production in any given centre-periphery setting into manufacturing characterised by increasing returns to scale (IRS), on the one hand, and local production with constant returns to scale (CRS), on the other. The IRS sector tends to concentrate in certain regions, provided that key parameters of

[2] A comprehensive and cumulative review of the Geographical Economics, also known as New Economic Geography, is presented by Duranton and Puga (2000).

Krugman's (1991a) model obtain critical values, while the local CRS sector is dispersed over all regions.

The distinguishing feature of the CRS sector impacting the model is the usage of immobile, local resources. It follows that the spatial distribution of CRS production coincides with the distribution of these resources. In contrast, IRS manufacturing does not require as much of these resources with increasing production. To reap the benefits of the resulting scale economies, production will already tend to concentrate and locate near large markets in an attempt to minimise transportation costs and other trade barriers. Thus, the geography of demand plays a crucial role in determining the location of IRS manufacturing production.

To make things more dynamic, total demand for manufacturing is affected not only by the demand from the CRS sector, but also by that from the manufacturing sector itself. It follows, according to Krugman (1991a), that demand is determined by backward and forward linkages in a circular fashion. According to the concept of *backward* linkage, manufacturing prefers the vicinity of large markets, because they provide a sufficient base of economic activity for purchasing inputs and selling outputs. The size and attraction of such markets increases with additional IRS companies agglomerating around them. The concept of *forward* linkage implies that the concentration of manufacturing production will attract additional demand other than that created by manufacturing itself, since the costs of purchasing products provided by the agglomeration are minimised by settling close to it. These circular linkages work in the same direction and self-reinforce the spatial distribution of manufacturing towards agglomeration.

In the end, the strength of the circularity depends on fundamental parameters of the economy. To roughly summarise the essence of his discourse, Krugman (1991a) identifies three central parameters.

First, since the IRS sector labour is mobile over regions, *the share of the population employed in the IRS sector* determines the sensitivity of the formation of agglomerated centres. A high share of the IRS sector labour of the total labour population increases the potential backward linkage effect and supports the formation of agglomerated centres. With wage levels being high in these centres, additional labour is constantly encouraged to migrate to them. However, with constantly increasing wage levels companies will be discouraged from locating in the agglomerated regions at a point where high wage levels and other crowding-out effects outweigh the benefits of locating in a centre. At this point, companies will find manufacturing to be more profitable in the periphery again.

Second, the degree to which manufacturing is characterised by *economies of scale* affects its opportunities to reap the benefits of locating close to a large market. For a sector with low potential scale economies a large market is not necessarily any better than a smaller one. According to the original model of monopolist competition by Dixit and Stiglitz (1977), large economies of scale imply, by definition, high sunk costs (e.g. R&D costs), which, in turn, have an impact on the entire market structure. Dixit and Stiglitz state that high IRS, here high development, costs indicate a smaller number of active companies in a given sector. Thus, while high sunk costs tend to increase companies' tendencies to agglomerate, on the one hand, they also limit the number of active companies to start with, on the other.

Finally, *transportation costs and other trade barriers* between regions counteract with the benefits of locating in an agglomerated area, since a share of products equal to the reciprocal share of demand of a company's local market still has to be transported to the peripheries if one chooses to locate centrally. Once transportation costs fall below a critical level the benefits of concentration outweigh and it is more profitable to serve the periphery from the agglomerated location. In Krugman's (1991a) model trade costs take the form of Samuelson's (1954) "iceberg" costs with high costs implying low *actual* consumption of *initially* produced goods.

In his model, Krugman (1991a) operationalises these three parameters and defines their critical values at which self-reinforcing agglomeration sets in. For our purposes it is not necessary to review the formal details of Krugman's (1991a) model. We content ourselves with the intuition of the model to form implications for our empirical analysis.

In a complementary discourse, Martin and Rogers (1995) and Monfort and Nicolini (2000) examine the effect that public infrastructure has on companies' propensity to agglomerate in a model combining domestic and international settings. Differentiating between domestic and international infrastructure, deficient public infrastructure generates costs affecting trade within and among countries negatively. Like transport costs or other trade barriers in Krugman's (1991a) work, Martin and Rogers (1995) assess the costs imposed by domestic infrastructure that affect the location choices of internationally mobile companies and labour. Infrastructure itself is defined as "comprising any facility, good, or institution provided by the state which facilitates the juncture between production and consumption" (Martin and Rogers, 1995, p. 336).

In their work Martin and Rogers (1995) argue that companies seek to maximise their profit by minimising costs related to infrastructure. To do so, companies in an IRS industry will seek to locate in a country with the best possible infrastructure since it translates into a lower price and a superior relative demand for those goods that have been produced in that particular country. To put it simpler, companies locating in a country with superior infrastructure are able to benefit from economies of scale more than companies in countries with inferior domestic infrastructure. Good international infrastructure is argued to strengthen the effect as it enables even distant markets to be serviced from a locally optimal location, which leads into even stronger agglomeration of economic activity in countries with superior public infrastructures.

Monfort and Nicolini (2000) investigate how economic integration (reduction of trade barriers) affects the location decision of the companies within a country. They find that, in some circumstances, economic integration favours the regional agglomeration of the IRS industry within a country.

In yet another seminal study that provides a complementary part of the background for our purposes Venables (1995, 1996), too, examines the effects that economic integration can have on spatial agglomeration of economic activity. The new perspective in Venables' (1995, 1996) model is that all companies in a given region utilise each other's output as intermediate input in their vertically linked production processes. This in turn gives rise to demand and cost linkages among the companies. These linkages act as centripetal forces and cause regional agglomeration once trade costs (analogous to Krugman's (1991a, 1991b) transport costs and trade barriers) fall below a critical level. To provide the intuition in brief, demand linkages emerge because a portion of any company's costs is spent on intermediate products provided by the other companies in the same region. Thus, establishing or relocating an additional company in a region will add to the demand of all existing companies in that region. This is equivalent to Krugman's (1991a) concept of backward linkages. The cost- or forward linkages emerge, because establishing or relocating a company in a region lowers the trade costs for its intermediate products as borne by the existing companies in the region and *vice versa*. Venables (1995) concludes that, given a low enough level of trade costs *or* a large enough initial number of companies in a region, the linkages set a self-reinforcing agglomeration in motion. A large enough existing company base is needed for agglomeration to set in if trade costs approach the critical level but are still too high for companies to relocate. Since economic integration of regions lowers trade costs by definition and purpose, *ceteris paribus*, it should lead to regional agglomeration of economic activity.

Krugman and Venables (1995) extend on Venables' (1995, 1996) frameworks by showing in a formal model that the effect of decreasing trade costs is not necessarily linear at all. According to their argumentation, falling trade costs entail spatial agglomeration to a certain level as presented by Venables (1995, 1996), after which further decreasing trade costs invoke spatial convergence again. This inverted U - shaped progress of agglomeration is a function of labour costs that are an integral part of Krugman and Venables' (1995) model. The model shows that labour costs rise constantly with progressing agglomeration, because the demand for labour in the agglomerating region grows. These costs start feeding on the benefits resulting from agglomeration. At the same time, labour costs in the waning peripheries decrease constantly. At some point, labour costs in the peripheries fall below a critical level and, with ever-decreasing trade costs between the agglomerated core and the peripheries, production in the peripheries becomes favourable again. This is because low enough labour costs and low enough transport costs to the core region's market offset the declining benefits accruing to companies via forward and backward linkages in the agglomerated region. At this point production shifts towards the peripheries again.

2.2 Regional specialisation effects

Having established a theoretical backdrop for the phenomenon of agglomeration, we will now turn to the effects of specialisation.

According to Krugman and Venables (1996) as well as Forslid and Wooton (2003) agglomeration and specialisation are, in fact, phenomena closely linked to each other. While Krugman and Venables (1996) build their framework to model specialisation on the international level between countries, it is easily transferable to our national scenario with regions in lieu of countries. For instance, Martin and Rogers (1995), as well as Monfort and Nicolini (2000), extend the approach to an intra-country framework.

In Krugman and Venables (1996) vital preconditions for the specialised co-location of economic activities are, as in the case of agglomeration, the presence of intermediate input linkages among firms of an industry and low trade costs between regions. When both conditions are satisfied, a region with an initially large number of intermediate input and final goods producers in a given sector (e.g. drug development, diagnostics, biomaterials) might gain a self-energising advantage over other regions, because final goods producers in that particular sector prefer the region due to the relatively larger base of intermediate producers capable of supplying them with relevant sector-specific input. When trade costs are low enough, the benefits of locating near the intermediate producers as opposed to final markets outweigh the costs of exporting goods outside the region. The result is a strengthening of specialisation of the industrial activity in the region. Intermediate input producers in the same sector, in turn, prefer to locate near final goods producers to minimise costs. It follows that each sector of the industry will tend to concentrate in some region.

Krugman and Venables's (1996) argumentation will lead to an industry structure, in which all regions are specialised in a certain sector of the industry with no two given regions specialising in the same sector. Due to an extreme degree of economic integration and almost non-existent regional differences in trade costs[3] that prevail within the boundaries of a single country, even the most peripheral hubs of the industry can exist profitably while benefiting from regional intra-sector externalities. In other words, such a structure is justified given that all regions specialise in some sector. From the point of view of a single firm, then, locating in a region that is specialised in the firms own production is profitable, as the firm is able to benefit from forward and backward linkages resulting from the closeness and inter-connectedness of relevant intermediate and end product producers.

Another argument in defense of a geographically dispersed and specialised industry structure is provided by Brezis and Krugman (1997). They argue that the emergence of a new technology, which renders the accumulated technological experience of established older centres irrelevant, creates a situation, in which the established centres will rather stick to the incumbent technology than abandon it for the emerging one, because they are more efficient in applying the older technology. New, younger and more peripheral centres, on the other hand, will adopt the new technology despite its still undeveloped state, as land rents and wages in these more peripheral centres are lower and compensate for the initially lower returns on the new technology. Given time, the emerging technology will be developed further in the new centres surpassing the old technology in absolute returns at some point. When this occurs, the younger centres will start attracting human capital from the incumbent ones resulting in a gradual decay of the older centres.

Brezis and Krugman's (1997) concept justifies the existence of multiple peripheral centres, assuming that every single one of them specialises in the development of a technology, which has sufficient commercial potential in the future and is based on knowledge outside the knowledge base accumulated in older and more established centres. In other words, peripheral centres need to be specialised in the development of cutting edge technologies, and, in doing so, always be one step ahead of the larger and established centres to justify their existence and fulfill a purpose that these older centres cannot. These pre-conditions clearly set high demands on the innovative and commercial performance of companies in peripheral regions and serve as a reminder that their justification is far from self-evident.

It is appropriate to note at this point that in a multi-region scenario the two distinct discourses, spatial agglomeration, on the one hand, and specialisation, on the other, predict diverging outcomes in equilibrium[4]. While the agglomeration literature predicts divergence of regions once the agglomeration process has started, the specialisation literature predicts convergence of regions in terms of density of activities with the type of production differing from region to region. To be more precise, both of the latter two specialisation related frameworks (Krugman and Venables, 1996 as well as Brezis and Krugman, 1997) predict a geographically dispersed structure of an industry with regionally specialised hubs of commercial activity, just as it is observed to be

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3 Hermans (2004) labels the level of integration within a single country extreme integration, a level of integration at which trade costs are minimal. At this stage we should point out, however, that in the Finnish case the state of extreme integration is affected to some extent by the active regional policy of the 1990s subsidising technology development activities in the geographical peripheries of the country. This has left core areas, situated mainly in the south of the country, at a relative disadvantage by elevating relative trade costs from core areas to peripheries.

4 Except for very low trade costs as argued by Krugman and Venables (1995).

partially the case in our data set depicted further below. Neither of the models, however, can provide a rationale for the existence, and more importantly, perseverance of large and diversified centres that, too, exist in the data. Krugman and Venables (1996) predict that diversified centres disperse their activities into specialised centres according to the sectors that those centres are specialised in, while Brezis and Krugman (1997) do not assume the existence of diversified centres in the first place differentiating only between specialised incumbent and emerging centres.

Backed by empirical findings from Feldman and Audretsch (1999), Duranton and Puga (2001) bridge this theoretical gap by suggesting a dynamic model that justifies diversified as well as specialised and more peripheral centres. According to their proposition, diversified and large centres are the birthplace of companies that, in a first step, are able to innovate and learn quickly and efficiently because of the plethora of different technologies available in a diversified centre through knowledge spillover and other technology transfer mechanisms. Once these start-ups have learnt enough to move to the production stage in their lifecycle, they relocate their activities to more peripheral and specialised regions close to other companies based on similar technologies. They do so to avoid the “crowding-out effects” of larger diversified centres (e.g. resource competition, higher wages, elevated rents) and benefit from positive intra-sector externalities that arise when locating in the vicinity of peers basing their activities on a similar, or better, complementary knowledge base.

Thus, Duranton and Puga (2001) see large diversified centres as creative factories facilitating the conceptualisation of innovative technologies based on the multidisciplinary knowledge base that can be tapped into. At the same time, peripheral and specialised centres are the locations for efficient development, production and marketing of these technologies. In this sense Duranton and Puga (2001) predict a very similar geographic industry structure as Krugman and Venables (1996) and Brezis and Krugman (1997), but allow also for the existence of large and diversified centres.

3 Analysis

3.1 Data

The empirical evidence of this study is based on data gathered in the 2004 ETLA Survey. The survey encompasses data from the Finnish biotechnology industry collected via a telephone questionnaire in late autumn 2004. It is supplemented by financial statement data from The National Board of Patents and Registration of Finland (NBPR). All data describing the current state of the companies represent 2003 figures. In some individual cases financial statement data from NBPR originates from periods before 2003, as 2003 statements were not submitted to NBPR by all sample companies at the time of collection. However, no data from NBPR is used that originates from periods before 2001.

The survey covers the majority of small and medium sized companies[5] that operated in the Finnish biotechnology sector at the end of 2004. As the survey focuses on

5 SMEs in this study are defined according to official definitions of the EU excluding companies with over 250 employees and match additionally at least one of the following criteria: (i) Annual turnover > 50 mill. EUR, (ii) balance sheet total > 43 mill. EUR. Departing from the official EU definition, we include in our SME sample those daughter companies owned by large parent companies that match the above definition in every other aspect.

dedicated biotechnology companies only, cluster companies specialising solely on distribution, import, consulting, and other support functions are excluded from the survey. Our sample includes 72 SMEs out of 123 then active dedicated biotechnology companies of all sizes. The total population of SMEs was 111. Thus the response rate was 65%. Reasons for not obtaining data covering the complete population include no response, incoherent data and no exhaustive list of companies active in the sector at the time of the survey[6]. Although firms of all ages are represented by the sample fairly evenly, very young firms, on the one hand, and very old ones, on the other, are slightly better represented than adolescent or middle aged ones. Regarding NBPR data on financial statements the sample is almost identical to the total number of Finnish dedicated biotechnology companies, as financial statements could be retrieved from 117 companies (95%) altogether. Analyses based on this data are therefore highly representative. The same is true for data concerning the size and location of companies used to construct variables related to agglomeration and specialisation patterns among regions. The identification of the population was facilitated by Finnish Bioindustries, Finland's biotechnology industry association.

The companies in the final sample are independent businesses, partnerships or subsidiaries of bigger corporations. In the latter two cases the businesses had to be independently responsible business units in order to be included in the sample. If the criteria were not fulfilled, the data was collected from the parent company.

The final number of companies included in the principal component analysis in Section 3 is 62. This final sample is smaller due to missing data.

3.2 Descriptive findings – Empirical Evidence on Agglomeration, Specialisation and Public Funding Patterns

In section 2 we have elaborated in-depth on the theoretical background of factors that we expect to affect the geographical structure of the sample industry. This subsection provides initial descriptive findings on the three factors under special scrutiny: agglomeration, specialisation and public funding. The section serves to shed more light on the actual empirical setting and provide a concrete basis for interpreting the results of the actual analysis later on.

3.2.1 Agglomeration

Figure 1.1 in section 1.2 placed all Finnish small and medium sized biotechnology companies on the map. The size of the dots in the figure represents the number of companies resident in the particular regions. The multi-centred structure of the industry is plainly visible with local agglomerations in the Helsinki, Turku, Tampere, Oulu and Kuopio regions. In the following, we will present the spatial patterns of employment that can then be related to the number of firms in each region. Thereby, it is possible to deduce information on the true volume of business activities in the regions instead of relying on mere firm frequencies as a proxy. At this point, we want to emphasise again that the underlying figures are, as throughout this study, based on the small- and medium sized biotechnology industry excluding all large biotechnology

6 In autumn 2004 the Finnish Bioindustries Association Index was updated. During that time the definite number of companies active in the Finnish Biotechnology sector could not be determined. Our sample of 123 firms is based on the Index as valid in September 2004, but includes additional firms tracked down from a variety of sources.

related companies resident in Finland. Being extreme outliers, the inclusion of large companies in the sample would render the results senseless. For instance, some of the large corporations excluded from the analysis employ more than twice as many employees than the SME industry as a whole. Also sales figures of single large corporations exceed the total sales of the entire SME industry many times over. This must be kept in mind while interpreting our results.

Figure 3.1 below is a graphical illustration of the employment distribution of the Finnish SME biotechnology industry[7]. The Helsinki and Turku regions clearly account for the majority of employment with Lahti, Tampere and Kuopio following.

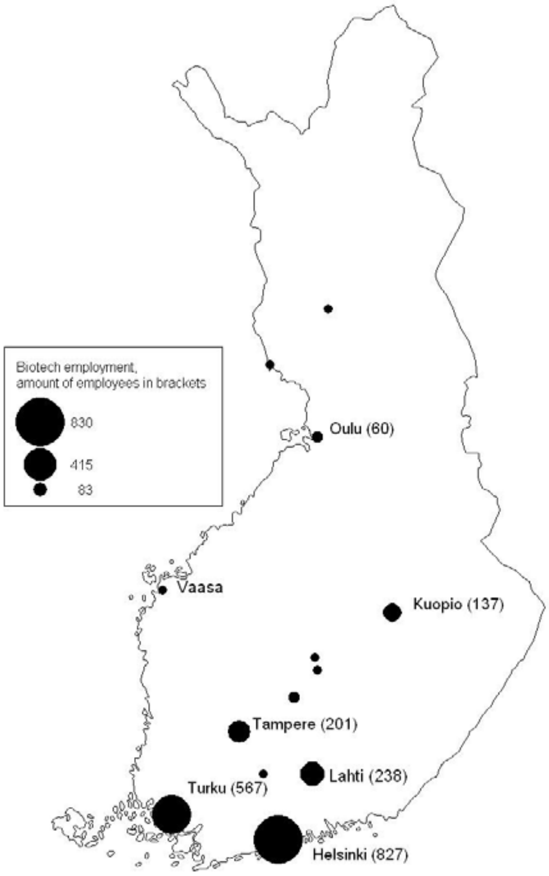

Figure 3.1 Spatial distribution of employment in the biotechnology industry 2003/4

Although the Oulu region has over 10 % of companies, more than Tampere, Kuopio or Lahti, the number of employees in the region is comparatively low. This implies that the average company size is rather small as corroborated in Table 3.1.

7 The N of Table 3.1 is considerably higher than the N in our actual survey sample, because of broader access to data concerning employment figures through the NBPR database. We used all available information to generate descriptive findings in order to maximise accuracy.

Table 3.1 Average size of companies (number of employees) by region

Region	N	Mean	Std. Deviation	Skewness	Kurtosis
Helsinki	35	25	40.229	2.406	5.903
Turku	31	16	16.513	1.653	2.136
Tampere	6	34	34.703	0.435	-2.408
Kuopio	7	11	9.798	1.246	2.071
Oulu	9	6	6.333	1.063	-0.125
Other	9	43	75.090	2.709	7.570
All	97	22	36.046	3.650	16.483

Given that the Lahti region is not considered a hotspot of Finnish biotechnology in terms of firm frequency, one might be surprised by the size of the workforce in the region. Lahti is the home of a few old and well-established companies of considerable size, which explains the finding. The Lahti region is aggregated into the category "Other" in all descriptive tables in this section.

The average age of companies (Table 3.2) in none of the five observed regions deviates to a significant extent from the industry average ($p > 0.1$ in t-test). The average age of companies located outside these regions (designated as "Other" in Table 3.2) is the only exception, as it deviates significantly from the overall average age ($p < 0.01$ in t-test).

Table 3.2 Average age of companies by region

Region	N	Mean	Std. Deviation	Skewness	Kurtosis
Helsinki	37	11	10.041	3.031	11.879
Turku	35	8	5.387	1.504	4.094
Tampere	7	11	5.900	0.656	-1.246
Kuopio	8	11	5.263	0.745	-0.747
Oulu	12	9	5.006	0.395	-1.663
Other	9	25	36.586	2.895	8.537
All	108	11	13.015	6.311	50.388

3.2.2 Specialisation

This section will complement the picture with further details by determining the regions' local specialisation patterns. We will show descriptively whether and how the five regions of agglomeration show signs of specialisation. All of the constructed indices measure different aspects indicating the degree of a region's specialisation in any of the sectors of the biotechnology industry. We will go through each of the indices separately before combining them into a single concise index.

The following two tables depict specialisation as measured by two different *labour input* shares. In Table 3.3 the grey background indicates that a given sector employs a higher proportion of the labour in a region than the *sector* (e.g biomaterials) does on average in Finland[8]. For instance, drug development employs 26.8 % of labour of

8 The formal condition for flagging a quotient is $\frac{L_{ij}}{L_j} > \frac{L_i}{L_{Total}}$, where L is labour, i denotes the sector of the biotechnology industry and j indicates the region.

the small biotechnology industry in Finland. 37 % of the Turku region's labour force in biotechnology is involved in drug development and, thus, the region is specialised in that sector in terms of labour input.

Table 3.3 Labour specialisation by sector

	Finland	Helsinki	Turku	Tampere	Kuopio	Oulu
Total	100.0 %	41.9 %	24.3 %	8.6 %	5.9 %	2.5 %
Drug developm	26.8 %	26.4 %	37.0 %	19.9 %	46.0 %	33.6 %
Diagnostics	37.3 %	46.0 %	41.5 %	22.9 %	80.3 %	31.1 %
Biomaterials	11.0 %	6.5 %	3.4 %	75.6 %	4.4 %	25.2 %
Bioinformatics	3.8 %	7.2 %	3.1 %	0.0 %	0.0 %	0.0 %
Enzymes	19.4 %	27.5 %	12.7 %	0.0 %	0.0 %	0.0 %
Food and feed	19.7 %	2.2 %	25.9 %	0.0 %	0.0 %	1.7 %
Agroforest	1.5 %	1.9 %	0.0 %	0.0 %	0.0 %	15.1 %
Environment	2.4 %	1.5 %	4.5 %	0.0 %	0.0 %	0.0 %
R&D services	15.9 %	8.7 %	26.0 %	19.9 %	35.8 %	43.7 %

In Table 3.4 the grey background signifies that a region employs a higher proportion of labour of a specific sector than the *whole industry* does on a national level[9]. For instance, the Helsinki region employs 41.3 % of the labour active in drug development in Finland, whereas the Turku region employs only 33.5 %. However, with Helsinki employing 41.9 % of the labour in the entire biotechnology industry, it is not specialised in drug development (41.3 % < 41.9 %). By contrast, the Turku region is specialised in drug development (33.5 % > 24.3 %).

Table 3.4 Labour specialisation by region

	Total	Drug dev.	Diagnost.	Biomat.	Bioinf.	Enzymes	Food&feed	Agroforest	Environm.	R&Dserv.
Finland	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Helsinki	41.9 %	41.3 %	51.8 %	25.0 %	80.2 %	59.5 %	4.8 %	54.3 %	26.5 %	22.9 %
Turku	24.3 %	33.5 %	27.1 %	7.4 %	19.8 %	15.9 %	32.0 %	0.0 %	45.1 %	39.7 %
Tampere	8.6 %	6.4 %	5.3 %	59.4 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	10.8 %
Kuopio	5.9 %	10.1 %	12.6 %	2.3 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	13.2 %
Oulu	2.5 %	3.2 %	2.1 %	5.9 %	0.0 %	0.0 %	0.2 %	25.7 %	0.0 %	7.0 %

The second set of tables measures specialisation with two different *sales output* shares. In Table 3.5 the grey background indicates that a sector's sales share of a region's total sales exceeds that sector's sales share of the total sales of the *entire industry*[10]. For instance, biomaterial-based sales are about 4.2 % of the total sales of the small biotechnology industry while constituting a staggering 93.6 % of the sales of the Tampere region. According to this measurement, Tampere region is specialised in the production of biomaterials.

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9 The formal condition for flagging a quotient is $\frac{L_{ij}}{L_i} > \frac{L_j}{L_{Total}}$, where L is labour, i denotes the sector of the biotechnology industry and j indicates the region.

10 The formal condition for flagging a quotient is $\frac{S_{ij}}{S_j} > \frac{S_i}{S_{Totall}}$, where S stands for sales, i denotes the sector of the biotechnology industry and j indicates the region.

Table 3.5 Sales specialisation by sector

	Finland	Helsinki	Turku	Tampere	Kuopio	Oulu
Total	100.0 %	59.6 %	15.9 %	2.9 %	1.3 %	0.8 %
Drug developm	30.5 %	41.8 %	20.2 %	1.3 %	32.5 %	33.6 %
Diagnostics	19.2 %	24.6 %	16.3 %	6.4 %	70.5 %	13.5 %
Biomaterials	4.2 %	1.6 %	2.5 %	93.6 %	1.9 %	13.0 %
Bioinformatics	0.3 %	0.3 %	1.1 %	0.0 %	0.0 %	0.0 %
Enzymes	46.7 %	36.4 %	53.9 %	0.0 %	0.0 %	0.0 %
Food and feed	25.4 %	3.1 %	61.7 %	0.0 %	0.0 %	3.3 %
Agroforest	1.4 %	1.1 %	0.0 %	0.0 %	0.0 %	2.6 %
Environment	1.1 %	0.2 %	1.4 %	0.0 %	0.0 %	0.0 %
R&D services	4.5 %	1.8 %	10.5 %	1.3 %	19.3 %	44.9 %

Table 3.6 depicts regional specialisation as approximated by regional sales shares of the total sales of *a given sector*[11]. For instance, the Tampere region generates only 2.9 % of the total sales of the biotechnology industry in Finland. Nevertheless one could say that the region is highly specialised in the production of biomaterials, as it generates 64.7 % of the sales in this sector on a national level.

Table 3.6 Sales specialisation by region

	Total	Drug dev.	Diagnost.	Biomat.	Bioinf.	Enzymes	Food&feed	Agroforest	Environm.	R&Dserv.
Finland	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Helsinki	59.6 %	81.7 %	76.1 %	22.7 %	48.7 %	46.4 %	7.3 %	44.0 %	10.8 %	23.1 %
Turku	15.9 %	10.5 %	13.4 %	9.5 %	51.3 %	18.3 %	38.5 %	0.0 %	18.7 %	36.6 %
Tampere	2.9 %	0.1 %	1.0 %	64.7 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.8 %
Kuopio	1.3 %	1.4 %	4.9 %	0.6 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	5.6 %
Oulu	0.8 %	0.9 %	0.6 %	2.5 %	0.0 %	0.0 %	0.1 %	1.5 %	0.0 %	8.0 %

While Tables 3.3 and 3.4 observed specialisation as measured by input factors, more precisely labour shares, and Tables 3.5 and 3.6 by output, namely sales, Table 3.7 combines these two and measures specialisation by labour productivity as indicated by sales per worker. The grey flagging denotes that the per head sales in a particular region and a particular industrial sector exceeds that sector's average per head sales[12]. For instance, sales per worker in drug development is 196 061 euros on average in Finland. The corresponding measure of productivity is 310 547 euros in the Helsinki region. Consequently, the region is specialised in drug development in terms of productivity.

Table 3.7 Labour productivity by region

	Total	Drug dev.	Diagnost.	Biomat.	Bioinf.	Enzymes	Food&feed	Agroforest	Environm.	R&Dserv.
Finland	138 032	156 805	71 279	53 300	11 927	333 240	178 165	133 441	65 498	39 444
Helsinki	196 061	310 547	104 589	48 451	7 234	259 666	270 630	108 041	26 661	39 850
Turku	90 141	49 261	35 316	68 312	30 971	382 548	214 400	0	27 150	36 400
Tampere	46 936	3 097	13 184	58 076	0	0	0	0	0	3 097
Kuopio	31 208	22 086	27 408	13 381	0	0	0	0	0	16 829
Oulu	43 838	43 816	19 041	22 549	0	0	85 649	7 579	0	45 090

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11 The formal condition for flagging a quotient is $\frac{S_{ij}}{S_i} > \frac{S_j}{S_{Total}}$, where S stands for sales, i denotes the sector of the biotechnology industry and j indicates the region.

12 The formal condition for flagging a quotient is $\frac{S_{ij}}{L_i} > \frac{S_i}{L_i}$, where L is labour, S stands for sales, i denotes the sector of the biotechnology industry and j indicates the region.

Now that we have obtained a fairly detailed and broken-down depiction of the regional specialisation patterns, it is valuable to combine the above indices into one single index that draws us a more concise picture. To get one coherent composite index of specialisation, we transform the single indices as follows.

We first assign the value one (1) to all flagged observations in every single index. Those observations, that are not flagged, are assigned the value zero (0). As a result, we obtain a matrix for each single index that indicates whether a region is specialised in any of the sectors regarding the particular index. Combining all five matrices by simply adding the transformed values, we obtain a compound index of regional specialisation. The index values range from zero to five, with 5 indicating strong specialisation and meaning that the particular region is specialised in the particular sector as measured by all five single indices. Table 3.8 exhibits the compound index.

Table 3.8 Composite Index of Specialisation

Region	Drug dev.	Diagnost.	Biomat.	Bioinf.	Enzymes	Food&feed	Agroforest	Environm.	R&Dserv.
Helsinki	op 3	5	0	ip 2	ip 2	1	ip 2	0	1
Turku	ip 2	ip 2	1	op 3	op 3	5	0	4	4
Tampere	0	0	5	0	0	0	0	0	ip 2
Kuopio	4	4	0	0	0	0	0	0	4
Oulu	4	0	4	0	0	0	4	0	5

As revealed by Table 3.8, one can indeed observe specialisation patterns among the regions, especially when only sectors of highest specialisation are regarded. The Helsinki region is specialised in diagnostics, Turku in food and feed, Tampere in biomaterials and Oulu in providing R&D services to other companies. Kuopio does not exhibit a field of strongest specialisation, but has a fairly strong focus on drug development and diagnostics in addition to R&D services. The Turku region is the most versatile with fairly strong indices in environmental applications and R&D –services as well as significant indices in bioinformatics and enzymes. Also drug development and diagnostics are sectors of focus as measured by input based specialisation.

At this point it must be pointed out that R&D services cannot be regarded as a sector of its own, as it can encompass services of any of the other sectors. It is rather a mode of business. Nevertheless, companies specialising in R&D services operate a distinct business model and distinguish themselves often strongly from companies focusing on proprietary R&D. They deserve, therefore, separate treatment in the index.

In addition to showing the regional sectors of specialisation, Table 3.8 can be interpreted as a cross-section of the development cycles of regional industry structures in the chronological dimension. With the figures marked with “ip” indicating specialisation as measured by input and those marked with “op” indicating output specialisation, we can infer the regions’ alleged directions of development. Helsinki is strongest in diagnostics investing heavily in it and simultaneously creating relatively large revenues in an efficient manner as measured by per head sales. Helsinki’s drug development sector is mature in the sense that it generates relatively large sales volumes utilising efficient processes that increase the per head in-flow of cash although it is not specialised in terms of input. Bioinformatics, enzymes and the agro-forest sectors can be assumed to have great priority in the region as it has invested heavily in them in terms of labour. However, returns on the investments have not yet materialised leaving these sectors a promise for the future. One might argue that they are in an early stage of their lifecycle.

Turku has a very strong food and feed sector and comparatively mature environmental, bioinformatics and enzymes sectors. Additionally, the region invests heavily in drug development and diagnostics displaying above average employment shares. Having said that, Turku's biomaterials and enzymes sectors are doing comparatively well as sales are generated efficiently without investing super-normally in terms of the number of people employed.

Kuopio is strengthening its drug development and diagnostics sectors that do not seem to be productive yet compared to the entire sectors' averages. Oulu has invested in biomaterials, drug development and agro-forestry creating expectations for the future in these sectors while leaning heavily on R&D services at the moment. It should be emphasised at this point that most biomaterial companies in Oulu develop solutions that are not perceived to represent biomaterials as defined according to the current conception, which encompasses mainly *in vivo* products. As the categorisation of activities in biotechnology is often a rather ambiguous task, Oulu's biomaterial companies could just as easily be assigned to the sectors of food and feed and agriculture. Be that as it may, for a region quite isolated in the geographical sense and rather small in terms of size, Oulu spreads resources over a relatively wide sector base. In contrast, Tampere stands out from all the regions by focusing very determinedly on biomaterials having already created success stories in this sector.

Table 3.9 Krugman's (1991b) Regional Divergence Index within the small and medium-sized biotechnology industry

SME Personnel	Helsinki region	Turku region	Tampere region	Kuopio region	Oulu region
Helsinki region		0.399	0.767	0.648	0.581
Turku region	0.399		0.576	0.285	0.413
Tampere region	0.767	0.576		0.644	0.495
Kuopio region	0.648	0.285	0.644		0.37
Oulu region	0.581	0.413	0.495	0.37	
Other regions	0.629	0.748	1	0.995	0.886
Average	**0.605**	**0.484**	**0.696**	**0.588**	**0.549**

To conclude the descriptive discourse on specialisation patterns, we compare the regions' degree of specialisation based on the Regional Divergence Index by Krugman (1991b)[13]. The index measures how different the industry structures of any two regions are. Here, we apply the index to measure the regional differences within the Finnish biotechnology industry. Table 3.9 cross-tabulates the index over all five regions with the value zero indicating a non-existent difference and the value one indicating a large difference in industry structures. It is possible to calculate the average deviation of industry structure for all regions separately. The averages support our prior findings. Tampere is the most specialised region of all with Helsinki following close behind. On the other extreme, Turku most resembles the average structures of Finland as its activities are quite extensive in most of the sectors.

A final comment concerning specialisation must be made here. Specialisation in a given sector does not mean specialisation in, for example, general drug development. There might still be considerable differences in the research substance of two distinct regions focusing on the same sector as measured by our indices, because both regions are probably specialised in specific niches of a certain sector. While one

13 $\sum_i \left| s_i - s_i^* \right|$, where s_i is the share of sector i in total biotechnology manufacturing employment in some region and * indicates refers to some other region. In addition, we have standardised the index outcomes to range between 0 and 1.

region might conduct research related to health care solutions in cardiovascular diseases, the other could be specialised in neurological disorders. Furthermore, research in one sector can have positive externality effects on other sectors nearby through knowledge spillovers. For instance, in this example first-rate medical research does not necessarily create large-scale pharmaceutical industry plants in the region, but it can contribute extensively to the development, growth and success of some other closely related sectors with strong, even matured, local industries such as diagnostics or enzymes. This potential scenario would serve as a good example for Duranton and Puga's (2001) line of argumentation justifying the existence of innovative diversified centres introduced earlier.

3.2.3 Public policy

Before turning to the actual analysis in section 3.3 we present the patterns of financing that has been directed to the companies and universities in the different regions. Although not anchored to any particular literature, we expect that public sector financing as the epitome of public innovation policy potentially has the power to alter location incentives as predicted by GE theories through the infusion of resources unrelated to market mechanisms that these theories rely on.

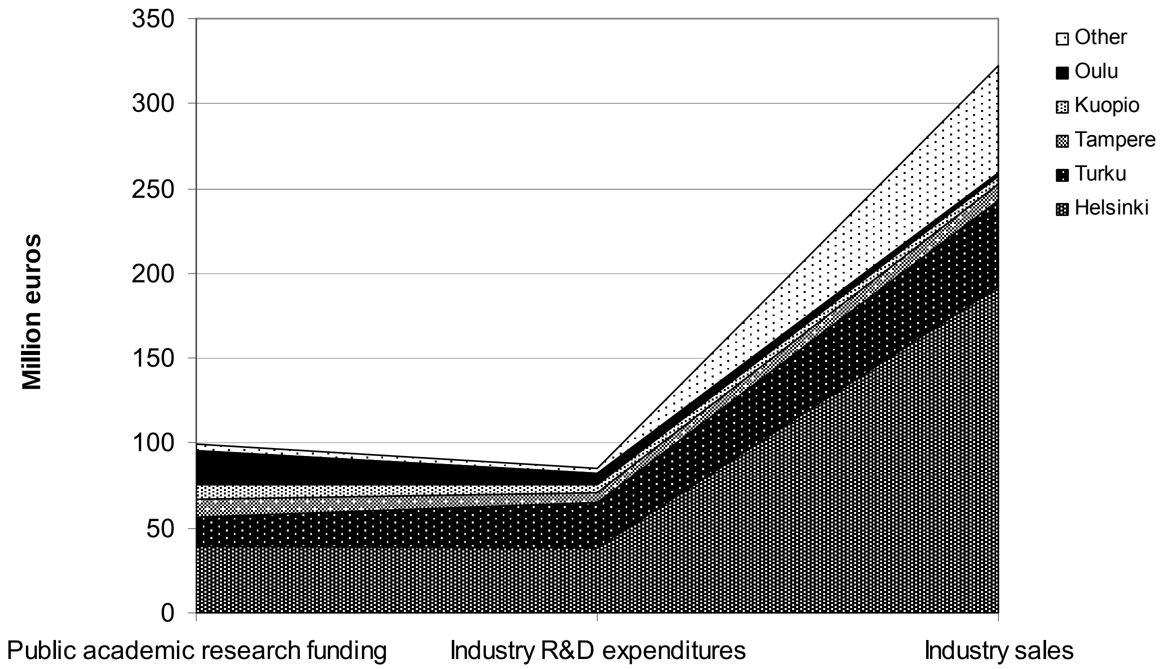

Figure 3.2 Comparing public research funding, industry R&D and sales by region

Figure 3.2 relates the region specific shares of total governmental funding provided for academic research to industry R&D expenditures and industry sales. It gives rise to two possible interpretations. According to the first interpretation, one could say the figure displays a continuum at the beginning of which there is the amount of public money spent on basic research that then, in a second phase, induces industrial R&D that is commercialised in the third and last phase. Following this line of interpretation, the Helsinki region has done quite well in transforming publicly financed research into growing private product development and succeeding in commercialising the development by conquering close to 60% of markets reached by Finnish biotechnology companies. The relation between public sector funding infused into the academic sector, the private R&D emerging from that and the sales generated by these efforts is always positive from one phase to the other. The Helsinki region seems to create value.[14] Turku is actively transforming publicly financed research into corporate R&D activities but seems to perform less well in commercialising it with a share of just below 16% of total sales of the industry. Kuopio and Tampere are similar to Turku albeit displaying much smaller volumes. Oulu seems to perform poorly, as public sector money flowing rather generously into academic research in the region does not lead to industry performed R&D, which, comparatively speaking, is commercialised to an even lesser degree.

Another way of interpreting the figure is to look at it as a cross-section in time. One might say, for example, that the Helsinki region is already in a more mature state having had time to go through all three stages and having set up the necessary down-stream assets and tapped into the markets. Following this interpretation, Oulu might still be in an infant state of development just building up the necessary infrastructure and company base necessary for successful R&D, to say nothing of commercialisation. Given time, the region might then very well create value. Thus, the figure might simply be showing regions in different stages of development and growing towards the markets.

However, it has to be stated clearly that the data presented in Table 3.2 is unsupportive of the latter avenue of interpretation, as the average age of companies in the Oulu or any other given region does not deviate to a significant extent from the industry average ($p > 0.1$ in t-test).

Thus, it seems indeed that there are differences in the performance of single regions when comparing the funding of the regional research, the employment created thereby and the output the regions have generated. To check our results for sensitivity, it is interesting to mirror the outcomes presented above to outcomes based on different sampling policies. The exclusion of subsidiary companies from the sample, for instance, has a fairly great influence on the distribution of regions' sales shares. For example, companies that are part of larger corporations generate in the Helsinki region close to 75% of all sales. In Turku, subsidiaries are responsible for 56% of sales. The distribution of total SME industry sales shares among the regions changes slightly when only independent companies are included in the analysis. Helsinki still leads with 55% of markets followed by Turku with 26%. Tampere, Kuopio and Oulu regions contribute 2%, 5% and 1% respectively. Altogether subsidiary companies make 73% of the SME industry sales with a compound 235 million Euro in 2003.

In addition to public sector funding of academic research it is also relevant to observe public sector funding that has gone directly to companies in a form or another. Direct public support of companies in different regions can be expected to affect their location decisions strongly. It is especially interesting to see whether certain types of region rely relatively more on public funding than others. Since our data does not include all companies active at the time of data collection, the funding variables used to produce Tables 3.8 - 3.10 have been weighted based on company size to obtain a representation as close to the original population as possible.

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14 It has to be stated here that sales figures are a measure of output, not profitability. Whether companies in the region actually generate net profit is a separate issue and is not touched on here. The focus is on examining the extent to which the companies in different regions have been able to tap into markets. Sales figures are the appropriate measure for this purpose.

Table 3.10 Shares of equity funding by source in each region

Source	Helsinki	Turku	Tampere	Oulu	Kuopio	Other
Staff	10%	9%	5%	26%	35%	8%
Oth. indv.	10%	9%	5%	2%	31%	75%
Sitra	4%	22%		21%	18%	
Gov. VC		7%			1%	
Priv. VC	10%	16%	84%	21%	15%	6%
Oth.comp.	54%	25%		29%		11%
Other	12%	11%	5%	1%		
Total t€	*160,924*	*137,073*	*39,987*	*4,389*	*3,351*	*35,924*

Table 3.10 presents the breakdown of equity funding by source in each region. Before proceeding with its analysis, however, one should notice the rather large differences in total equity between regions. In regions with very limited amounts in equity, such as Oulu or Kuopio, the inclusion or exclusion of single companies might have a significant impact on the distribution of equity over different sources. One is advised to caution when drawing strong conclusions of the results presented. With that being said, the distribution of equity differs radically from one region to another. Companies in the Helsinki region receive their equity primarily from other private companies. Over 50 % of equity is owned by other businesses. Another combined 30 % is owned by private instances be they individuals or venture capitalists. Ownership by governmental instances such as Sitra, the Finnish Innovation Fund, is of negligible significance. In contrast, companies in the Turku region are owned to almost 30 % by governmental institutions. Private VCs and other private companies make up just over 40 % of the ownership base while individuals provide close to 20 % of the remaining equity. Thus, Turku relies most extensively on public ownership in relative terms. The Tampere region is distinctively owned by private venture capitalists. Public funding is non-existent. Oulu, on the other hand, draws its equity from a very heterogeneous base of equity sources with no single source being of overwhelming importance. Companies around Kuopio are owned mainly by individuals and private VCs while governmental ownership makes up close to a fifth of the total.

Summarising, governmental equity based funding has served as a major pillar for two of the most peripheral regions, Oulu and Kuopio, but in both relative and total terms it seems to have played the most significant role in the Turku region, one of the two major hotspots of Finnish biotechnology. As Oulu is a non-specialised region, it seems that the public policy directing equity funding to regions has not been based on a strategy prioritising the specialisation of peripheries as advocated by the literature utilised in this study.

Table 3.11 Shares of capital loans by source in each region

Source	Helsinki	Turku	Tampere	Oulu	Kuopio	Other
Tekes	68%	60%	86%	61%	4%	
Sitra	8%	23%		13%	39%	
Oth.gov.		1%	11%		24%	23%
Priv.VC				13%		77%
Fin.inst.		4%			13%	
Oth.comp.	6%	1%	3%			
Other	18%	10%		13%	20%	
Total t€	*36,613*	*56,457*	*26,945*	*542*	*4,363*	*1,869*

Table 3.11 displays the distribution of capital loans by source in each region. As capital loans are the primary financing tool of governmental institutions such as Tekes, the Finnish Funding Agency for Technology and Innovation, it is not surprising to see governmental sources accounting for the majority of capital loans. All of the observed regions draw over 70 % of their capital loans from governmental sources. Tampere is the region with the highest share of publicly provided capital loans on the balance sheet. It is evident that capital loans constitute a major component of funding in the Finnish biotechnology sector as a whole when set in relation to other forms of financing. None of the regions can be pointed out to serve as a distinctive example. Again, there is little evidence of a dominant regional strategy of public policy in the distributions.

Table 3.12 Shares of debt by source in each region

Region	Helsinki	Turku	Tampere	Oulu	Kuopio	Other
Staff	1%					
Oth.indv.						
Banks	11%	31%	16%	66%	38%	80%
Oth.fin.inst.	24%		7%	24%		
Oth.comp.		35%				2%
Bonds						
Tekes	29%	7%	16%			3%
Oth.gov.	33%	18%	29%	9%	62%	10%
Other	1%	9%	32%			5%
Total t€	*8,906*	*4,229*	*15,252*	*1,770*	*1,092*	*6,197*

Also the distributions debt from governmental sources presented in Table 3.12 fail to offer distinct patterns of a clear regional strategy. Regions like Helsinki being the most agglomerated and one of the most heterogeneous centres of Finnish biotechnology reverts to governmental debt to the same extent as more specialised and peripheral regions such as Kuopio or Tampere. At the same time Turku as an agglomerated and diversified hub draws its debt financing to an equal extent of private sources as the most peripheral region of Oulu.

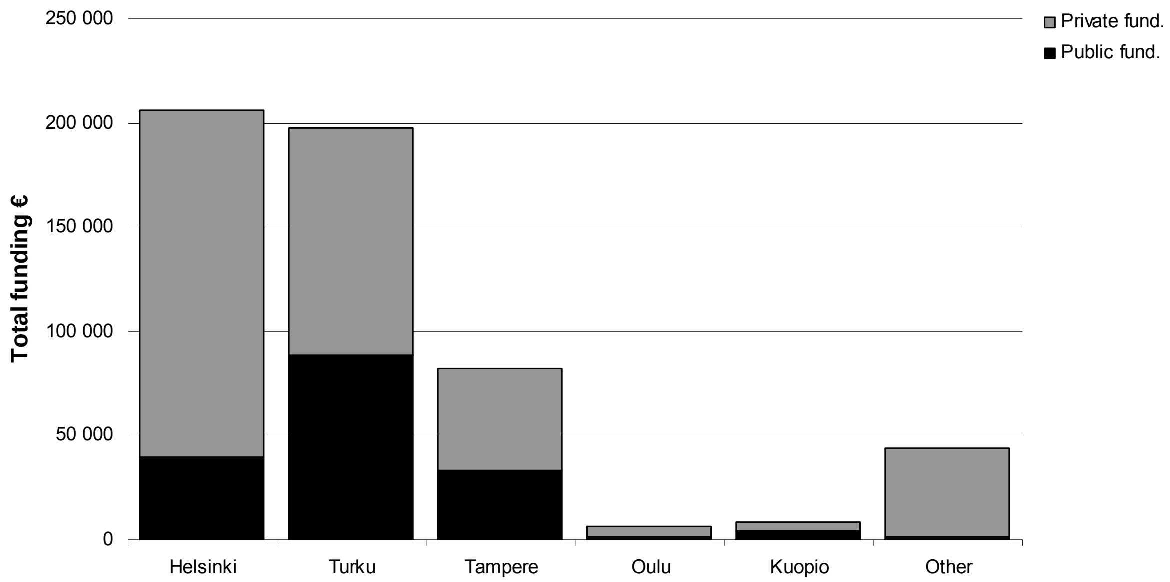

Figure 3.3 Private *vs*. public funding by region

Figure 3.3 crystallises our central findings on the distribution of public sector funding provided to companies in different regions. All three types of financing discussed above have been aggregated in Figure 3.3. The bulk of governmental funding has been injected into the most southern regions, which leads us to two interpretations that complement our previous descriptions. First, the public sector has supported the diversification strategy of the Turku region which is in line with Brezis and Krugman's (1997) notion of a younger emerging diversified centre that, focusing on new technologies, challenges the incumbent diversified centre, the Helsinki region. Second, the government has substantially funded the Tampere region that displays a highly specialised pattern of biotechnology business *á la* Duranton and Puga (2003) who provide justification for specialised peripheries. However, there is little evidence that specialisation has been pursued consistently in all peripheral regions.

Having established a detailed descriptive picture of our empirical setting it is time to turn to a more rigorous analysis of the data.

3.3 Principal Component Analysis (PCA)

As already discussed in earlier sections of this study, the geographic structure is determined by the interplay of many different drivers that interact with each other as opposed to the interaction of independent drivers with a single type of outcome represented by a single variable. The same drivers might be more or less part of the equation in many different kinds of outcomes. Furthermore, it is not clear *ex ante* what kind of outcomes to expect in the first place. The descriptive findings provide us with some initial ideas but fail to convey information on their statistical significance and unobserved interaction of drivers. Our methodological approach to the empirical analysis is built around a PCA due to its ability to address these issues and reveal the multiple and simultaneous interactions of variables as described in the underlying literature.

Moreover, we want to approach our research question on a company level, not on a regional level, a fact that has not been overly stressed earlier on in the study for the sake of being able to present the research setting in its broader context. We chose the company as the level of analysis mainly for one reason. It is our view that regions do not have a consciousness and do not have a decision-making organ with the help of which they would lay out and determine the best geographic structure. It is single companies deciding where to locate and what to produce that implicitly determine the structure of the regions. It is also single companies that trade intermediate inputs and benefit from local infrastructures. By operationalising the reviewed drivers of geographic structure onto the company-level we will obtain a micro-level picture that will provide us with a richer and more detailed picture of the determinants of location and specialisation than a region-level analysis could.

With this said, we expect to find several distinct configurations of geographic drivers that characterise different companies active in different kinds of regions. It is the strength of the PCA to find such configurations and, thereby, outline distinct company types out of a mass of data. We use un-rotated results for drawing conclusions, because it is in our interest to enable single variables to be correlated with several components. Using the popular Varimax algorithm that results in a rotated component matrix would unnecessarily force each variable to correlate with only one component. Thus, although a rotated solution would give us simpler and more illustrative results than the basic solution without rotation, the rotated results might potentially suppress much information that could contribute important nuances to the larger picture. A major weakness of the PCA, on the other hand, is related to the difficulty of interpreting causal relations. A PCA resembles a correlation analysis in the sense that it does not provide built-in references to causalities between the predictors in any given model. The causalities have to be carefully interpreted into the results by leaning heavily against the theoretical backdrop.

In the following we introduce the variables used in our analysis and briefly clarify how they are operationalised from theory.

3.3.1 Agglomeration index (*AggInd*)

As one of the three main aspects of geographic structure the degree of agglomeration needs to be carefully modeled. Since we intend to conduct a company-level analysis the variable measuring the degree of agglomeration needs to express the phenomenon from a company's perspective. The idea is to build a measure indicating the density of economic activity of other biotechnology companies around each of the sample companies[15]. Using exact geographic coordinates of the sample companies, their multilateral distances to each other were determined first. Next, the distances were multiplied with the average cost per time-unit of traveling the given distances in order to capture non-linear agglomeration effects that might emerge with ever growing distances[16].

Then separately, for each sample company, the cost-corrected company-specific distances were used as a discount factor to discount the number of personnel of all other active biotech companies in Finland. The number of personnel served as a proxy for economic activity that was considered more accurate than the number of companies, as it quantifies true company size. In a last step, the discounted numbers of personnel of all companies were aggregated for each sample company to form the final variable Agglomeration Index, *AggInd*. The agglomeration index is of the same form as originally suggested by Harris (1954) and more recently Hanson (1998). Equation 1 shows the formal construction of the variable for firm *i*:

$$\text{AggInd } i = \sum_{j=1}^{N} \frac{L_j}{cd_{ij}}, i \neq j, i = [1, n], j = [1, N], n \in N,$$

where *N* is the population of all active biotechnology companies in Finland, *n* is our sample, *c* represents the travel costs per time-unit over all distances, *d* denotes the distance between firm *i* and *j*, and *L* is the number of personnel in company *j*.

One should point out that, since $i \neq j$, the discounted number of personnel of any firm *i* is not part of its own agglomeration index. Instead, the effect of economic activ-

15 To this end we had to use all 123 biotechnology companies active in Finland, since important activity outside the sample might otherwise be left unheeded and distort the measure of real agglomeration.

16 Although distances are always linear by definition, the costs and times related to bridging them might not. Since the utilized theory base related to intermediate input trade, forward and backward linkages, as well as knowledge diffusion, presume that companies interact with each other concretely, we have to consider real costs related to distances if we attempt to model agglomeration. To calculate travel costs per time-unit we utilised prices and travel times obtained from airlines, railway companies, bus companies and calculations based on using a car. We determined that, in fact, travel costs per time-unit are rather linear over all distances. Thus, the cost multiple of distances merely constitutes a fixed factor.

ity of firm *i* is captured by all other companies in its environment only and *vice versa*. The size of firm *i*, thus, cannot dominate its own index and render *AggInd* an index of mere size rather than surrounding agglomeration.

3.3.2 Specialisation index (SpecInd)

The construction of the *compound* specialisation index was already covered in section 3.2.2. For the purposes of the PCA, however, we only use the labour specialisation –related components of the index and discard the sales specialisation –related ones. The decision to do so is grounded in the argument that factually deployed specialised labour is a true indicator of what companies are doing and to what extent they are doing it. In contrast, sales based indicators might be influenced not only by differences in the respective total volumes of different industrial sectors, but also by the stage of company-specific life-cycles. The inclusion of sales based specialisation indices into our compound index could distort the measure in favor of older and more established companies that do not necessarily specialise in a certain sector. Thus, the compound index shown in Figure 3.8 was used for the earlier descriptive conclusions only with the specialisation index *SpecInd* in our final PCA being a stripped version of it. To operationalise the region-level specialisation index on the company-level, we recoded it into a dummy variable indicating whether a particular company locates in a region that as a whole specialises in the company's own sector in terms of labour inputs.

Following Krugman and Venables' (1996) argumentation, we should expect to see a two-fold relationship between *SpecInd* and *AggInd*. As detailed earlier, Krugman and Venables (1996) suggest a geographical structure, in which there are several hubs that each specialise in a certain industrial sector. Duranton and Puga's (2001) line of argumentation, on the other hand, gives rise to opposite or less strong expectations regarding the two indices, because, in their framework, specialised and diversified agglomeration hubs both have their justification.

3.3.3 Public and private financing

The two variables *PublVC* and *Tekes* proxy the funding received from governmental sources. As elaborated on earlier, we feel that public sector funding is a major incentive that might have a significant effect on geographic location, especially, as it is the embodiment of active regional innovation policy. If public innovation policy has implemented a strategy for supporting certain geographic areas, we should find a positive relationship between agglomeration and public funding. With this said, one could argue that regional public sector funding is a form of publicly provided infrastructure very much along the lines of Martin and Rogers' (1995) argumentation, as it lowers the costs of operating in any given region that receives this funding. Companies are expected to agglomerate in an area where public infrastructure, here public funding, is sufficiently advanced.

Public VC financing proxied by *PublVC* is mainly provided by Sitra, the Finnish Innovation Fund, that has strategically invested in Finnish biotechnology for nearly 20 years. Biotechnology has been one of Sitra's main focus areas receiving up to a third of all annual investments of the fund. Despite exit difficulties after the burst of the technology bubble at the turn of the new millennium, Sitra still continues to provide VC financing to its now streamlined portfolio. Despite being a public institution, Sitra's funding comes with roughly the same claims as private VC funding. The important difference to private VCs is that Sitra invests out of its own balance sheet instead of pooling funds from external investors. It also invests the funds according to current public policy guidelines determined by the government. The variable *PublVC* measures the Euro amount of Sitra financing on a company's balance sheet. In the construction of the variable, the equity mitigating effects of accrued losses from past accounting periods were eliminated in an effort to measure the aggregate amount of public sector VC financing that the companies have received during their entire life-cycle.

The major source of non-equity governmental financing (grants, loans and capital loans) in Finland is Tekes, the Finnish Funding Agency for Technology and Innovation. Tekes' funding is represented in our analysis by the variable *Tekes*. Tekes provides funding for industrial R&D projects, as well as projects in universities and research institutes, by focusing on promoting innovative, risk-intensive projects. The agency proclaims that its "primary objective […] is to promote the competitiveness of Finnish industry and the service sector by assisting in the creation of world-class technology and technological know-how. Specifically, Tekes' activities aim to diversify production structures, increase production and exports, and create a foundation for employment and social wellbeing".[17] Biotechnology has been a major focus area since the mid-eighties and still continues to be a focal area of commitment. Very many biotechnology companies founded since the eighties have received funding from Tekes in one form or the other. Since Tekes financing is not equity based, it is difficult to estimate the accumulated Tekes funding in sample companies. Thus, our dummy-type proxy simply indicates whether a particular company has received any Tekes funding in one form or another. The variables receives a value of one (1), if this is the case, and the value zero (0) if the company has not received financing.

Corporate financing (*CorpFin*). The variable indicates the Euro amount of loss-corrected equity provided by other companies. It is included to map interactions with public financing patterns, on the one hand, and whether companies in agglomerated and/or specialised regions are seen as attractive investment targets on the other. Interaction of corporate financing with public financing is of interest here, because Tekes, for instance, requires 50 % of a company's project to be financed from private sources. Thus, there might be a linkage between private and public funding that needs to be possibly addressed when interpreting the results.

Employee financing (*EmplFin*). The loss-corrected Euro amount of investments provided by companies' employees represents another source of private financing that has to be controlled for the same reasons as *CorpFin*. In the economics of finance literature the amount of internally provided equity financing also serves as a signal for a company's internally perceived quality (Leeland and Pyle 1977). Although controlling the interaction of *EmplFin* with the public funding measures is the actual reason for including the variable in the analysis, the signaling discourse provides the interesting possibility to observe whether there is a connection between the internally perceived quality of business and the location in agglomerated and/or specialised regions.

Private VC financing (*PrivVC*). The loss-corrected Euro amount of financing provided by private venture capitalists is indicated by this variable. Showing the effects of the small size of the country, historically common organisational backgrounds with Sitra might affect the funding behaviour of major Finnish VCs specialising in biotech-

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17 http://www.tekes.fi/eng/tekes/ , accessed on July 26th 2007.

nology. There might be interconnectedness between Sitra as well as private VCs and *vice versa*. Again, this is of potential importance when interpreting results.

3.3.4 Collaboration indicators

With a 90 % share of its sales being exports the Finnish biotechnology sector is very export intensive. Thus, Krugman's (1991a) initial argument of industrial agglomeration emerging merely due to the vicinity of large local markets applies in our empirical setting only to a limited extent. While the initial phases of biotechnology development might well locate in Finland, Krugman's argument predicts the later development phases to relocate outside the country in the vicinity of larger markets, especially with ever decreasing trade costs on globalising markets. The relatively high export intensity of the sample industry, as well as the significant presence of adolescent and old companies in the population, are at odds with such predictions. Therefore, we need to revert to Krugman's (1991a) broader framework including the dynamic linkages between production and demand. As depicted earlier, Krugman (1991a) states that strong enough local demand linkages are a requirement for agglomeration to begin. In our analysis, we approximate demand linkages by capturing R&D collaboration patterns among companies in the same region. Collaboration, among other means of technology transfer, is one of the most efficient ways of exchanging knowledge, the substance of technology, and arguably the most valuable goods produced and sought after by biotechnology companies. R&D collaboration is defined very broadly in our data and includes all kinds of collaboration arrangements from contract R&D to joint research projects. With this said, established local demand linkages are represented by the dummy-type variable *ColLO* indicating whether a company is in a collaborative relationship with companies in its own region. Based on Krugman and Venables (1995) we expect to find a positive relationship between demand linkages proxied by *ColLO* and the agglomeration index *AggInd*.

Additionally, *ColLO* also represents intermediate input trade among local companies along the lines of Venables (1995). Active intermediate input trade adds to the demand of the local company base and results in similar demand linkages as in Krugman (1991a). Venables' (1995) framework implies the same positive relationship between *ColLO* and *AggInd*.

ColLU, collaboration with a local university, is an approximation of established links to regional public infrastructure. According to Martin and Rogers (1995) and Monfort and Nicolini (2000), good public infrastructure that facilitates interaction in the interface of production and consumption is expected to correlate positively with economic agglomeration regionally. Active links to universities' basic research can be argued to maintain an organisation's understanding of current developments in relevant generic technologies. Know-how in basic research, in turn, enhances an organisation's technological absorptive capacity that is key in tapping into other organisations' more specialised knowledge and sharing it (Cohen and Levinthal 1990). Thus, links to basic research at universities facilitate the interaction of production and consumption of relevant technological knowledge and is, thereby, to be considered a vital component of public infrastructure providing incentives for geographical agglomeration in the same region. *ColLU* is a dummy variable indicating whether a company collaborates with a local university or not.

Collaboration with a foreign university (*ColFU*) and collaboration with other foreign organisations (*ColFO*) both represent established links with partners abroad. In relation to Martin and Roger's (1995) framework, they both approximate international infrastructure that is factually being exploited. Good international infrastructure enhances local agglomeration tendencies as it enables serving distant foreign markets in an efficient manner by lowering trade costs. *ColFU* is a dummy variable indicating whether or not a company is engaged in R&D activities with a foreign university. *ColFO* is a discrete measure taking values between zero (0) and three (3). The value increases by one for each major continent (EU, US and Asia) that a company has collaborative arrangements on with any type of organisation other than a university. We distinguish university partners from others in an attempt to obtain a more precise picture of the nature of foreign collaboration. We expect both variables to correlate positively with the agglomeration index.

Although not being a collaboration indicator *per se*, the export ratio (*ExpR*) of a company quantifies the number of business transactions with international partners and, at the same time, characterises the type of relationship indicated by *ColFO* further. By including *ExpR* into the analysis, we obtain a more detailed picture of what kind of collaboration the international infrastructure is utilised for.

3.3.5 Innovation indicators

The number of patents per employee (*PatE*) and the turnover share of products or services that have entered markets in the past three fiscal periods (*InnoS*) are both indicators of the innovative capability of a company. While *PatE* measures the actual innovative capacity of a company (see *e.g.* Furman et al. 2002), *InnoS* gives an idea of how much innovations have impacted company sales and to what extent the market appreciates the value of the innovations.

According to Brezis and Krugman's (1997) framework we should see a positive correlation between specialisation and *PatE*, but not necessarily between specialisation and *InnoS*. This is because newly emerging and specialised peripheral centres are expected to surpass incumbent centres in terms of innovativeness, as they embrace novel technologies aiming at substituting the incumbents' conventional technology. Initially, this should be visible in patenting activity with the younger centres performing better than the incumbent centres. But it is not until much later that the new technologies start to become viable on markets. Until then incumbent technologies have to provide the income flow even in newly established companies. Thus, we do not necessarily expect to find any correlation between *InnoS* and *SpecInd*. With this said, we expect to find a negative correlation between *InnoS* and the age of a company, as older incumbent companies rely on proven technologies that provide them with steady income flows. Should there be a positive correlation between *InnoS* and *SpecInd*, however, then it would serve as an even stronger indicator of a focus on novel technologies than *PatE*, since it would measure the technology directly rather than indirectly through *PatE*.

In contrast to Brezis and Krugman (1997), following Duranton and Puga's (2001) framework we should expect rather different findings for both *InnoS* and *PatE*. Given that diversified agglomerations are argued to function as hotspots of innovation due to local knowledge spillovers between sectors, we should find a positive correlation between the agglomeration index and *PatE*. Since Duranton and Puga (2001) predict a relocation of production into less expensive, specialised peripheries once a viable technology has been conceived, there should be a positive relationship between the specialisation index and the share of innovations of total sales.

3.3.6 Sunk cost indicator

The absolute annual amount spent on research and development serves as a measure of sunk costs invested into a business that is characteristic of increasing returns to scale industries like biotechnology. R&D expenses are invested upfront, usually long before generating the first revenue streams, and are not variable with the volume of subsequent production. Krugman's (1991a) line of argumentation is based on the assumption of existing sunk costs that, together with the other factors, drive agglomeration. We expect to find a positive correlation between the sunk cost variable (*SC)* and agglomeration.

Furthermore, *SC* might be correlated to the stage in a company's lifecycle. Since the initial earnings in the research intensive biotechnology industry are generated relatively late, the costs related to the research and development phase are considerably high in the first few years of a company's existence. The variable *SC* might be strongly correlated with public funding indicators, as the majority of public resources are directed towards supporting the early research and development phase and, thereby, the emergence of new technologies that are not yet ripe for market introduction. Thus, in addition to serving as a sunk cost measure, *SC* has to be included into the analysis in order to be able to distinguish between public funding supporting regional development and that supporting new technology development.

3.3.7 Employee compensation indicator

Salaries and wages per employee (*EmplC*). As an implicit result of Krugman's (1991a) and Krugman and Venables' (1996) frameworks agglomeration always entails higher employee expenses as qualified labour becomes a scarce resource within the growing regions. We include *EmplC* in the analysis to test this aspect of theory empirically and expect the variable to be positively correlated with the agglomeration index.

3.3.8 Control variables

Number of personnel (*Staff*). *Staff* measures the number of personnel employed by a particular company. It is a straightforward measure of organisational size.

Age (*Age*). This variable is self-explanatory and controls for age effects. It provides information on the characteristics of companies in agglomerated and/or specialised regions.

Annual Turnover (*AT*). Where *Staff* proxies the organisational size of a company, AT measures the volume of business that a company generates. It is the reported turnover of the fiscal year 2003.

Sector controls *Drug*, *Enzs* and *Biom*. The dummies respectively indicate whether a company is active in the drug development, enzymes or biomaterials sectors of the biotechnology industry. They control for sector-specific effects that might be strong, as each of the sectors of the industry is characterised by very distinct business models, development times, approval procedures etc. The three sector controls do not represent the entire biotechnology industry exhaustively, but are chosen for their large differences in the features mentioned. Other sectors include forestry, food and feeds, agriculture, diagnostic services, and health care instruments amongst others.

Location within major economic centre (*LHub*). As economic activity in general is highly agglomerated in the triangle formed by the Helsinki, Turku and Tampere regions, we have to control for the regions' effects on location incentives if we aim at singling out theory related intra-industry aspects clearly. By including location dummies for the three hubs in the analysis we control for effects that economic activity outside the biotechnology industry in these hubs might have on sample companies. In addition to its controlling function, *LHub* serves as a geographical anchor for the agglomeration index that does not independently provide any information on where exactly agglomeration tends to be high. With this said, we expect to find a very strong correlation between the agglomeration index and the dummy *LHub* indicating whether a company locates within one of the major economic centres of Finland.

Share of Ph.D.s of personnel (*PhDs*). The share of personnel holding a PhD degree is a control related to the sunk cost measure *SC*. It controls for effects that might emerge due to differences in the business models of companies and affect the sunk cost measure. Depending on the established business model, companies are very diverse in their R&D intensities with some focusing solely on developing novel technologies based on new science (e.g. drug production in genetically modified plants) while others build their business on less research intensive product development (e.g. utilisation of known bacteria in functional foods) that requires smaller investments in highly qualified human resources. In order to negate the effect on the *SC* variable we include the share of PhDs, people with scientific expertise, in the analysis as a proxy for the intended business model. The underlying assumption implies that the more scientific personnel a company employs the more it is research focused. Table 3.13 summarises all variables included in the analysis.

Table 3.13 Summary of variables

Variables	Operationalisation	Purpose
Agglomeration and specialisation indices		
AggInd	Agglomeration Index based on the number of personnel.	Degree of agglomeration in company's vicinity.
SpecInd	Specialisation Index based on labor input.	Company locates within a region specialised in company's own sector.
Public policy indicators and interaction controls		
PublVC	The € amount of public VC funding received by a company.	Indicator of active public innovation policy.
Tekes	Company has received funding from Tekes.	Indicator of active public innovation policy.
CorpFin	The € amount of loss-corrected equity provided by other companies.	Control for public funding indicator interaction.
EmplFin	The € amount of loss-corrected investments provided by a company's employees.	Control for public funding indicator interaction.
PrivVC	The € amount of loss-corrected financing provided by private venture capitalists.	Control for public funding indicator interaction.
Intermediate input trade indicator		
ColLO	Collaboration with companies in the same region.	Proxy for intra-industry intermediate input trade.
Public and international infrastructure indicators		
ColLU	Collaboration with a university in in the same region.	Indicator of public infrastructure quality.
ColFU	Collaboration with a foreign university.	Indicator of international infrastructure quality.
ColFO	Collaboration with a foreign organisation other than a university.	Indicator of international infrastructure quality.
ExpR	Export ratio.	Indicator of type of international infrastructure.
Innovative capacity indicators		
PatE	Patents per employee.	Indicator of innovative activity.
InnoS	Turnover share of products or services launched in the past 3 yrs.	Indicator of innovative activity with commercial potential.
Sunk cost indicator		
SC	Annual R&D expenditure.	Indicator for sunk costs.
Wage level indicator		
EmplC	Salary or wage per employee.	Indicator of the level of compensation.
Control variables		
Staff	Number of personnel.	Size control.
Age	Age of company in years.	Age control.
AT	Annual turnover.	Volume control.
Drug	Company active in drug development sector.	Industry control.
Enzs	Company active in enzymes sector.	Industry control.
Biom	Company active in biomaterials sector.	Industry control.
LHub	Company locates in one of three main centres of economic activity.	Economic environment control.
PhDs	The number of personnel with PhD degree.	Business model control.

Table A6 in the appendices presents the concise descriptive statistics and Table A3 displays the results of the correlation analysis for all variables included.

4 Results and discussion

Table 4.1 displays the results of our final un-rotated PCA.[18] We obtained nine distinct components, each of which represents a configuration of variables that co-vary, or present high loadings, with each other. The model explains 72 % of the variance in the data.

Variables that are loaded above the threshold level defined critical for our sample size and show a co-efficient above .3 are flagged with a single asterisk, while strongly loaded variables with coefficient values above .4 are flagged with a double asterisk. The configurations of loaded variables can be interpreted as company typologies depicting characteristics that go hand-in-hand in the underlying data. Although none of the components, as a whole, are correlated with each other by methodology, they are not exclusive in the sense that any single company can show characteristics defined by several different components. These typologies just do not co-vary on the level of the whole sample.

Table 4.1 Component matrix

Variables	**Components**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Agglomeration and specialisation indices									
AggInd	-0.073	** 0.543	* 0.364	**-0.611	*-0.301	0.021	0.011	-0.106	-0.105
SpecInd	0.117	* 0.303	-0.112	* 0.376	-0.174	-0.117	** 0.550	0.065	*-0.366
Public policy indicators and interaction controls									
PublVC	0.144	** 0.524	-0.264	0.135	-0.143	0.024	**-0.462	* 0.311	-0.131
Tekes	0.284	0.228	0.005	0.043	0.237	-0.184	-0.236	0.134	** 0.621
CorpFin	** 0.413	0.033	** 0.688	* 0.394	-0.218	0.272	-0.082	0.175	-0.009
EmplFin	** 0.433	0.046	-0.270	*-0.304	-0.138	0.144	** 0.504	0.104	0.293
PrivVC	0.195	0.240	*-0.369	0.014	0.030	** 0.590	-0.151	-0.244	0.065
Intermediate input trade indicator									
ColLO	-0.210	0.118	** 0.616	-0.252	** 0.466	0.041	-0.072	-0.042	-0.080
Public and international infrastructure indicators									
ColLU	-0.126	** 0.476	0.211	* 0.394	0.181	*-0.362	-0.103	0.052	0.079
ColFU	** 0.603	* 0.329	0.063	0.058	** 0.468	-0.042	0.016	-0.281	-0.095
ColFO	** 0.554	0.170	-0.077	0.073	** 0.454	-0.252	-0.089	*-0.326	-0.162
ExpR	** 0.402	-0.009	** 0.713	* 0.385	-0.182	0.282	-0.028	0.110	0.010
Innovative capacity indicators									
PatE	*-0.318	0.223	0.035	0.176	* 0.325	0.296	0.218	0.229	0.089
InnoS	-0.214	0.173	-0.210	* 0.304	* 0.300	** 0.424	0.016	-0.234	*-0.339
Sunk cost indicator									
SC	** 0.563	* 0.399	-0.226	-0.032	-0.009	-0.045	0.068	-0.103	0.208
Wage level indicator									
EmplC	** 0.408	0.189	*-0.358	0.163	*-0.381	0.027	-0.263	0.077	-0.041
Control variables									
Staff	** 0.733	-0.096	-0.072	-0.316	0.282	0.180	0.107	* 0.314	-0.089
Age	* 0.354	**-0.406	0.015	*-0.329	* 0.315	0.034	-0.120	** 0.459	*-0.302
AT	** 0.688	-0.178	0.183	0.045	0.026	0.078	0.236	-0.064	0.115
Drug	-0.114	** 0.557	-0.219	0.290	0.044	-0.080	0.176	* 0.394	-0.084
Enzs	0.210	*-0.361	0.099	** 0.479	-0.179	-0.092	0.102	-0.288	0.114
Biom	*-0.361	0.003	-0.103	0.081	0.132	** 0.644	-0.058	-0.014	0.235
LHub	0.031	** 0.670	* 0.310	**-0.478	*-0.303	0.104	0.049	-0.175	-0.056
PhDs	**-0.508	* 0.313	0.149	0.043	0.299	-0.059	0.281	0.115	0.237

Extraction Method: Principal Component Analysis.
9 components extracted.

18 A rotated component matrix is provided in Table A4 in the appendices. KMO and Bartlett's test are displayed in Table A1 showing the adequacy of the analysis in relation to the utilised data. The total variance explained is reported in Table A2. Communalities can be found in Table A5.

With this said, we will proceed with describing and discussing each of the components one by one and, in doing so, try to rise to our initial challenge of fleshing out the rationale behind the geographic structure of the sample industry.

4.1 Component 1: Internationally oriented heavyweights

Component 1 depicts established and thriving companies. These companies enjoy large revenues, are relatively independent of domestic markets as indicated by a large export ratio, they look back at a long history in business and employ a large staff that enjoys relatively high compensation. It also displays high sunk costs, as it invests heavily into R&D engaging mainly in foreign R&D collaboration with diverse instances including universities. At the same time, the companies do not employ many PhDs nor do they show a high per head patent count, both of which indicate a business model based on a more generic or incumbent technology. With the ownership of the company being mainly in private hands of other corporations and its own employees it is relatively independent of public support.

What does this tell us in the light of our research question? How do these characteristics relate to geographic structure? First, it is notable that neither the agglomeration nor the specialisation indexes seem to be loaded with the component in any significant way. This implies that a company endowed with the above characteristics could locate virtually anywhere in Finland. One could find it in the most distant periphery just as well as in the country's most dense economic hotspots. Also the location's regional sector of specialisation does not really matter with a highly specialised region being equally probable to host a company depicted by component 1 as a highly diversified region. Clearly, also public support plays only a trivial role in the company's businesses, as the bulk of funding is provided by private owners and internal revenue generation. With this said, it seems that component 1 reflects important interrelational features of the industry that exist independently of geographic location. Neither Krugman's (1991a, 1991b) notions nor Duranton and Puga's (2001) or Brezis and Krugman's (1997) alternative intuitions relating to the role of incumbent regions fail to provide a rationale for companies characterised by component 1, as the agglomeration and specialisation indices simply do not correlate with the component.

One possible avenue of explanation could be opened by Martin and Roger's (1995) notion of international infrastructure. Looking at component 1 it seems that the companies in question rely heavily on foreign collaboration both in terms of sales and product development, while connections to local markets or collaboration partners seem insignificant for running a successful business. This could signify that the international infrastructure between a company's country of origin, here Finland, and those of its partners is of such a high quality that serving these markets and maintaining collaborative relationships from a great distance do not pose a disadvantage. Compared to the significance of these foreign linkages the gains achieved by optimising location *within* the country of origin then seem to be trivial. This is actually rather intuitive, since most of the reviewed studies emphasise the role of local demand linkages as a precondition for any emerging benefits of agglomeration and specialisation. Given that, according to component 1, even R&D collaboration, a measure of intra-industry demand linkages, is mainly conducted jointly with instances abroad and not locally, local intra-industry linkages simply do not exist. Thus, companies characterised by component 1 are rather indifferent in terms of location *within* Finland, as there are no gains to be made by locating near domestic partners that do not provide any relevant input.

We stress this as one of the central findings that will have major implications on regional policy design.

4.2 Component 2: Agglomerated drug developers

Companies characterised by component 2 are relatively young R&D-intensive drug development companies that are located in agglomerated regions, mainly the general economic hotspots in Finland, specialising in the same sector.

As opposed to component 1, component 2 conforms to the underlying theories very well: High sunk costs proxied by R&D expenses are correlated positively with the agglomeration index in accordance with Krugman (1991a), which attests to an attempt to reap the benefits of increasing returns to scale by locating within an economic centre close to potential demand for the companies' services, on the one hand, and the pool of knowledge provided by other companies in close vicinity that can be tapped into through intra-industry linkages, on the other. The high sunk costs are a function of the business model that is characterised by intensive scientific development of technology in the early phase of the organisational life-cycle. A high share of personnel with PhDs and the relatively young age of companies characterised by component 2 support this interpretation.

In accordance with Krugman and Venables (1996), component 2 shows that agglomeration has gone hand in hand with specialisation, here drug development, providing resident companies with the opportunity to take advantage of intra-industry linkages. However, these opportunities have not been exploited to an extent that would be statistically significant. Thus, companies characterised by component 2 may or may not engage in intra-industry trade. They might even engage in harsh competition instead of collaborating with each other. Moreover, the theory-predicted innovativeness of companies in agglomerated areas lacks statistical significance as expressed by variable *PatE*. These two evident weaknesses of some companies can be argued to be interrelated. The heightened innovative capacity of agglomerated regions is based on co-operation between companies that allow for knowledge spillovers or other mechanisms of technology transfer. Since there is a lack of systematic intra-industry activity between companies in regions characterised by component 2, it is not surprising to also see an equal lack of systematic innovativeness. Thus, intra-industry co-operation is a central challenge to be conquered by companies in these regions, because costs related to crowding-out effects in agglomerated centres might otherwise not be offset and the strength of the economic justification of the regions might deteriorate.

While intra-industry linkages fail to manifest themselves in a statistically significant fashion among companies characterised by component 2, links between agglomeration and public, as well as international infrastructure are evident in the component. Along the lines of Martin and Rogers' (1995) framework, companies depicted by the component utilise both local and international infrastructure to achieve further gains by maintaining co-operation with local and foreign universities. Agglomeration is strengthened as the local university attracts related economic activity in its vicinity while good international infrastructure enables necessary contacts to foreign universities without having to relocate.

The fact that collaboration is maintained mainly with academic institutions provides a further indication for the companies' young age and early stage in their lifecycle. The finding is corroborated by the statistically insignificant turnover measure and export share indicators. These companies are probably still in a pre-market phase. The decision of location is most likely based on the existence of relevant public infrastructure and the vicinity of potential future markets.

Public VC funding is also correlated with the component. Although we cannot pinpoint the exact variable that *PublVC* co-varies with most within a single component because the coefficients indicate only correlation with the component as a whole, comparing component 2 to other components discussed in the following reveals that public VC funding seems to be more frequently associated with the drug development sector than with agglomeration. This might hint at a more substance related investment strategy than one based on regional policy. To be more precise, according to component 2 public sector VC funding has been invested to a relatively large extent especially in those drug development companies that locate in regions characterised by both a relatively dense agglomeration and a company base specialised in drug development.

4.3 Component 3: Internationally competitive subsidiaries

Companies characterised by component 3 are again somewhat at odds with our theoretical background. While locating in agglomerated areas within one of the three major economic centres of the country, these companies compensate their employees relatively poorly. This runs opposite to what we expected to find to be the case in agglomerated areas that usually have to compete over qualified labour. It is especially odd, as the companies in our biotechnology based data run businesses that usually demand very highly qualified individuals. The low compensation of employees might be explained by a very generic business model that does not rely on highly skilled personnel. Companies characterised by component 3 might serve as a more production and distribution oriented organisation, for instance. As these organisations are mainly owned by other companies, such a specialised function could be envisioned with ease to fit into the larger structure of a conglomerate. The story would further explain why both innovativeness measures and collaboration with local and foreign universities are insignificant in contrast to expectations based on the theories. R&D related functions are performed elsewhere in the larger conglomerate (see also Markusen 1998).

At this point it is important keep in mind, however, that pure logistics companies, as well as all other companies providing similar support services, were excluded from the data from the onset because we were primarily interested in businesses dedicated to biotechnology. Thus, none of the sample companies focus solely on production or distribution functions. They might, however, emphasise such functions more than others.

On the other hand, component 3 shows a positive relation between agglomeration and local co-operation with instances other than universities, as well as with the export ratio indicator. These findings are both in line with the theory base. Local co-operation indicates active local intra-industry trade that enhances agglomeration. Locating within an agglomeration, in turn, provides access to a large base of intermediate input producers in very close vicinity. Assuming that the business model of companies characterised by component 3 is really based on generic technology as discussed above, the key to profitable operations is in efficient procurement. In such a setting the ideal location is within an agglomeration. With a high export ratio indicating exploitation of a well-established international infrastructure, it is sensible to tap into the companies' main markets abroad from the agglomerated location in Finland.

4.4 Component 4: Specialised periphery

Component 4 represents a model example of a company in a specialised periphery. Being in congruence with Duranton and Puga's (2001) and Brezis and Krugman's (1997) notions, the component characterises companies locating in a peripheral region that is specialised in the companies' industrial sector with the specialisation index being positively and the agglomeration index being negatively correlated with the component. Further in line with both theoretical discourses, the companies in the region are focused on developing novel technologies as indicated by a positive correlation of the *InnoS* variable proxying the sales share of innovations. Companies characterised by component 4 locate in a highly specialised periphery that focuses its activities on cutting edge niche technologies that do not compete on the same markets with agglomerated centres. Locating in the periphery, these companies avoid crowding-out effects and compensate, thereby, for the lower returns on innovations still in an early phase of their market lifecycle. The young age of companies indicated in component 4 supports this interpretation. In the light of Brezis and Krugman (1997), these technologies represent future technology paradigms that will eventually displace those promoted by older incumbent centres. Interpreting component 4 inversely supports this notion, as the agglomeration and innovation proxies are loaded negatively with each other. The sales share of innovations is lower in the case of centrally located companies characterised by the inverse component 4. Duranton and Puga's (2001) interpretation of the finding differs from those of Brezis and Krugman (1997) to the extent that it does not spell doom for agglomerated centres. According to their view, centres serve the role of innovation engines, while peripheries perform the task of developing those innovations to products and bringing them to the markets. The results back this notion in the sense that it provides evidence of the peripheries' role in action.

In compliance with Martin and Rogers (1995), the development of technologies in the periphery depicted by component 4 is facilitated among other things by taking advantage of the well-established public infrastructure represented by co-operation with local universities. A well functioning international infrastructure proxied by a relatively high export ratio additionally facilitates benefiting from externalities of specialisation by lowering trade costs to the extent that serving foreign markets from the periphery becomes viable.

However, there are also some concerns. According to Krugman and Venables' (1996) argumentation, the most significant externalities of specialisation emerge through intra-industry trade of specialised intermediate inputs concentrated in the location of specialisation. Tapping into a common pool of specialised resources generates synergies that attract further activities of similar specialisation into the area. Thus, active intra-regional trade is key to the region's success and a requirement for the justification of its peripheral location. In the case of biotechnology, which is a highly R&D intensive business, the most significant input can be argued to be knowledge. Knowledge, in turn, is traded through collaborative arrangements such as R&D collaboration. Unfortunately, the measure for intra-regional R&D collaboration is statistically insignificant. It follows that some of the companies characterised by component 4 are engaged in intra-regional collaboration while some are not. Those companies will be unable to tap into the synergies offered by the specialised environment they are embedded in and forfeit significant benefits. This poses a challenge not only to the companies in question, but also to the region as a whole because forfeiting collaborative opportunities by some companies impacts the total size of the resource pool that companies in the region can tap into.

4.5 Component 5: Collaborative periphery

Component 5 depicts another model example of companies that take advantage of lower labour costs in the geographical peripheries to develop novel technologies. Their sales share of innovations and the per-head-count of patents are relatively high while wages and salaries paid to employees are relatively low at the same time. The share of highly educated personnel is another indication of the companies' focus on developing innovations as a business model.

In contrast to component 4, active local co-operation with diverse partners implies the existence of established intra-industry linkages that could serve as a basis for emerging agglomeration in the long-run. Most importantly it is evidence of companies taking advantage of the specialised knowledge pool available in the region.

A functioning public and international infrastructure further reinforce the foundation for future growth of the region. Thus, speculating slightly, these regions might represent the seed of future centres of agglomeration.

However, there is again a major concern. In the current cross-section there is no significant sign of agglomeration or specialisation in component 5 yet. Leaning on the discussed literature, the success of growth and economic potential in the future has to be based on regional specialisation in these peripheral regions. As component 5 does not indicate such a development, one could argue that regions inhabited by companies characterised by the component are at a critical crossroads in their evolution. To be sustainable in the long run, these regions need to develop a genuine focus.

The lack of a geographic focus by some public sector funding discussed earlier does nothing to push the development in the right direction, because unfocused funds can be used to keep businesses on life-support despite being at odds with their particular region's specialisation.

With that being said, component 5 draws a coherent picture that is in congruence especially with Brezis and Krugman's (1997) framework, which bestows peripheral centres with the burden of being the locomotives of innovation and future growth. Meanwhile, incumbent centres are destined to decay slowly, as they stick to conventional technology trajectories. With this in mind, interpreting component 5 inversely provides us with the first signs of decay of incumbent centres, as companies characterised by the inverse component show low innovative activity and reliance on established technology (low sales share of innovations) while locating in the midst of economic hotspots. These companies do not exploit local or international infrastructure and suffer from crowding-out effects of intense agglomeration in the form of high salaries.

4.6 Component 6: Geographically dispersed biomaterials

Component 6 is a residual component that basically describes companies active in the biomaterials sector of the biotechnology industry. It does not provide further implications related to the geographical structure of the industry. All we can infer is that companies focused on developing biomaterials show a relatively high sales share of innovations and are privately owned. As neither the agglomeration index nor the specialisation index correlate significantly with the component, companies active in biomaterials could be found in any geographic location.

4.7 Component 7: Entrepreneurial specialisation

Component 7 provides us with one central message: Public equity financing as provided by Sitra has not been a factor leading to specialised regions with the two indicators being loaded negatively with each other. Instead, public VC funding has favoured companies in diversified regions. When these regions locate in the peripheries component 7 tells a rather gloomy story, as the bulk of the literature serving as the theoretical backbone of this study justifies the existence of peripheries only if they are specialised. Where these regions are simultaneously centres of agglomeration this is good news, as especially Duranton and Puga (2001) accord the vital role of innovation engine to diversified larger centres.

Since component 7 shows no significant correlation with the agglomeration index, however, we have to conclude that public equity funding has been equally provided to both agglomerated and peripheral regions and, thus, being invested with no clear strategy related to the economic aspects of geography. Instead, companies in these specialised regions are entrepreneurial in the sense that they finance their operations internally.

4.8 Component 8: Experienced drug development with significant public equity funding

As touched on earlier, this component establishes the positive relationship between the drug development sector of the biotechnology industry and public equity financing provided by Sitra. Combining the finding with that of component 7, it seems that Sitra's investment strategy is more related to the substance of technology than its geography. The question arises whether investing partly against the forces of the economies of geography resembles swimming against the stream. To make a certain sector thrive in a region that does not provide the right environment in terms of the necessary intra-industry linkages associated with specialisation necessitates continuous subsidies. In contrast, investments in companies that locate in regions conducive to their business in terms of specialisation or other relevant inputs could lead to the acceleration of the virtuous circle of specialised agglomeration, as each thriving member in the region adds to the success of others in its vicinity.

4.9 Component 9: Tekes encouraging regional multi-functionality

In accordance with its rather broadly defined mission, Tekes provides financing to incorporated R&D activity still in the early phases of development and would not survive independently on commercial markets. Component 9 correlates negatively with the age and the sales share of innovations. As already discussed in conjunction with Sitra's equity financing, such a broadly defined mission might have significant adverse effects. While providing initial support for emerging technologies will potentially lead to success in some instances, some support will inevitably flow to endeavours unable to strike roots in soil that cannot provide them with the necessary externalities. Once public support ends, companies that locate in less conducive regions from the perspective of their expertise and substance are forced to re-locate or risk failure.

5 Conclusions

This study set out to answer the question whether contemporary literature in the field of Geographic Economics is able to provide a justifying rationale for the much- debated geographic distribution of a science-driven industry, such as the Finnish biotechnology industry, which, according to opposing criticism, is said to be overly dispersed.

Concluding, our results indeed provide evidence of a theory-based rationale that is able to deepen our understanding of the roles that different regions have enacted in the development of the focal industry. The analysis is able to explain 72 % of the variance in our sample. Simultaneously, however, the rationale also reveals several challenges that different types of regions still have to overcome in order to keep on the track of sustainable economic development in the future. With that being said, the current course of regional evolution of the industry cannot be fully justified.

5.1 Agglomerated centres - Lack of regional co-operation and innovative capacity

The analysis clearly exposed the distinct pattern of a centre-periphery setting that is also supported by our descriptive findings. Large returns to scale are a strong incentive to locate in agglomerated centres. Companies in agglomerated centres take advantage of a well-built public infrastructure by co-operating with local universities and increasing their absorptive capacity thereby. However, these young and highly research intensive companies fail to link themselves to the regional network of intra-industry trade that could provide them with valuable channels to access complementary assets in the form of interdisciplinary knowledge provided by partners within the agglomeration. Such knowledge, in turn, is the seed for breakthrough innovations. The lack of such innovations is evident in the data. In the long run the lack of innovations entails the decay of agglomerated regions as hotspots of economic activity. Moreover, if partners are sought mainly outside one's own region, the demand linkages necessary to spur the growth of a strong local cluster fail to emerge. This has strong inhibitory effects on the growth of the regional economy that each company is a part of. Thus, failing to seek regional collaboration initiates a vicious circle in many ways.

Companies that run a more generic business model and are less research intensive seek agglomerated areas due to the closeness of intermediate input producers. The data reveals that this type of company is closely interlinked with partners in the same region. They choose an agglomerated location to minimise procurement costs and sell their products on foreign markets. From the perspective of economic justification this company type is rather favourable, as it benefits from local demand linkages and strengthens the growth of the region at the same time.

5.2 Innovative peripheries – Missing intra-industry linkages and focus

Peripheries need to meet two interrelated critical success factors to achieve necessary efficiencies through economies of scope that, in turn, compensate for the lack of agglomeration related benefits. Firstly, it is paramount to specialise strongly in some sector of the industry. Krugman and Venables (1996) predict that a periphery's economic growth becomes self-energising once a sufficiently large base of companies specialised in the same sector exists in any given region. Secondly, for this virtuous circle to set in, companies in peripheries need to establish strong intra-industry linkages in the region, as these linkages enable the exploitation of specialised complementary resources and spur demand that, in turn, attracts new sector-specific economic activity and accelerates the growth of the specialised region.

While still other success and justification criteria, such as a well-structured public infrastructure in the region, easy access to foreign markets, high innovative capacity and low personnel costs, were widely met among different types of peripheral companies, very many of them failed to meet at least one of the two aforesaid critical success factors. They were either not located in a region specialised into their own sector or links to the local industry were insignificant. In the long run this might impact the development of these peripheries negatively, because a self-sustaining and self-energising critical mass of specialised economic activity will be difficult to reach. Peripheries too diversified relative to their sise do not provide sufficiently large local markets to justify any single company's decision to establish a business in that region as opposed to locating in a strongly agglomerated region with far larger markets.

5.3 Strong international collaboration and the irrelevance of location

One of the central findings of our analysis indicates that very strong emphasis on international ties in R&D collaboration and sales renders the choice of domestic location irrelevant from the perspective of success. Companies that perform R&D to a large extent in co-operation with foreign partners and export a significant share of their products and services generate considerable turnover, employ a large staff and pay high salaries despite a seemingly random domestic location. It seems that local demand and intermediate input linkages are not of relevance to these companies because international infrastructure is utilised to access demand and intermediate inputs abroad. Thus, given low enough trade costs facilitated by infrastructure, the choice of domestic location becomes irrelevant.

5.4 Public policy implications

The study establishes that public funding, the primary implementation mechanism of innovation policy in Finland, has seemingly not been coordinated based on a regional strategy that would recognise the unique features and criteria that different types of regions need to meet in order to develop in a sustainable way. Instead, there are weak indications that public funding has rather been supportive of certain industrial sectors like drug development. In the worst case, regionally aimless public sector funding provides artificial life-support to companies strongly at odds with their regional environment in terms of specialisation and co-operation. This, in turn, can potentially inhibit the evolution of the region as a whole, which is dependent on the emergence of a critical mass of companies with shared complementary and synergetic assets.

Our findings call for a revision of the current public sector funding practices in the field of biotechnology in Finland. Funding criteria should be channeled through a set of criteria that encourages specialisation and close regional co-operation especially among companies located in peripheries.

Whether unfocused public funding has been the single major factor that has displaced incentives to specialise and co-operate in peripheries remains a question to be answered in further studies.

In terms of regional innovation policy, the irrelevance of location in the presence of strong international collaboration implies that efforts to activate companies to reach out and network internationally are an effective means to boost macro-economic development and regional vitality irrespective of the location of companies.

5.5 Contribution to geographical economics

As a contribution to the existing body of knowledge the study shows that the Geographical Economics literature indeed provides an effective tool for evaluating the challenges faced by industries in terms of their geographical distribution and its justification. The literature provides a framework suggesting a set of criteria for the successful development of different types of regions that empirical settings can be tested against. Implicitly, we have shown that the operationalisation of the GE literature is feasible and that it can serve as a basis for drawing implications on the development of single regions.

With this being said, our study serves as a useful basis for future empirical analyses that scrutinise specific questions arising from our results more in-depth. One promising avenue of research could be built around the question of how public funding and other types of public innovation policy affect the location decision of companies. In an attempt to improve the efficiency and effectiveness of public policies we need to understand in depth how the evolution of industries is affected by geography and what role public sector funding and other mechanisms of policy play in determining it. Our results merely point at the relevance of that question, while a rigorous study attempting to answer it would necessitate more extensive time-series data that preferably encompasses several countries for the purposes of benchmarking results and controlling for country effects.

Another effort with promising potential would consist of relating different regional agglomeration and specialisation patterns to firm performance indicators. In such a setting it would be possible to actually test the validity of implications of the geographical economics literature itself by asking whether location matters after all. Such an endeavour would pose considerable requirements to data. The choice of performance measures has to be made with care, because many of the younger research-intensive industries such as biotechnology, for example, still struggle with being profitable, not because they necessarily perform poorly but because of their early stage in the characteristically long development cycle of products. Moreover, effects of location on firm performance can be observed more effectively with changes in geographic patterns of the given industry over time and, therefore, would greatly benefit from the utilisation of time-series data as a basis for analyses.

6 References

Brezis, E.S. – Krugman, P. (1997): Technology and the Life Cycle of Cities. *Journal of Economic Growth*, Vol. 2, No. 4, pp. 369-383.

Dixit, A. K. – Stiglitz, J. E. (1997): Monopolistic Competition and Optimal Product Diversity. *American Economic Review*, Vol. 67, No. 3, pp. 297-308.

Duranton, G. – Puga, D. (2000): Diversity and Specialization in Cities: Why, Where and When Does it Matter? *Urban Studies*, Vol. 37, No. 3, pp. 533-555.

Duranton, G. – Puga, D. (2001): Nursery Cities: Urban Diversity, Process Innovation, and the Life Cycle of Products. *American Economic Review*, Vol. 91, No. 5, pp. 1454-1478.

Feldman, M.P. – Audretsch, D.B.(1999): Innovation in Cities: Science-Based Diversity, Specialization and Localized Competition. *European Economic Review*, Vol. 43, No. 2, pp. 409-429.

Forslid, R – Wooton, I. (2003): Comparative Advantage and the Location of Production. *Review of International Economics*, 11(4), 588–603.

Furman, J.L. – Porter, M.E. – Stern, S. (2002): The determinants of national innovative capacity. *Research Policy*, Vol. 31, pp. 899–933.

Harris, C. (1954): The market as a factor in the localization of industry in the United States”,Annals of the Association of American Geographers, Vol. 64, pp. 315-348.

Hanson, G. (1998): Market Potential, Increasing Returns, and Geographic Concentration, NBER Working Paper 6429.

Hermans, R. (2004): International Mega-Trends and Growth Prospects of the Finnish Biotechnology Industry. Doctoral thesis for the Department of Industrial Engineering and Management, Helsinki University of Technology. ETLA A-40, 172 pages. Taloustieto Oy, Helsinki.

Hermans, R. – Kulvik, M. – Tahvanainen, A.-J. (2006): The Biotechnology Industry in Finland. In Hermans, R. and Kulvik, M. (eds): Sustainable Biotechnology Development – New Insights into Finland. ETLA, B series, Helsinki.

Hermans, R. – Löffler, A. – Stern, S. (2008): The Globalization of Biotechnology: Science-Driven Clusters in a “Flat” World. To be published by The National Academies, Board on Science, Technology, and Economic Policy.

Hermans, R. –Tahvanainen, A.-J. (2006): Regional Differences in Patterns of Collaboration, Specialisation and Performance. In Hermans, R. and Kulvik, M. (eds): Sustainable Biotechnology Development – New Insights into Finland. ETLA, B series, Helsinki.

Kafatos, F.C. – Beyreuther, K. – Chua, N. – Mach, B. – Owen, D. – Steitz, J. (2002): Biotechnology in Finland –Impact of Public Funding and Strategies for the Future – Evaluation Report. *Publications of the Academy of Finland*, No. 11/02.

Krugman, P. (1991a): Increasing Returns and Economic Geography. *The Journal of Political Economy*, Vol. 99, No. 3, pp. 483-499.

Krugman, P. (1991b): Geography and trade, Gaston Eyskens lecture series. Leuwen University Press, Leuwen. MIT Press.

Krugman, P. – Venables, A.J. (1995): Globalization and the Inequality of Nations. *The Quarterly Journal of Economics*, Vol. 110, No. 4, pp. 857-880.

Krugman, P. – Venables, A.J. (1996): Integration, Specialization, and Adjustment. *European Economic Review*, Vol. 40, No. 3-5, pp. 959-967.

Leland, H. E. – Pyle, D. H. (1997): Informational asymmetries, financial structure, and financial intermediation. *Journal of Finance*, MAY, Vol. 32, No. 2, pp. 371-387.

Markusen, J. R. (1998): Multinational firms, location and trade. *The World Economy*, Vol. 21, pp. 733-756.
Martin, P. – Rogers, C.A. (1995): *Journal of International Economics* Vol. 39, pp. 335-351.
Monfort, P. – Nicolini, R. (2000): Regional Convergence and International Integration. *Journal of Urban Economics*, Vol. 48, pp. 286-306.
Nationmaster: http://www.nationmaster.com, accessed on 09.02.2006.
Samuelson, P. (1954): The Transfer Problem and Transport Costs, II: Analysis of Effects of Trade Impediments. *Economic Journal* Vol. 64, p. 264-289.
Tahvanainen, A.-J. (2004). Growth Inhibitors of Entrepreneurial Academic Spin-offs: The Case of Finnish Biotechnology. *International Journal of Innovation and Technology Management*, vol. 1, no 4, 455-475.
Venables, A. (1995): International Location of Economic Activity – Economic Integration and the Location of Firms. *The American economic review*, Vol. 85, No. 2, pp. 296-300.
Venables, A. (1996): Equilibrium locations of vertically linked industries. *International Economic Review*, Vol. 37, no. 2, 341-359.

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8 Appendix

Table A1 KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.488
Bartlett's Test of Sphericity	*Approx. Chi-Square*	661.477
	df	276
	Sig.	0.000

The KMO measure of sampling adequacy does not quite meet the limit of .600, which is conventionally held as a critical value. However, Bartlett's test of sphericity shows that a factor analysis can be applied on the data at a 0.1 percentage risk level.

Table A2 Total variance explained

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	3.622	15.091	15.091	3.622	15.091	15.091	2.334	9.724	9.724
2	2.619	10.914	26.005	2.619	10.914	26.005	2.305	9.603	19.327
3	2.290	9.543	35.548	2.290	9.543	35.548	2.260	9.417	28.744
4	2.070	8.625	44.173	2.070	8.625	44.173	2.077	8.656	37.400
5	1.726	7.192	51.365	1.726	7.192	51.365	1.962	8.177	45.577
6	1.523	6.347	57.712	1.523	6.347	57.712	1.803	7.513	53.089
7	1.210	5.040	62.752	1.210	5.040	62.752	1.703	7.095	60.184
8	1.151	4.797	67.549	1.151	4.797	67.549	1.643	6.846	67.030
9	1.101	4.589	72.138	1.101	4.589	72.138	1.226	5.108	72.138
10	0.956	3.982	76.120						
11	0.809	3.372	79.492						
12	0.798	3.327	82.819						
13	0.669	2.786	85.605						
14	0.605	2.521	88.126						
15	0.582	2.424	90.550						
16	0.492	2.050	92.601						
17	0.458	1.907	94.508						
18	0.337	1.402	95.910						
19	0.319	1.328	97.238						
20	0.273	1.137	98.375						
21	0.217	0.903	99.278						
22	0.112	0.467	99.745						
23	0.045	0.186	99.931						
24	0.017	0.069	100.000						

Extraction Method: Principal Component Analysis.

Table A3 Correlation matrix

	InnoS	PatE	SC	AT	Staff	EmplC	AggInd	SpecInd	Age	ExpR	PhDs	ColFO	ColFU	ColLO	ColLU	Drug	Enzs	Biom	EmplFin	CorpFin	PrivVC	PublVC	Tekes
PatE	0.204																						
SC	-0.118	0.056																					
AT	-0.143	-0.068	0.107																				
Staff	-0.073	-0.144	**.344	**.580																			
EmplC	-0.010	-0.063	*.263	**.290	0.208																		
AggInd	-0.159	0.038	0.119	-0.134	-0.081	-0.116																	
SpecInd	0.138	-0.083	0.050	0.005	0.005	0.069	-0.085																
Age	-0.097	-0.089	0.005	0.138	**.647	-0.047	-0.083	-0.131															
ExpR	-0.061	-0.044	0.041	**.352	0.151	0.045	0.004	0.075	0.024														
PhDs	0.115	*.277	-0.098	*-.270	*-.282	*-.277	0.049	-0.036	*-.246	-0.109													
ColFO	0.018	0.051	**.387	**.315	*.244	0.197	-0.025	-0.062	0.102	0.020	-0.126												
ColFU	0.104	-0.083	**.418	**.382	**.408	0.158	-0.004	0.082	0.131	0.191	-0.036	**.588											
ColLO	0.068	0.075	-0.220	-0.095	-0.031	**-.361	0.224	-0.161	0.049	0.141	0.215	0.047	0.102										
ColLU	0.049	0.148	0.153	-0.168	-0.191	-0.077	0.016	0.153	-0.176	0.075	0.180	0.058	0.162	0.214									
Drug	0.113	0.120	0.109	-0.160	-0.081	0.070	-0.010	**.323	-0.200	-0.071	*.236	0.029	0.065	0.005	0.209								
Enzs	-0.052	-0.148	0.064	0.198	-0.041	0.030	*-.257	0.093	-0.062	*.232	-0.122	0.048	-0.021	*-.247	-0.109	-0.007							
Biom	0.133	**.322	-0.067	-0.155	-0.171	-0.112	-0.072	-0.194	-0.120	-0.070	0.173	-0.210	-0.146	-0.049	-0.042	0.006	-0.039						
EmplFin	-0.122	-0.096	*.244	**.328	**.436	0.154	0.034	0.102	0.032	-0.038	-0.138	0.048	0.146	-0.174	*-.238	0.021	-0.072	-0.075					
CorpFin	-0.105	**.312	**.320	0.123	0.014	0.084	0.114	-0.120	-0.001	**.419	-0.140	*.234	-0.003	-0.026	0.130	-0.092	0.028	0.159	-0.068				
PrivVC	0.223	0.070	**.325	-0.052	0.149	0.139	-0.024	0.005	-0.071	-0.023	-0.111	0.176	0.143	-0.168	-0.118	0.023	-0.113	*.277	0.137	0.221			
PublVC	0.093	-0.029	0.177	-0.074	0.094	**.342	0.113	0.042	-0.093	-0.029	-0.075	0.085	0.109	-0.146	0.193	**.351	-0.174	-0.056	-0.013	0.002	0.172		
Tekes	-0.084	-0.001	*.235	0.023	0.096	0.070	0.063	0.012	-0.003	0.055	0.004	0.087	0.159	-0.019	0.170	0.063	-0.005	-0.060	0.104	0.076	0.100	0.116	
LHub	-0.027	0.026	0.180	-0.035	-0.016	0.051	**.903	0.058	-0.191	0.068	0.009	0.012	0.078	0.176	0.042	0.063	*-.271	-0.057	0.092	0.104	0.112	0.157	0.060

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table A4 Rotated component matrix

Variables	Components								
	1	2	3	4	5	6	7	8	9
CorpFin	** 0.973	0.023	0.047	0.069	0.021	-0.044	0.039	-0.026	0.027
ExpR	** 0.969	0.045	0.029	-0.015	-0.018	-0.016	0.010	-0.012	0.010
ColFU	0.143	** 0.855	0.072	0.001	0.058	0.092	0.098	0.071	0.066
ColFO	-0.033	** 0.852	-0.081	0.073	-0.046	-0.026	0.085	-0.083	0.040
SC	0.015	** 0.466	0.146	* 0.346	0.091	** 0.419	-0.066	0.009	0.207
AggInd	0.011	-0.043	** 0.949	-0.049	-0.030	0.019	-0.048	-0.104	-0.027
LHub	0.084	0.076	** 0.929	0.041	0.042	0.101	-0.151	0.009	-0.024
Enzs	** 0.336	0.090	**-0.462	0.024	-0.246	0.088	*-0.356	-0.139	-0.105
EmplC	0.073	0.087	-0.012	** 0.744	-0.012	0.113	-0.015	0.004	0.024
PublVC	-0.003	0.067	0.196	** 0.680	* 0.348	-0.234	0.119	0.102	0.162
ColLO	0.151	0.147	* 0.347	**-0.620	0.034	*-0.359	0.186	0.044	0.129
Drug	-0.073	0.009	0.044	0.224	** 0.771	0.014	-0.036	0.024	-0.048
ColLU	0.116	0.237	0.031	-0.023	** 0.518	*-0.339	*-0.300	-0.179	0.222
PhDs	-0.148	-0.126	0.108	**-0.480	** 0.514	-0.053	-0.205	0.088	0.158
PatE	0.023	-0.111	-0.038	-0.293	** 0.491	-0.010	0.026	* 0.376	0.030
EmplFin	-0.063	0.037	0.092	0.081	0.002	** 0.842	0.118	0.010	0.041
AT	** 0.433	* 0.350	-0.133	-0.009	-0.212	** 0.465	0.144	-0.106	0.024
Age	0.021	0.055	-0.137	-0.037	-0.155	0.007	** 0.864	-0.140	-0.012
Staff	0.140	* 0.352	0.001	0.094	-0.073	** 0.447	** 0.721	0.006	0.068
Biom	-0.006	-0.293	-0.055	-0.139	0.038	-0.021	-0.060	** 0.716	0.106
PrivVC	-0.040	0.195	0.087	* 0.330	-0.103	0.168	-0.033	** 0.687	0.017
InnoS	-0.082	0.201	-0.111	-0.028	0.188	-0.236	-0.071	** 0.601	*-0.367
Tekes	0.055	0.234	-0.052	0.082	0.144	0.122	-0.036	-0.051	** 0.760
SpecInd	0.115	0.159	-0.047	0.150	** 0.501	0.240	-0.182	-0.163	**-0.559

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization
a. Rotation converged in 12 iterations.

Table A5 Communalities

Variables	Initial	Extraction
InnoS	1.000	0.652
PatE	1.000	0.484
SC	1.000	0.590
AT	1.000	0.621
Staff	1.000	0.882
EmplC	1.000	0.580
AggInd	1.000	0.920
SpecInd	1.000	0.744
Age	1.000	0.815
ExpR	1.000	0.944
PhDs	1.000	0.622
ColFO	1.000	0.757
ColFU	1.000	0.788
ColLO	1.000	0.733
ColLU	1.000	0.626
Drug	1.000	0.657
Enzs	1.000	0.560
Biom	1.000	0.638
EmplFin	1.000	0.746
CorpFin	1.000	0.960
PrivVC	1.000	0.668
PublVC	1.000	0.732
Tekes	1.000	0.684
LHub	1.000	0.912

Extraction Method: Principal Component Analysis.

Table A6 Descriptive statistics

Variables	N	Minimum	Maximum	Sum	Mean	Std. Deviation
InnoS	75	0	1	14	0.18	0.337
PatE	77	0	10	41	0.53	1.406
SC	95	0	7 200 000	69 654 842	733 208.87	1258850.561
AT	103	0	34 941 568	242 505 420	2 354 421.56	6692446.116
Staff	97	0	238	2 093	21.58	36.055
EmplC	89	0.00	160 586	3 112 279	34 969.43	25356.989
AggInd	104	7.38	47.88	3 643	35.03	12.908
SpecInd	77	0.00	1.00	55	0.71	0.455
Age	77	1	121	824	10.70	15.102
ExpR	76	0	98	124	1.64	11.208
PhDs	75	0	100	2 285	30.47	29.708
ColFO	77	0	3	70	0.91	0.934
ColFU	77	0	1	22	0.29	0.455
ColLO	77	0	1	29	0.38	0.488
ColLU	77	0	1	54	0.70	0.461
Drug	77	0	1	21	0.27	0.448
Enzs	77	0	1	15	0.19	0.399
Biom	77	0	1	18	0.23	0.426
EmplFin	71	0	6 168 400	22 760 657	320 572.63	813721.534
CorpFin	71	0	32 877 589	59 791 060	842 127.61	4320725.955
PrivVC	71	0	20 947 056	47 101 107	663 395.87	2710336.163
PublVC	71	0	5 693 250	23 597 627	332 360.95	997524.004
Tekes	108	0	1	67	0.62	0.488
LHub	77	0	1	59	0.77	0.426
Valid N (listwise)	*62*					

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