Innovative activity and firm characteristics

a cluster analysis with firm-level data of Swiss manufacturing

Eidgenössische Technische Hochschule Zürich
Ecole polytechnique fédérale de Zurich
Politecnico federale di Zurigo
Swiss Federal Institute of Technology Zurich

Konjunkturforschungsstelle
Centre de recherches conjoncturelles
Centro di ricerche congiunturali
Swiss Institute for Business Cycle Research

Weinbergstrasse 35, ETH Zentrum
CH - 8092 Zürich

Phone *+41-1 / 632 42 39*
Direct *+41-1 / 632 51 68 and 53 29 resp.*
Telefax *+41-1 / 632 12 18*
e-mail *arvanitis@kof.gess.ethz.ch*
hollenstein@kof.gess.ethz.ch

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Innovative Activity and Firm Characteristics - A Cluster Analysis with Firm-level Data of Swiss Manufacturing

Spyros Arvanitis and Heinz Hollenstein

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Abstract

Innovative activities of firms differ with respect to their intensity, orientation, use of external knowledge, etc.. Applying cluster analysis to such characteristics (nine innovation indicators, seventeen knowledge sources) we grouped similar firms into „innovation types“. For Swiss manufacturing, this exercise yielded five innovation types, which, in a second step, were characterized by some structural properties (e.g. firm size, industry, export orientation) and factors relevant for innovation (e.g. market conditions, appropriability). A main result of the analysis is the low correspondence between industries and clusters. Moreover, the latter do not much differ in terms of economic performance; hence, several innovation types may coexist, at least during a certain time period. The findings are consistent with evolutionary economics stressing the heterogeneity of the innovation process.

1. Introduction

The innovation process is a complex phenomenon characterized by several stages reaching from basic research up to the penetration of the market with new products. Therefore a whole series of indicators is needed to describe and measure a firm’s innovative activities, each of them stressing specific aspects but also exhibiting measurement errors. Based on such a system of indicators one may look either for specific patterns of innovative activity („innovation types“) or for a ranking of firms according to a composite measure of innovativeness („innovation intensity“).[1] The first (classificatory) procedure is less restrictive because, in distinction from a ranking approach, it does not enforce „homogenization“ upon the basically heterogeneous nature of the innovation process. In addition, in concordance with the evolutionary view of technological change, it allows for the co-existence of different innovation types which, at least during a certain time period, may be viable in economic terms. This feature may reflect specific economic environments and/or a certain freedom for strategic choices by firms.

The present paper is based on such a classification approach. It aims at a description of the innovation process in Swiss manufacturing in terms of the prevalence and importance of specific innovation types and their impact on productivity. Drawing on firm-level data stemming from the KOF/ETH Innovation Survey 1996, which in its core questions is comparable to the „Community Innovation Survey“ (CIS) conducted in most European countries, we are able to determine a number of innovation types by use of cluster analysis.

What are the criteria to be applied in defining such innovation types? We think that such an exercise should be based on a set of:

- innovation indicators representing different aspects of the innovation pattern of firms, i.e. the input and the output side of technological innovation as well as its impact on the firms’ revenue,
- knowledge sources a firm may use in its innovative activities both in an informal way and through formal R&D cooperations depicting the network of the firms’ knowledge linkages.

Innovation types based on these two categories of variables are then to be described by a number of additional variables relevant for the innovation process such as human capital intensity, appropriability, market conditions or demand perspectives as well as some general firm characteristics such as size, activity field (2-digit industries) and export orientation and, finally, some measures of economic performance. In this way, a rather comprehensive picture of the structure of the Swiss firms' innovative activity should emerge.

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1 The latter approach has been explored in Hollenstein (1996) for product as well as process innovations based on a factor analysis of a large number of indicators.

The (analytical) point of reference for this investigation is the typology proposed by Pavitt (1984). But in distinction from his work the present paper is based on a statistical method (cluster analysis). Arundel et al. (1995) also used cluster analysis to classify firms with respect to several innovation indicators and knowledge sources, but they refrained from combining the two types of information in a systematic way. In addition, because their work is based on information for the 500 largest European firms, it is representative only of a small fraction of the economy. A recent study of Cesaratto and Mangano (1993), whose methodological procedure we adopted in the present paper, is less comprehensive; their cluster analysis is rectricted to innovation indicators only. In this perspective, our work may add some knowledge to the body of literature on typologies of innovative firms.

The set-up of the paper is as follows: The data base and the innovation indicators as well as the variables depicting the knowledge sources are shortly described in section 2, which gives also the necessary information on the procedure used to search for innovation types. The empirical results with respect to innovation indicators and knowledge sources are presented and discussed in section 3 and 4 respectively. In section 5 we are looking at the relationship between the groupings of firms based on their innovation and their knowledge pattern. Finally, we draw some conclusions and propose some elements for future research.

2. Data and method

The data used in this study are from a survey on innovative activity of Swiss private enterprises conducted in 1996, which was based on a stratified random sample (17 industries and three firm size classes for each industry with full sampling of the upper size class). The present analysis is confined to the subsample of 2966 manufacturing firms (seventeen industries) which were asked to fill in a questionnaire about their innovative activities and a large set of other variables relevant to the description of the innovation process and the explanation of innovation performance during the years 1994-96. We received valid answers from 1048 firms, i.e. 35.3% of the basic sample. This data set corresponds rather well to the structure of the underlying sample (see Arvanitis et al. (1998) for more details on the survey). The search for innovation types is based on the subsample of innovative firms (804 companies or 77% of the respondents), which had to be further reduced because of missing values for some of the innovation and knowledge source variables. This reduction led to a final data set of 516 firms with only some overrepresentation of large companies and firms of the machinery industry. Therefore the data at hand may be considered as representative of the basic sample.

The information collected enabled us to construct fifteen innovation indicators. Eight of them refer to the input- and the output-side of the generation of innovations with separate measures for product and process innovations, whereas the third type of indicators is oriented towards the introduction of novelties on the market. These variables together with their measurement scale and the corresponding value ranges are listed in the upper part of table 1. All input- and output-oriented measures used are qualitative variables (five-point Likert scale); the corresponding quantitative measures, for example R&D expenditures or total innovation costs as a percentage of sales, though available, are not used in the present study because of the larger number of missing values compared to ordinal measures. In earlier work we found that the information content of the two types of measurement is very similar (see Arvanitis and Hollenstein 1994, 1996). The three market-oriented indicators referring to different definitions of innovative products are quantitative variables measured as sales shares. Furthermore, the survey distinguishes seventeen firm-external sources of knowledge whose importance had to be assessed by the respondents again on a five-point Likert scale (see lower part of table 1). They may be grouped in four categories, the first one referring to knowledge from other firms, the second to the „science sector“ at large, the third to generally accessible knowledge and the last one to knowledge embodied in several input factors.

The search for innovation types is based on two cluster analyses, the first one referring to the innovation indicators listed in table 1, the second one based on the knowledge sources mentioned in the same table. Cluster analysis, however, is not directly applied to these variables. In a preliminary step the information content of these two sets of fifteen and seventeen measures respectively are synthesized, separately, by means of a factor analysis into a small number of variables (principal component factor analysis). Only in the second step we performed a cluster analysis in order to group the firms into a number of categories which are, with respect to the variables under investigation, as homogenous as possible (small within-cluster variance) and at the same time as different as possible from each other (large between-cluster variance). In a next step these two sets of clusters are interpreted in terms of the underlying variables (i.e. innovation indicators and knowledge sources respectively), a number of additional variables relevant for the innovation process (human capital intensity, appropriability conditions, R&D cooperation intensity), some general firm characteristics (size, industry, export orientation, market conditions, demand perspectives) as well as some measures of economic performance.

3. Innovation clusters

The preliminary step of factor analysis, as shown in detail in table A1 of the appendix, leads to statistically satisfactory results. The four factors extracted in the analysis account for 68% of total variance. The factor solution is also convincing in economic terms as can be seen from the factor pattern depicted in the same table. The first factor accounts for 21% of total variance and gives high weights to input- and output-oriented indicators for product innovations. The second component capturing 18% of the variance shows high loadings on market oriented indicators, which, by definition, refer to product innovation only. The third factor explaining 17% of total variance refers primarily to the engineering/design activities and follow-up investments and the fourth one to R&D activities (12% of total variance).

In the second step we performed a non-hierarchical cluster analysis[2] based on the four principal components which led to a grouping of the firms in terms of innovation indicators into five categories. The solution shows satisfactory statistical properties in terms of the relationship of within-cluster as compared to between-cluster variance. The approximate expected overall R^2 of .56 points to a rather good fit of the data to the underlying clustering model. Before describing the single clusters in some detail a general characterization may be helpful. The innovative activities of firms belonging to Cluster 1 are quite intensive and strongly based on engineering/design as well as follow-up investments both in products and processes. Cluster 2 is characterized by a low innovation intensity directed to products improved through some engineering/design efforts. Cluster 3 is the complement of cluster 2 in the process field with an (almost exclusively) investment-based innovation pattern. The firms of cluster 4 are very innovative in every aspect in both fields of innovation and are the most research-intensive ones. Cluster 5 contains a small number of product innovators who produce many world novelties based on heavy development and engineering activities. Let us now turn to a closer examination of the five clusters in terms of the information given in the tables 2, 3 and 4 and of some additional data from the Swiss Innovation Survey 1996.

Cluster 1:

This cluster is the largest one in terms of number of firms and employment as a share of the total of our sample, that is 36% and 39% respectively. Compared to the average of the manufacturing sector this cluster is concentrated to medium sized enterprises. The export share is distinctly above average though lower than that of clusters 4 and 5. Firms of the metalworking and the transport equipment industry are most prominent in this cluster but also the machinery sector as well as the paper and the printing industry are represented more than on average.

Innovative activities of firms belonging to cluster 1 are concentrated to engineering/design as well as follow-up investments whereas development inputs are almost equal to the average; own research is totally absent. The innovation intensity is high both in the product and the process field according to input- as well as output-oriented indicators. Consistent with the pattern and intensity of innovative

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2 This procedure involves partitioning of the sample with observations being allowed to move in and out of groups at different stages of the analysis. At the beginning some more or less arbitrary group centres are chosen and individual observations allocated to the nearest one. An observation is then moved to another group if it is closer to that group's centre than to the centre of the present group. This process during which close groups are merged and distant ones split is continued until stability is achieved with a predetermined number of clusters (Manly 1986, p.101). We used the FASTCLUS procedure of the statistical package SAS to perform the analysis.

activities is the focussing on in-depth product improvements whereas world novelties which require more R&D are rather rare. In sum, the innovation strategy of this cluster, though incremental in nature, is broadly based in terms of orientation and firm-internal efforts leading to high quality improvements.

No specific traits can be found with respect to market conditions in terms of concentration (number of competitors at world scale), intensity of price and non-price competition as well the medium-term development of the market potential.[3] The same holds for some rough measures of economic performance such as the ratio of value added to labour input and the share of capital income to total value added. However, these performance indicators do not take account of inter-firm differences with respect to physical and human capital intensity, a deficiency we try to correct for below. In view of the large company and employment share of this cluster the described innovation pattern is representative for a large part of Swiss manufacturing.

Cluster 2:

This cluster comprises almost as many firms as the first one (32% vs. 36%) but its employment share is much lower (19% vs. 39%) reflecting the absence of large and the high importance of very small firms with less than 50 employees. The export orientation corresponds to the industrial average. Compared to the other clusters firms of the food, textile, clothing and the watchmaking industry are mostly present in cluster 2; in addition, the industries chemicals (except pharmaceuticals), non-metallic mineral products and metal production are represented to a quite substantial extent.

Innovative activities of cluster 2, which are exclusively product-oriented, are rather modest. They are concentrated on development and engineering/design leading primarily to improvements of (existing) products whose importance in technological as well as economic terms is clearly below average. This pattern reflects a purely incremental, low profile innovation strategy.

Rather suprisingly we do not find any clear features with respect to economic and market conditions, except of slightly below-average growth perspectives for the product market.

Cluster 3:

This cluster is small in terms of the number of companies (9%) as well as employment (4%). Two third of its firms employ less than 100 workers and it is strongly oriented to the home market; more than half of the companies do not export at all. The strongholds of this cluster are wood processing, printing, the chemical industry (except pharmaceuticals), non-metallic mineral products and metal production; in addition, the food industry and electrical machinery (primarily the segment oriented towards the building sector) are quite strongly present in this category of firms.

Innovation in this cluster is exclusively oriented towards the introduction of new processes and involves primarily the acquisition of capital goods; follow-up investment is the only innovation input which is more important for these firms than on average. In view of this strongly process-biased innovation pattern it is surprising that the market-oriented indicators show higher shares of improved products than cluster 2 with its purely product-oriented innovative activities. Obviously the investment in new production techniques leads in many instances to product changes which are not negligible.

Cluster 3 differs with respect to several aspects of market conditions from the manufacturing average and all other clusters. The firms are confronted with more competitors at the product market. In addition, they face fierce price competition and an unfavourable demand. Therefore, one would expect that economic performance of the firms belonging to this cluster is worse than that of the other four categories. This is not confirmed by the performance indicators presented in table 3, presumably because of the above-average physical capital intensity characterizing the innovation strategy of cluster 3 which leads to an overestimate of the (relative) economic performance (for a more specific analysis of this aspect see below).

Cluster 4:

This category ranks third in terms of the number of companies (19%) but second with respect to the employment share (36%). Cluster 4 contains by far the highest share of large enterprises (500 and more workers). Furthermore, it is very strongly oriented towards foreign markets though not quite as pronounced as cluster 5. Compared to the manufacturing average the paper, the pharmaceutical and the plastics industry show the highest company share in this cluster. Very important are also non-metallic mineral products, the machinery sector, electronics/instruments as well as watchmaking.

Cluster 4 is a category of firms with a very high level of innovative activities linked to all stages of the innovation process from research to the introduction of new products at the market place, and aiming at both new products and new production techniques. R&D activities play a dominant role, whereas the intensity of engineering/design and follow-up investments is somewhat lower. The high innovation input, which is also reflected in a very intensive use of human capital, leads to a distinctly above-average presence of new/highly improved products and, to a somewhat lesser extent, world novelties. In sum, the innovation pattern of this cluster may be characterized as a high-profile, strongly R&D-based strategy which aims at fundamental changes of products and processes.

The firms of cluster 4 operate in significantly different market conditions than those in the first three clusters. Almost 40% of the firms compete worldwide with less than five other companies on markets which are strongly growing. In concordance with the innovation strategy, non-price competition is

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[3] For definition of these mainly ordinal measures see Arvanitis et al. (1998).

much more intensive than on the markets where the fîrms of the other clusters are operating. The performance measures, however, show on average not much higher values than those of total manufacturing.

Cluster 5:

Finally, there is a small cluster comprising 4% of all manufacturing firms which employ only 1% of total employment. These firms are predominantly very small, about 60% of them have less than 50 employees and not a single company employs more than 500 workers, which is not surprising because more than a third of these firms are start-ups of the nineties. Export orientation is even higher than in cluster 4; almost 60% of the firms are selling more than two thirds of their output abroad. Firms of this cluster belong almost exclusively to the machinery industry and to electronics/instruments.

Innovative activity in cluster 5 is very intensive and almost exclusively oriented towards new products. The firms of this group rely very strongly on human capital and use it primarily in development and engineering/design activities, to a lesser extent also in research (less than cluster 4 but more than the other three groups). These activities yield a very innovative product mix with a sales share of world novelties of about 50%. In sum, this cluster contains small young high tech-firms of the machinery industry and electronics/instruments which presumably supply narrowly defined niche-markets.

60% of the firms, i.e. twice the manufacturing average, operate in markets with less than five competitors where price competition is not very intensive. Most importantly, the growth potential of the markets supplied by cluster 5 is very high and even more favourable than that of cluster 4. With respect to the economic performance of these high-tech companies an assessment based on the available indicators seems very difficult; value added per employee, for example, is clearly below average but in view of the very high human capital intensity this measure does underestimate performance.

In sum, we can identify five innovation clusters which are characterized by specific innovation strategies which differ primarily with respect to:

- the (in-house) intensity of innovative activities: high in the case of the clusters 4 and 5, medium in cluster 1 and low in the remaining two clusters;
- the direction of innovation efforts: product as well as process in the case of the clusters 1 and 4, product only in the clusters 2 and 5 and process only in cluster 3;
- the type of ressources primarily used in innovative activities: development and engineering/design in the case of cluster 5 and to some extent also in cluster 2, these two components and follow-up investments in cluster 1, only follow-up investments in cluster 3 and all types of inputs with special emphasis on R&D in cluster 4;

- the impact of innovative activities on sales: high importance of world novelties in the case of clusters 4 and 5, high quality improvements/new products in cluster 1 and purely incremental product changes in the case of the clusters 2 and 3.

The five clusters differ also systematically in terms of other characteristics such as human capital intensity, firm size, export orientation, market conditions and demand potential, while the performance indicators used show rather similar values for all clusters. However, a closer look based on regression analysis in a production function framework, which allows to control for inter-firm differences with respect to physical and human capital intensity, shows that, in terms of economic performance, the five clusters may be grouped in two categories. The highly innovative clusters 4 and 5 exhibit a (statistically) significant higher economic performance than the other three (less innovative) clusters, whereas within these two groups no such statistically significant differences can be found.

The relationship between industries and clusters is not unequivocal in most cases. The majority of industries is distributed to a significant extent in two or three (or even more) clusters. This points either to a heterogeneous structure of industries in terms of product lines and/or to the existence of a certain room for individual firms to choose specific innovation strategies in similar technological and economic environments.

To conclude this section we shortly compare these results with those of Cesaratto and Mangano (1993) referring to the manufacturing sector of Italy. The latter study is, to our knowledge, the most comparable one in terms of its approach, the type of indicators used and the characteristics of the underlying sample.[4] The authors of the study for Italy identified six clusters representing specific innovation strategies. Some of them correspond more or less with certain innovation clusters we found for Switzerland, but there are also important differences. The latter reflect primarily on the one hand the higher stage of development of Swiss industry, on the other hand the obvious comparative disadvantage of the small Swiss economy with respect to scale-intensive industries/product lines. More specifically, in both countries there is a cluster with top-performers in terms of product as well as process innovations; however in the Swiss case this cluster covers 36% of employment, in Italy only 2%. The second top-performing cluster of Swiss manufacturing with a very small employment share (1%) which is exclusively oriented towards product innovations has not been found in the Italian case. In both countries there is a cluster of rather small firms concentrating on process innovations based on few in-house innovative activity; however, whereas in Italy almost half of manufacturing employment is concentrated in this category, it is only 4% in Switzerland. Furthermore, there is in both countries a cluster of firms following a low-profile incremental product-oriented innovation strategy whose em-

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4 In fact their work has been an important source of inspiration for the present analysis.

ployment share is quite similar (22% in Italy vs. 19% in Switzerland). The largest cluster (39% of employment) in Switzerland is characterized by a high-profile incremental strategy based on some development activities but primarily on engineering/design and follow-up investment and oriented towards in-depth product improvements and, to a lesser extent, process innovations as well. There is no cluster in Italy comparable to this one, though two of the Italian clusters show some similar traits: the first one follows an incremental strategy based on engineering/design and exclusively oriented towards new products; a second cluster is active in both types of innovative activity but stresses more the R&D component. The latter, together with another strongly process-oriented cluster, is characterized by an important share of large firms which are able to exploit economies of scale, an element hardly present in the Swiss case.

This comparison shows that each economy exhibits quite important specificities in terms of innovation patterns which has to be taken into account in policy design. It would be interesting to see to what extent this conclustion still holds in a comparison of countries of similar size and level of development. Finally, we want to point to a common finding of the Italian and the Swiss study which, if corroborated by further studies, is very important. In both cases the relationship between industries and innovation clusters is rather loose which may reflect, as mentioned, a not negligible degree of freedom to choose firm-specific innovation strategies; this interpretation of the results would be in concordance with a basic assumption of evolutionary economics.

4. Knowledge clusters

The first step is again factor analysis. As shown in detail in table A2 of the appendix, it leads to statistically satisfactory results; the four factors extracted in the analysis account for 52% of total variance. The factor solution is also convincing in economic terms as can be seen from the factor pattern depicted in the same table. The first factor accounts for 19% of total variance and is related to the sources of scientific knowledge produced by the science sector and science-based firms and diffused through some technology policy programmes. The second component capturing 12% of the variance stands for knowledge aquired through factor inputs with high knowledge content (experts, licences) as well as knowledge generated within the company group or by the acquisition of knowledge-intensive firms. The third factor explaining 11% of variance refers to knowledge gained from other firms (except suppliers) and from freely available sources (fairs, professional journals, etc.). Finally, there is a fourth factor accounting for 10% of the variance, which represents embodied and disembodied knowledge offered by suppliers of materials and capital goods. In a second step the firms, based on the results of factor analysis, have been grouped into four categories by use of cluster analysis. The solution of this exercise shows satisfactory statistical properties in terms of the relationship of within-cluster compared to between-cluster variance. The approximate expected overall R^2 of .46, though not overwhelming, reflects a satisfactory fit of the data to the underlying clustering model.

Before describing the single clusters in some detail a general characterization may be helpful. Firms of cluster 1 draw heavily on knowledge stemming from market partners and some freely accessible sources. Firms of cluster 2 absorb very intensively all types of external knowledge and are oriented mostly towards acquiring knowledge from the science sector. Cluster 3 contains firms which rely almost exclusively on knowledge from suppliers. The firms of cluster 4 rank second in terms of the absorption of scientific knowledge; in addition they use intensively specific knowledge acquired through the recruitment of experts. A more detailed characterization of these knowledge clusters is given below based on the information in tables 5 to 9 and some additional data from the Swiss Innovation Survey 1996.

Cluster 1:

A quarter of all firms, which represent only 13% of overall employment, belong to this category; it thus contains a high proportion of small companies. The export orientation of the firms of cluster 1 is about average. Compared to manufacturing as a whole the industries food, clothing and plastics show the highest company share in this cluster. Well represented are also metal working, the machinery industry and the production of transport equipment.

Innovative activity of these firms is sustained by intensive contacts with customers and through information gained from competitors; in addition, general accessible knowledge sources are much more important compared to the average of manufacturing. All other external knowledge sources are of low importance. Moreover, the intensity of formal cooperation with other firms and institutions is low: almost 60% of this cluster's firms have no such arrangements with Swiss partners and two third no cooperation across the national border. The effectiveness of knowledge protection is about average compared with manufacturing as a whole, with the time lead in introducing new products playing the major role. Human capital as well as R&D-intensity, which may be used as proxies for the firm-internal efforts in innovation, are slightly below average, pointing to rather modest capabilities in acquiring and absorbing external knowledge.[5] The (rough) indicators of economic performance of the firms of cluster 1 show about average values.

In sum, the knowledge pattern of cluster 1 is quite strongly geared to market-oriented sources with informal knowledge links dominating and the intensity of overall use of external knowledge somewhat below average.

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5 High intramural innovative activities foster the absorption of external knowledge because of a higher information and learning capacity (see Cohen and Levinthal 1989).

Cluster 2:

Cluster 2, like the other ones, contains about a quarter of all firms many of them medium-sized or large; the employment share is not less than 45%. Cluster 2 is highly export-oriented with 40% of the firms selling abroad more than two thirds of their output. Compared to total manufacturing the industries chemicals/pharmaceuticals, non-metallic mineral products, metal production, electrical machinery and transport equipment show the highest company share in this cluster. Strongly represented are also the industries paper, plastics, machinery as well as electronics/instruments.

Firms of cluster 2 are drawing heavily on external knowledge; they are the most intensive users of fourteen out of seventeen sources. In distinction to the other clusters, in particular to cluster 1 and 3, the links to the science sector at large are strong (unversities, technical colleges, other public and private research institutions as well as technology-oriented public promotion programmes). In many instances, the use of external knowledge is institutionalized through formal R&D cooperations. Almost half of this cluster's firms are engaged in three or more such arrangements in Switzerland and a third abroad as compared to 34% and 18% respectively in total manufacturing. An above-average endowment with human capital and a high R&D intensity as well as effective protection against imitation based on formal as well as informal strategies build a favourable environment for the absorption of external knowledge. Surprisingly, economic performance of cluster 2 is not above-average, presumably due to a poor quality of the performance indicators used.

In sum, the knowledge pattern of cluster 2 is strongly externally-oriented reflecting the use of all relevant external sources of knowledge. The absorptive capacity for such knowledge is strong given the high level of intramural innovative activities. The specificity of this cluster is the intensive use of scientific knowledge and the existence of formal R&D links with many domestic and foreign partners.

Cluster 3:

Cluster 3 again contains about a quarter of all firms which are, similar to cluster 1, predominantly small. As a result the employment share is only 16%. The export orientation of cluster 3 is the lowest of all categories. Compared to manufacturing as a whole, textiles, wood products, paper, printing/ publishing and metal working are the most prominent industries; food and clothing are also well represented, but to a lesser extent.

The knowledge pattern of cluster 3 is characterized by a very strong specialization towards the use of information from suppliers of materials/components and equipment as well as the acquisition of (embodied) knowledge by purchasing capital goods; the importance of all other sources is significantly below average. Therefore it is no surprise that formal R&D cooperation is rare and the R&D and human capital intensity are very low. The fact that external knowledge contributes significantly to innovative activity only in the case of new production techniques is consistent with this knowledge pattern. The economic performance indicators show values which are only slightly (if at all) below-average; however, in view of the above-average physical capital intensity of cluster 3, this result may be somewhat too optimistic.

In sum, the knowledge pattern of cluster 3 shows a rather low profile and is very specialized towards the use of embodied and disembodied knowledge from suppliers of materials and equipment, therefore strongly oriented towards the introduction of new production techniques.

Cluster 4:

28% of firms with almost the same share of employment (26%) belong to cluster 4. This category shows a polarized size structure with a large share of very small firms (35% with less than 50 employees) besides a high proportion of large firms. This cluster is the most export-oriented one with almost half of the firms selling more than two thirds of their output abroad. Compared to total manufacturing the machinery industry, electronics/instruments and watchmaking show the highest company share in this cluster. To a lesser extent, textiles as well as non-metallic mineral products are also well represented.

Firms of cluster 4, as those of cluster 2, are intensively using science-based knowledge (universities, technical colleges, other public research institutes and government support programmes for new technologies as well as patent disclosures and recruitment of experts). However, the extent of absorption of this type of knowledge, though above-average, is lower than that of cluster 2. In addition, the knowledge pattern of cluster 4 is much more specialized as can be seen from the below-average use of all other knowledge sources. The conditions for the absorption of external high-tech knowledge are very favourable in terms of endowment with human capital and R&D intensity; in this respect cluster 4 takes the first rank. Appropriability is also high though most protection mechanisms are not as effective as in cluster 2. The intensive use of external knowledge is reflected by a high percentage of firms with many formal R&D cooperations in Switzerland; however, the frequency of such arrangements with foreign partners is below the average of the manufacturing sector. Economic performance is almost the same as in the other clusters.

In sum, the knowledge pattern of cluster 4 is characterized in the first instance by its strong and exclusive orientation towards science-based knowledge which is reflected in a high number of R&D partnerships primarily with Swiss partners. These two characteristics, besides the lower intensity of use of science-based sources of knowledge, are the main distinguising features compared to the nearest cluster 2.

To conclude this section, it may be stated that the cluster analysis with seventeen extramural sources of knowledge allows to identify four knowledge clusters whose properties seem plausible. The four groups may be labelled as users of knowledge sources pertaining, first, to market-oriented knowledge, secondly, to all types of sources with scientific knowledge being particularily important, thirdly, to supplier-based knowledge and, finally, to scientific knowledge only. In addition, the four clusters differ with respect to the intensity of formal R&D cooperation (low in the case of cluster 1 and 3, high for clusters 2 and 4, but in the last case only with domestic partners) and to the internal conditions for the absorption of external knowledge in terms of human capital and R&D intensity (high in the case of cluster 2 and 4, low for cluster 3 and medium for cluster 1). The four clusters also significantly differ in terms of some structural characteristics of firms (size, export orientation). No substantial differences seem to exist with respect to (our rough proxies for) economic performance. Contrary to the innovation clusters this result is unchanged if we control for inter-firm differences with respect to physical and human capital intensity in the frame of a regression analysis. The relationship between industries and clusters is not clear-cut but seems to be stronger than in the case of innovation clusters; perhaps the available space for positioning a firm in the knowledge network is smaller than for choosing specific innovation strategies.

5. The relationship between innovation and knowledge clusters

In a last step the two cluster analyses are confronted with each other in order to see how innovation patterns and the pattern of knowledge sources are related. Of particular interest is the question to what extent the two clusterings are overlapping.

Table 10 shows for each innovation cluster (row) the corresponding distribution of firms with respect to the four clusters of knowledge sources (percentage share of firms). In this exercise the innovation clusters 1 to 5 are reordered according to the intensity and the range of innovative activities (product, process or both types of innovation). A similar ordering of the knowledge clusters is possible only to some extent. Cluster 2, which is highly intensive in the use of all sources of knowledge, unequivocally takes the first place (column 4) followed by cluster 4 which is the most nearest one to cluster 2 (column 3). The other two clusters are „ranked“ according to the presumed relationship with the innovation clusters, that is the process-oriented innovation pattern with supplier-based knowledge sources and product-oriented innovation with market-oriented knowledge.

The table shows that there is no clear-cut correspondence of the two types of clustering. To take an example, row 1 shows that one half of the process-oriented innovators belong to other knowledge clusters than that related to supplier-based knowledge. Nevertheless, given our a priori-ordering of the two types of clusters, we find an ordinal correspondance which, though not very high, is statistically significant at the 1% level (Goodman-Kruskal $\gamma = 0.19$).

A closer look at table 10 shows a series of plausible combinations of the two types of clusters:

- About 50% of process-oriented innovators (row 1) use primarily supplier-based knowledge (cell 1,1 of the table).
- For the firms in row 2, i.e. product-oriented innovators with a relatively low innovation intensity, correspondance with the market-oriented knowledge cluster (cell 2,2) is not surprising; however, this cell contains only about 30% of the firms of this row with the rest distributed to all other cells.
- The product/process innovators with an intermediate innovation intensity (row 3) are quite evenly distributed across all knowledge clusters. Because the innovation efforts of this cluster are primarily based on engineering/design and follow-up investment and not on R&D activities (see table 2), the combination with supplier-based and market-oriented knowledge clusters (cells 3,1 and 3,2) with about 50% of this row's firms seems intuitively plausible.
- The product-oriented innovation cluster with a high intensity of innovative activities (row 4) is strongly associated with the two clusters for which science-based knowledge is important (columns 3 and 4). The corresponding cells 4,3 and 4,4 contain about 60% of the firms with a significantly lower share in cell 4,4 (combination with the cluster of firms which use, in addition to scientific knowledge, also all other sources very intensively).
- A similar correspondence may be observed for the cluster whose firms are highly innovative in the product as well as the process field (row 5). 64% of the firms are found in the cells 5,3 and 5,4, in this case equally distributed among the two cells.

In sum, about 50% of all firms are covered by these economically plausible combinations of the two clusterings. These pertain to five innovation types/modes which are quite well defined: First, process-oriented innovators using primarily supplier-based knowledge; second, incremental product-oriented innovators drawing on market-oriented knowledge; third, incremental product-process innovators drawing primarily on supplier-based and market-oriented knowledge sources; fourth, fundamental product-oriented innnovators using in the first place scientific and expert knowledge, and fifth, high intensity product-process innovators combining scientific knowledge with an intensive use of all other knowledge sources. The share of these innovation types in the total number of firms seems rather high if one takes into consideration that the innovation cluster of row 3 in table 10 has partly the character of a residual intermediate stratum.

Because of the far from perfect concordance of the two types of clustering and the small differences among the innovation clusters as well as among the knowledge clusters with respect to economic performance, one could conclude that firms may dispose of a rather large degree of freedom in selecting an innovation mode to pursue their economic objectives. This view, which is consistent with evolutionary economic thinking, requires, however, further examination because it is possible that other variables we used in describing (but not in constructing) innovation and knowledge clusters will help to explain those cells of table 10 which are not intuitively plausible. Such variables are firm size, export orientation, industry, R&D cooperation, appropriability, human capital intensity, market conditions and demand perspectives.

6. Conclusions

By use of cluster analysis of Swiss manufacturing firms we identified specific patterns with respect to innovative activities as well as to the firms' use of external sources of knowledge. The combination of these two types of clusters yielded five innovation types/modes of which only two seem to be slightly superior than the others in terms of economic performance. This finding is in line with a basic assumption of evolutionary economics according to which several modes of economic behaviour may coexist, at least during a certain time period. In addition, the relationship between specific industries and innovation types is not straightforward; individual firms seem thus to dispose of a certain freedom in selecting an economically viable innovation strategy. This result, which is to some extent at variance with the notion of a sectoral taxonomy as proposed by Pavitt (1994) based on data for the United Kingdom, corresponds to the findings of Cesaratto and Mangano (1993) for Italy and Arundel et al. (1995) for the European industry.[6]

It seems rather difficult to compare the innovation types proposed in these three studies among themselves as well as with our findings because of different approaches, sample structures, data bases, etc. In particular, a comparison with Arundel et al. (1995) makes sense only for very specific aspects because his sample is confined to very large European companies, whereas the Swiss as well as the Italian one represent all size classes. This reservation holds in particular for Switzerland because its manufacturing sector is characterized by a very large share of small and medium-sized firms (72% of firms with between 5 and 200 employees). Therefore it is no surprise that, in distinction to Britain and Italy, no scale-intensive cluster is found for Switzerland. Pavitt's supplier-dominated cluster, consisting primarily of small firms that combine process-oriented innovation with supplier-based sources of knowledge and characterized by low appropriability, has been also identified in the studies for Italy and Switzerland. Furthermore, all investigations find a science-based cluster which, according to Pavitt, is characterized by a high innovation intensity both in the product and the process field, the dominance of internal R&D and scientific external knowledge sources as well as highly effective legal and informal appropriability mechanisms. This description, however, needs some qualifications: first, it seems that firms of this type exploit intensively not only science-based external knowledge but all types of knowledge sources (therefore labelled as „externally-oriented" knowledge source clusters in the European and the present study); secondly, many of these firms are also heavily drawing on engineering/design activities (Italy, Switzerland). At last, Pavitt's specialized production-intensive cluster (product-oriented, dominance of engineering/design activities, users as primary knowledge source, informal appropriability mechanisms) must be differentiated in several respects; in the Swiss case, for instance, this category is made up by three clusters which differ in terms of innovation intensity (three different levels), direction of innovative activity (one of the three groups is also highly active in the process field), knowledge sources (one category, for instance, uses most intensively scientific knowledge); in the Italian case, some differentiation seems to be necessary too.

Although Pavitt's seminal contribution dates back to the the early eighties there is still need for further research on this topic. First, the relationship between innovation and knowledge clusters should be investigated with more scrutiny along the lines described at the end of section 5. Secondly, the present analysis has to be extended towards the rapidly growing (private) service sector, an exercise which, for example, would be feasible with the data of the Swiss Innovation Survey 1996. Third, studies for other countries based on the methodology and type of data used in the present study would enable cross-country comparisons of which those between countries of similar size and level of economic development would be most interesting (e.g. Sweden vs. Switzerland); these could reveal whether even controlling for the two factors mentioned there remain significant country-specific aspects with respect to innovation types.

At this stage of analysis, one should be cautious in drawing policy conclusions. It may be just stated that in assessing or shaping policy measures one should take account of the variety of innovation types because firms belonging to specific clusters may have different needs with respect to public support. Process-oriented innovators drawing primarily on supplier-based knowledge, for example, may profit most from programmes directed to facilitate the diffusion of advanced manufacturing technologies, whereas firms looking out for scientific knowledge may be supported, in the first place, by strengthening the production of this type of knowledge as well as by measures to improve its transfer to the business sector. If it is true that the overlapping between industry structure and innovation as well as knowledge clusters is not very large and that economic performance differences across innovation types are rather small, it may be advisable not to direct policy measures towards specific sec-

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[6] It is, however, more than natural that Pavitt, in looking for a general typology, stressed the differences between industries more than those within them (see also Arundel et al., 1995, p.87).

tors (i.e. „classical“ industrial policy) or types of firms (e.g. prefering R&D intensive against engineering/design-oriented firms).

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Table 1: Innovation Indicators and Knowledge Sources

Variable[1] Definition	Measurement Scale	Value Range
A. Innovation Indicators		
1. Input-oriented measures		
Research input	ordinal	1, 5
Development input	ordinal	1, 5
Engineering/Design input	ordinal	1, 5
Follow-up investment	ordinal	1, 5
2. Output-oriented measures		
Technological assessment of innovations	ordinal	1, 5
Economic assessment of innovations	ordinal	1, 5
3. Market-oriented measures		
Sales share of world novelties (%)	metric	0, 100
Sales share of highly improved or new products (%)	metric	0, 100
Sales share of new and all types of improved products (%)	metric	0, 100
B. Knowledge Sources		
1. Other firms		
Customers/users of products	ordinal	1, 5
Suppliers of materials/components	ordinal	1, 5
Suppliers of equipment	ordinal	1, 5
Competitors	ordinal	1, 5
Subsidiaries/mother firms	ordinal	1, 5
2. Institutions, consulting		
Universities/technical schools	ordinal	1, 5
Other government research institutions	ordinal	1, 5
Private scientific laboratories/consulting firms	ordinal	1, 5
Government technology programmes	ordinal	1, 5
Technoparks/other technology transfer agencies	ordinal	1, 5
3. Generally accessible information		
Patent disclosures	ordinal	1, 5
Fairs/expositions	ordinal	1, 5
Professional conferences/journals	ordinal	1, 5
4. Acquisition of inputs		
Recruitment of experts	ordinal	1, 5
Acquisition of licenses	ordinal	1, 5
Acquisition of capital goods	ordinal	1, 5
Acquisition of other firms	ordinal	1, 5

[1] Input- and output-oriented indicators are measured separately for product and process innovations whereas market-oriented measures are related to product innovations only.

Table 2: Description of Innovation Clusters Based on the Innovation Variables Used in the Statistical Analysis[1]

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Final Data Set
Number of Observations	184	167	47	96	22	
1. Input-oriented measures						
Research input						
Product	1	7	0	40	15	12
Process	0	0	0	42	14	8
Development						
Product	57	27	0	76	82	47
Process	32	7	15	70	23	29
Engineering/Design input						
Product	71	26	4	47	73	46
Process	46	4	26	45	18	29
Follow-up investment						
Product	52	15	4	43	46	34
Process	60	7	49	44	5	36
2. Output-oriented measures						
Technological assessment of innovations						
Product	69	39	21	80	77	57
Process	59	22	55	71	18	47
Economic assessment of innovations						
Product	71	42	21	81	82	60
Process	75	26	53	79	32	56
3. Market-oriented measures						
World novelties (%)	4	2	3	11	52	7
Highly improved or new products (%)	24	14	18	31	78	24
All types of improved/new products (%)	53	31	48	58	89	48

[1] Figures for input- and output-oriented indicators represent the percentage share of firms with the values 4 („high") or 5 („very high") on a five-point scale, for market-oriented indicators the sales shares of innovative products (%).

Table 3: Description of Innovation Clusters in Terms of General Characteristics of Firms and Performance Measures

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Final Data Set
Number of Observations	184	167	47	96	22	
A. General Firm Characteristics			Percentage Shares			
1. Firm Size (number of employees)						
5 - 49	22	41	47	29	59	33
50 - 99	17	17	17	16	14	17
100 - 199	26	20	17	19	18	22
200 - 499	23	16	13	19	9	18
500 and more	12	6	6	18	0	10
2. Industries						
Food/beverages/tobacco	2.2	9.0	8.5	6.3	0	5.7
Textiles	3.8	4.8	0	4.2	0	3.7
Apparel/leather/footwear	0.5	4.2	0	1.0	0	1.7
Wood products	3.3	2.4	14.9	1.0	0	3.5
Paper	2.7	1.8	2.1	3.1	0	2.3
Printing/publishing	5.4	4.8	10.6	0	0	4.5
Chemicals/pharmaceuticals[1]	1.1	6.0	10.6	7.4	0	4.7
Plastics	4.9	4.8	0	7.3	0	4.7
Non-metallic mineral products	1.6	6.6	8.5	7.3	0	4.8
Metal production	2.2	3.0	4.3	1.0	0	2.3
Metal working	20.7	14.9	15.0	15.6	13.6	17.1
Machinery	21.2	14.3	8.5	20.8	45.5	18.8
Electrical machinery	6.5	4.2	6.4	6.3	0	5.4
Electronics/instruments	12.0	11.4	2.1	13.5	40.9	12.4
Watches	1.6	2.4	0	2.1	0	1.7
Transport equipment	3.8	1.2	0	1.0	0	1.9
Other manufacturing	6.5	4.2	8.5	2.1	0	4.8
3. Sales Share of Exports (%)						
0	10	21	53	13	0	18
1 - 33	32	38	17	23	29	30
34 - 66	22	16	13	19	14	18
67 - 100	36	25	17	45	57	34
4. Vocational skills (% of employees)						
University, other high qualifications	15.2	13.8	11.9	24.6	37.1	17.1
High and intermediate qualifications	57.7	55.0	56.2	65.3	76.4	58.9
B.Performance Measures						
Value added per employee (1'000 sFr.)	136	135	148	145	126	138
Value added share of capital income (%)	39	42	41	41	45	41

[1] Inspection shows that cluster 4 is dominated by pharmaceutical firms whereas the firms in clusters 2 and 3 produce primarily other chemicals. This pattern is more accentuated if we take account of two very large pharmaceutical firms, not included in the cluster analysis (some missing values), which clearly would belong to cluster 4.

Table 4: Characteristics of Innovation Clusters

Cluster 1 (35.6% of firms, 39.4% of employment):

Innovation pattern: Firms with a good innovation performance in the product as well as the process field strongly based on engineering activities and follow-up investments leading primarily to significantly improved products.

Firm size	Medium and large
Industry	Metal working and transport equipment and, to a lesser extent, paper, printing/ publishing, machinery, electrical machinery and other manufacturing
Export orientation	Quite high
Human capital intensity	Low
Economic performance	Average

Cluster 2 (32.4% of firms,19.3% of employment):

Innovation pattern: Firms with a low innovation intensity solely based on new products reflected primarily by some development and engineering activities leading to incremental product improvements.

Firm size	Small
Industry	Food, textiles, clothing and, to a somewhat lesser extent, chemicals (except pharmaceuticals), metal production, non-metallic mineral products and watchmaking
Export orientation	Average
Human capital intensity	Low
Economic performance	Average

Cluster 3 (9.1% of firms, 4.0% of employment):

Innovation pattern: Firms with a very low innovation intensity solely based on new processes reflected primarily by high follow-up investments.

Firm size	Small
Industry	Wood products, printing/publishing, chemicals, non-metallic minerals products, metal production and, to a lesser extent, also food, electrical machinery as well as other manufacturing
Export orientation	Very low
Human capital intensity	Very low
Economic performance	Average

Cluster 4 (18.6% of firms, 36.2% of employment):

Innovation pattern: Firms with an extremely high innovation intensity for products as well as processes leading to fundamental (and incremental) innovations based on a high level of R&D.

Firm size	Average and some very large firms.
Industry	Paper, pharmaceuticals, plastics and, to a lesser extent, also non-metallic mineral products, machinery, electrical machinery, electronics/instruments and watchmaking
Export orientation	Very high
Human capital intensity	Very high
Economic performance	Average

Cluster 5 (4.3% of firms, 1.1% of employment):

Innovation pattern: Firms with an extremely high product innovation intensity leading to fundamental (world) novelties based (primarily) on very high development activities.

Firm size	Very small
Industry	Machinery, electronics/instruments
Export orientation	Very high
Human capital intensity	Extremely high
Economic performance	Average

Table 5: Description of Clusters for Knowledge Sources Based on the Variables for Knowledge Sources Used in the Statistical Analysis[1]

Variable	Cluster 1	2	3	4	Final Data Set
Number of Observations	123	118	116	138	
1. Other firms					
Customers/users of products	86	74	46	40	60
Suppliers of materials/components	52	66	74	17	50
Suppliers of equipment	20	43	67	4	32
Competitors	49	58	24	14	36
Subsidiaries/mother firms	27	49	11	17	25
2. Institutions, consulting					
Universities/technical schools	14	48	6	33	24
Other government research institutions	7	34	9	22	17
Private scientific laboratories/consulting firms	9	27	8	8	12
Government technology programms	1	20	3	19	11
Technology transfer agencies	6	32	3	15	14
3. Generally accessible information					
Patent disclosures	13	34	4	20	17
Fairs/expositions	82	59	42	33	53
Professional conferences/journals	55	64	39	38	47
4. Acquisition of Inputs					
Recruitment of experts	24	73	24	37	38
Acquisition of licenses	2	30	5	9	11
Acquisition of capital goods	9	34	42	11	23
Acquisition of other firms	7	47	2	7	15

[1] Figures in this table are percentage shares of firms with the values 4 („high“) or 5 („very high“) on a five-point Likert scale.

Table 6: Description of Clusters for Knowledge Sources in Terms of General Characteristics of Firms and Performance Measures

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Final Data Set
Number of Observations	123	118	116	138	
A. General Firm Characteristics	Percentage Shares				
1. Firm Size (number of employees)					
5 - 49	39	20	32	35	33
50 - 99	18	13	23	15	17
100 - 199	23	30	22	15	22
200 - 499	13	23	16	22	18
500 and more	7	14	7	13	10
2. Industries					
Food/beverages/tobacco	7.3	1.7	6.9	5.8	5.7
Textiles	1.6	0.8	6.0	5.1	3.7
Apparel/leather/footwear	3.3	0.0	2.6	1.4	1.7
Wood products	3.3	0.0	6.9	2.2	3.5
Paper	0.8	4.2	5.2	0.0	2.3
Printing/publishing	0.8	2.5	12.1	0.7	4.5
Chemicals/pharmaceuticals	3.3	6.8	5.2	4.3	4.7
Plastics	6.5	5.9	3.4	2.2	4.7
Non-metallic mineral products	3.3	6.8	4.3	5.8	4.8
Metal production	1.6	3.4	2.6	1.4	2.3
Metal working	18.7	16.2	20.7	13.8	17.1
Machinery	23.5	22.1	6.9	24.0	18.8
Electrical machinery	4.9	7.6	3.4	5.8	5.4
Electronics/instruments	10.6	16.2	3.4	20.4	12.4
Watches	0.8	0.8	0.9	4.3	1.7
Transport equipment	2.4	2.5	1.7	1.4	1.9
Other manufacturing	7.3	2.5	7.8	1.4	4.8
3. Sales Share of Exports (%)					
0	15	14	22	15	18
1 - 33	35	26	37	25	30
34 - 66	22	20	18	13	18
67 - 100	28	40	23	47	34
4. Vocational skills (% of employees)					
University, other high qualifications	14.7	20.1	11.2	22.6	17.1
High and intermediate qualifications	60.6	63.6	51.1	60.6	58.9
B.Performance Measures					
Value added per employee (1'000 sFr)	142	139	133	144	138
Value added share of capital income (%)	42	41	41	41	41

Table 7: Description of Clusters for Knowledge Sources in Tems of Measures of the Intensity of R&D Cooperation[1]

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Final Data Set
Number of Observations	123	118	116	138	
Number of Types of R&D Cooperation Partners	Switzerland				
0	59	41	51	38	47
1	11	8	6	12	9
2	8	5	14	10	10
3	8	16	13	15	13
4	9	14	9	12	11
5	3	7	4	7	5
6	1	5	3	4	3
7	0	3	0	1	1
8	1	1	0	1	1
Number of Types of R&D Cooperation Partners	Abroad				
0	67	50	62	50	57
1	8	10	11	19	12
2	12	9	15	17	13
3	5	11	6	7	7
4	4	7	4	5	5
5	2	6	1	2	3
6	2	3	1	0	1
7	0	3	0	0	1
8	0	1	0	0	1

[1] Figures in this table are percentage shares of firms with the corresponding number of types of R&D cooperation partners. Considered are 10 types of R&D-cooperation partners: (a) customers, (b) suppliers,(3) competitors, (d) firms from other industries (without customers and competitors), (e) firms of the same conglomerate, (f) universities/ technical colleges, (g) other research institutions and (i) technology transfer agencies.

Table 8: Description of Clusters for Knowledge Sources in Terms of Variables Measuring the Effectiveness of Various Appropriability Mechanisms[1]

Variable	Cluster 1	2	3	4	Final Data Set
Number of Observations	123	118	116	138	
Effectiveness as Means of Protection					
1. Product Innovations					
Patents/other formal means	25	34	14	28	25
Secrecy	28	36	18	28	27
Complexity of product design	39	48	36	46	42
Time lead when introducing new products	74	80	60	71	69
Retention of specifically qualified personnel	25	42	21	31	30
Intensive sales and service efforts	56	69	49	48	54
2. Process Innovations					
Patents/other formal means	7	17	9	10	11
Secrecy	21	40	18	26	25
Complexity of process design	29	43	37	38	36
Time lead when introducing new processes	46	63	55	49	52
Retention of specifically qualified personnel	24	44	28	30	31
Intensive sales and service efforts	56	69	49	48	54

[1] Figures in this table are percentage shares of firms with the values 4 („high“) or 5 („very high“) on a five-point Likert scale.

Table 9: Characteristics of Clusters for Knowledge Sources

Cluster 1 (24.8% of firms, 13.5% of employment):

Knowledge pattern: Firms with a rather high intensity of using external information primarily from customers, competitors, fairs and expositions, professional confernces and journals (market-oriented knowledge).

R&D cooperation intensity	Low
Appropriability	Medium effectiveness primarily of informal protection mechanisms
Human capital intensity	Average
Firm size	Small
Industry	Food, clothing, plastics, and, to a somewhat lesser extent, metal working, machinery, transport equipment and other manufacturing
Export orientation	Average
Economic performance	Average

Cluster 2 (23.8% of firms, 45.1% of employment):

Knowledge pattern: Firms with a very high intensity of using information from practically every external source, relying heavily on information from universities, technical colleges, other research institutions as well as government technology programms and technology transfer agencies (science-based knowledge).

R&D cooperation intensity	Very high (domestic as well as foreign partners)
Appropriability	High effectiveness of legal as well as informal protection mechanisms
Human capital intensity	High
Firm size	Large/medium
Industry	Chemicals/pharmaceuticals, non-metallic mineral products, metal production, electrical machinery, transport equipment and, to a somewhat lesser extent, paper, plastics, machinery as well as electronics/instruments
Export orientation	High
Economic performance	Average

Cluster 3 (23.4% of firms, 15.6% of employment):

Knowledge pattern: Firms with a very high intensity of use of information from suppliers of materials/ components and equipment as well as by purchasing capital goods, but rather low information use of other knowledge sources (supplier-oriented knowledge).

R&D cooperation Intensity	Medium
Appropriability	Low effectiveness of all protection mechanisms
Human capital intensity	Low
Firm size	Small
Industry	Textiles, wood products, paper, printing/publishing, metal working as well as other manufacturing and, to a lesser extent, food and clothing.
Export orientation	Low
Economic performance	Average

Cluster 4 (28.0% of firms, 25.8% of employment):

Knowledge pattern: Firms with a high intensity of using information primarily from science-oriented institutions as well as from patent disclosures and specialized experts (knowledge for specialized producers).

R&D cooperation intensity	High (primarily domestic partners)
Appropriability	Medium effectiveness of most appropriability mechanisms, to some extent also legal ones
Human capital intensity	High
Firm size	Large/small
Industry	Machinery, electronics/instruments, watchmaking and, to a lesser extent, textiles as well as non-metallic mineral products
Export orientation	Very high
Economic performance	Average

Table 10: Joint Consideration of Innovation Clusters and Clusters for Knowledge Sources[1]

Innovation Clusters				Clusters for Knowledge Sources				
	Innovative Activities			Cluster3 (supplier)	Cluster1 (market)	Cluster4 (science)	Cluster2 (science and all other)	
	Intensity	Orientation		Row Percentages[2]				N
				(1)	(2)	(3)	(4)	
Cluster 3:	low	process	(1)	49	14	23	14	43
Cluster 2	low	product	(2)	21	29	32	18	154
Cluster 1	medium	product/process	(3)	28	23	21	28	181
Cluster 5	high	product	(4)	9	32	45	14	22
Cluster 4	high	product/process	(5)	10	25	33	32	95
Final Data Set				23	25	28	24	495

[1] The innovation clusters are reordered in terms of innovation intensity and direction of innovative activity, the knowledge clusters according to type and intensity of use of external sources (see section 5).

[2] Figures in this table are percentage shares of firms of a certain innovation cluster belonging also to a certain cluster for knowledge sources (row percentages).

Appendix: Results of the factor analysis

1. Innovation indicators

The variables used in the factor analysis of innovation indicators correspond basically to those listed in table 1, but for technical reasons some of them are analyzed in a transformed way. Thus, in the case of each input-oriented measure, we included the sum of the scores for product and process innovations. Similarly, we first added the scores of the four types of assessments of the importance of an innovation (i.e. product/process and technological/economic assessment). In both cases we considered the product-share of the overall scores as additional variables.

The factor analysis with these innovation measures led to satisfactory results as can be seen from the statistical information presented in the lower part of table A1. According to Kaiser's MSA the original variables are quite strongly correlated; hence, a basic requirement for a factor analysis to be sensible is fulfilled. Furthermore, the RMSE of the residual is low enough, and the variance accounted for by the first four principal components is quite high. Finally, the factor pattern identified in this analysis seems plausible in economic terms (see main text, section 3).

Table A1: Factor Analysis with Innovation Indicators

Variable	Rotated factor pattern[1]			
Total research input				.89
Total development input			.48	.66
Total engineering/design input			.77	
Total follow-up investment			.79	
Innovation assessment			.67	
Product share of research/development input	.77			
Product share of engineering/design input	.78			
Product share of follow-up investment	.77			
Product share of the innovation assessment score	.82			
Sales share of world novelties		.82		
Sales share of highly improved or new products		.89		
Sales share of all types of improved/new products		.72		
Number of observations				516
Kaiser's overall measure of sampling adequacy (MSA)				.764
Variance accounted for by the first four components (%)				67.6
Root mean square off-diagonal residuals (RMSE)				.072
Variance accounted for by each factor	2.52	2.11	1.99	1.48
Final communality estimate (total)				8.10

[1] The tables shows only factor loadings above 0.4.

2. Knowledge sources

The variables used in the factor analysis of knowledge sources are those listed in table 1. Again, the results are satisfactory from the statistical point of view. Kaiser's MSA is even higher compared to table A1. The RMSE of the residual is satisfactory in this case too, and the variance accounted for by the first four principal components, though somewhat lower than for the innovation indicators, is high enough. Finally, the factor pattern seems plausible in economic terms (see main text, section 4).

Table A2: Factor Analysis with Knowledge Source Variables

Variable	Rotated factor pattern[1]			
Customers/users of products			.65	
Suppliers of materials/components				.65
Suppliers of equipment				.83
Competitors			.58	
Subsidiaries/mother firms		.69		
Universities/technical schools	.72			
Other government research institutions	.64			
Private scientific laboratories, consulting firms	.54			
Government technology programmes	.80			
Technoparks/other technology transfer agencies	.73			
Patent disclosures	.48			
Fairs, expositions			.77	
Professional conferences/journals			.48	
Recruitment of experts		.59		
Acquisition of licenses		.54		
Acquisition of capital goods				.64
Acquisition of other firms		.65		
Number of observations				495
Kaiser's overall measure of sampling adequacy				.823
Variance accounted for by the first four components (%)				51.8
Root mean square off-diagonal residuals				.075
Variance accounted for by each factor	3.10	2.03	1.91	1.76
Final communality estimate (total)				8.81

[1] The tables shows only factor loadings above 0.4.