# Norwegian Innovation and Industrial Structure: Insiders and Outsiders?[1]

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## Abstract

We examine the hypothesis that the Norwegian innovation system is locked-in to a specialization pattern of scale dependent, resource intensive industries, in which innovation depends mainly on the in-house activities of (a few) large firms. To this extent, we employ a sectoral empirical analysis using data on industrial dynamics and innovation in the Norwegian economy. Our results indicate that although the Norwegian economy has parts that are resource- and scale dependent, and also sectors in which the market structure is inert and concentrated, these characteristics are not systematically related to the level and nature of innovation activities. Our results indicate that innovation in Norway takes place in two main regimes: a high-intensive and a low-intensive regime. This is not correlated systematically with industrial dynamics.

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## *Introduction*

Narula (2002) has argued that in "(…) Norway, two groups of firms exist. Group A firms benefit from a systemic lock-in. These are large firms in traditional sectors, which are highly embedded, and around whom the Norwegian SI [system of innovation] has been built. (…) Group B firms are in science based sectors for whom lock-in results in inefficiencies" (p.795). This suggests that the three innovation system layers or paths identified in a historical analysis of the Norwegian SI (Wicken, 2007) have a lasting influence in today's innovation system in Norway. According to Wicken (2007) the Norwegian National Innovation System (NIS) is a historical outcome of three major industrial transformation processes: A small scale decentralized path, a large scale path, and a science based network path. These paths have given rise to 3 distinct innovation system layers which currently characterize the Norwegian economy: Group A firms are clearly recognizable as belonging to a large scale industrialization path, while those in Group B are representative of a R&D intensive network based industrialization path. Narula's hypothesis of systemic lock-in argues that the historical co-evolution of the institutional context in which innovation takes place, and industrial dynamics within each of the paths, has led to a situation in which the Group B firms are at a disadvantage because of a mismatch between their *modus operandus* and the way in which the broad innovation system in Norway works.

The argument about lock-in of the Norwegian innovation system says that subsets of sectors in the Norwegian economy share a broad institutional context, shaped by the particular Norwegian specialization pattern and historical development of policies, and that these characteristics are important drivers of the innovation performance of the sectors. The historically dominant role of resource based firms, according to this argument, has led to a set of institutions that is particularly suited to support firms in these sectors. A mechanism of mutual reinforcement is at work: the institutions make the firms successful, and this in turn leads to a larger demand for policies, developing the institutional structure further in the direction of the resource based and large scale industries. As a result, the wider innovation system in Norway becomes inert and little inclined to change to a new development path. The system becomes relatively closed off to new science based entrants associated with the third development path.

Narula's analysis is carried out in the context of the internationalization of R&D by large companies, but it obviously has implications for the broader context of innovation, including the activities of smaller firms and those that operate exclusively domestically. Our aim in this paper is to investigate the possibility of systemic lock-in of the Norwegian innovation system in such a broader context, using recent quantitative evidence on innovation and industrial dynamics in Norway. We argue that the way to extend Narula's argument to this broader context is to use the notion of innovation regimes, which has been proposed in the recent literature covering the empirically observed diversity between sectors in terms of innovation and industrial dynamics. Obviously, the conceptualizations that Narula uses do not readily extend to the broader issues of industrial dynamics and innovation, and we will therefore have to formulate an adaptation of the lock-in hypothesis below.

In more general terms, this paper seeks to provide a broader empirical basis for a categorization of economic activity and innovation at the industrial sector level in Norway. We will use the term taxonomy to describe this process, and our aim is to advance the understanding of how differences and similarities between industrial sectors in Norway are related to the nature of innovation and knowledge underlying industrial innovation on the one hand, and the dynamics of market structure on the other hand, by using the notion of "technological regimes". The concept of a technological regime has been proposed by Nelson and Winter (1982) as a framework for interpreting the observed differences in innovative behavior and industrial dynamics across industrial sectors, and has been broadly used to describe the knowledge environment in which firms search for refinements to their production routines (Winter, 1984).

We focus on the properties of innovative processes and the link with the patterns and dynamics of industrial structure and competition. At the empirical level, we measure the relevant dimensions and characteristics of the technology and knowledge domain underlying innovation in industrial sectors, as well as the dynamics of industrial structure. We use a combination of factor and cluster analysis to carry out the taxonomy. The analysis results in a classification of sectors into two technology regimes, and four industrial dynamics regimes. Combining the technology and industrial dynamics classifications yields eight regimes capturing the main technological and market environments in which firms operate in Norway.

The paper extends previous work in this line of inquiry in at least three ways: (1) The analysis is extended to cover the service sector, which is increasingly important to the economies of industrialized countries, such as Norway, (2) in the innovation domain, the analysis is based on a detailed database on innovation activities, not just R&D data, and (3) detailed data on industrial dynamics is used and subsequently related to the technology dynamics underlying industrial sectors. The analysis suggests that a part of the industrial landscape in Norway can be described as insider dominated and relatively closed off to new entrants, in line with Narula's (2002) Group A. However, our results also suggest that these sectors are relatively highly innovative, i.e., the closed nature of this part of the economy does not seem to lead to low innovative activity. Also, we find that some of the sectors that are perhaps most likely to belong to the closed and inert part of the Norwegian economy are more open to entry and innovation than often thought. A particularly interesting finding in our analysis is that although the dichotomy between sectors that we find in the innovation domain can in many respects be seen as a high- and low-innovation intensity dichotomy, this seems largely unrelated to industrial dynamics. In other words, the innovation regimes cut across industrial regimes (or vice versa) rather than a strong correlation existing between the two.

The paper is organized as follows. In section 2 we will discuss theory and empirical evidence regarding the interpretation of the relationship between innovation and the dynamics of market structure and competition. This section will conclude with a discussion of how we extend Narula's argument about systemic lock-in, and formulate the hypotheses that we will test in the empirical part. Section 3 describes the data used in the measurement of the relevant aspects of technology and industrial dynamics, as well as the methodology used to classify industrial sectors into a set of technological regimes. In section 4 we apply a combination of factor and cluster analysis to the data and report, as well as discuss the results. The last section, 5, summarizes the main conclusions.

## *Innovation and the dynamics of market structure and competition*

A main theoretical aim in this paper is to reconcile research on industrial innovation with that on market structure and industrial dynamics in order to understand the sectoral specialization pattern of the Norwegian economy. While the relation between market structure and innovation (or more properly, R&D intensity) was the topic of much early literature, we start from a line of research developed only recently. The reason is that in the early literature, which focused mostly on relating measures of market concentration with R&D intensity, sectors where largely considered as relatively homogenous entities that could usefully be represented by simple and uni-dimensional measures of concentration and innovation.[2] But reviews of this empirical literature have concluded that firm size and industry concentration are not clear-cut determinants of industrial innovation, as empirical results have been mixed, and that the impact of firm size upon R&D seems to be conditioned by the industry context (Cohen and Levin, 1989; Levin et al 1985). Hence there seems to be a need for a more elaborate measuring tool.

Therefore, our theoretical approach starts from the notion that the empirical relationship between firm size and industry concentration on technological change is conditioned by inter-industry differences in technological opportunities and appropriability conditions (Winter, 1984), suggesting that the nature of technology sets boundaries to the pattern of industrial competition. This is line with, e.g., Nelson and Winter's (1982) evolutionary approach, which argues that innovation and market structure are jointly determined by technological conditions. They use the term technological regime to describe this, and define such a regime as the technological or knowledge environment encompassing and setting boundaries to firms learning activities (Winter, 1984; Marsili and Verspagen, 2002). A particularly relevant dimension of the technological condition is the ability of new firms to enter the market via novel innovations, as opposed to technological environments where incumbents can cumulatively build upon past innovative success. Nelson and Winter (1982) and Winter (1984) have accordingly identified two technological regimes: an "entrepreneurial" regime associated with science based technology and easy entry of innovative new firms due to a universal and non-cumulative knowledge base, and a "routinized" regime that favours innovation by incumbents due to the cumulative nature of technology and the knowledge base. In simulation models, these two technological regimes generated distinct properties of the structure and performance of industries, where innovation rates, average firm age, profitability and market concentration were higher in the "routinized" regime as opposed to the "entrepreneurial" regime (Nelson and Winter, 1982; Winter, 1984).

This work has been extended by more empirically oriented scholars (e.g., Breschi et al, 2000; Malerba and Orsinigo, 1996; Marsili and Verspagen 2002; Van Dijk, 2000) whose aim has been to empirically identify the existence of technological regimes, and to relate differences in market structure and industrial dynamics across industries to the technological environment encompassing and setting boundaries to firms' innovative activities. One empirical approach has been to rely closely on the specific dimensions of technological opportunity, appropriability conditions, cumulativeness of learning, and the nature of the knowledge base (Dosi, 1988; Dosi et al, 1995; Malerba and Orsenigo 1996; Van Dijk, 2000), which were the main variables of interest in the theoretical work in Nelson and Winter (1982) and Winter (1984). In most cases this empirical work has led to the identification of a Schumpeter Mark 1 and Schumpeter Mark 2 taxonomy of regimes with technological characteristics similar to the "entrepreneurial" and "routinized" distinction advocated by Nelson and Winter (1982).

A related approach has been to explore sectoral patterns of innovation from the point of view of knowledge sources. This was pioneered by Pavitt (1984), in his work based on the SPRU Innovation database. Pavitt identified the following three dominant patterns of industrial innovation and sectoral technical change in the UK manufacturing sector; (1) supplier dominated, (2) production intensive, and (3) science based. His second category (production intensive) is further subdivided into scale intensive and specialized suppliers sectors. Marsili (2001) modified the Pavitt taxonomy, arriving at five clusters of sectors. Marsili and Verspagen (2002) applied the Marsili taxonomy to the Dutch manufacturing sector, using datasources similar to ours. Castellacci (2007) has further extended the line of inquiry pioneered by Pavitt and developed a new taxonomy of technological regimes which is confirmed by using a database of European industries, although this work does not include aspects of market structure and dynamics in the analysis.

With the exception of Miozzo and Soete (2001) few attempts have been made to include service sectors in the analysis. Based upon a refinement of Pavitt's taxonomy, Miozzo & Soete (2001) identified the three following regimes in the service sector: (1) supplier dominated, (2) Scale intensive physical networks sectors and information network sectors, and (3) Science based and specialized suppliers sectors. A central aspect of Miozzo and Soete's (2001) argument is the emphasis on the close linkage between manufacturing and service in the origin and application of technological change (e.g., user-producer interactions). It is thus interesting to note that prior research in this tradition, although arguing for the technological closeness of manufacturing and service industries has not included these industries in the same analysis. Hence, we know little about the extent to which technological regimes cut across the manufacturing and services distinction, and this is an issue that we intend to tackle here.

The literature on technological regimes that we have discussed so far is largely quantitatively oriented, and therefore relies on the type of information that can be captured in the Innovation surveys (CIS) and/or industrial dynamics statistics. The recently developed Sectoral Innovation Systems approach (SIS, see Malerba, 2005) extends this to include more qualitative data based on interviews and sector specific studies of interaction between various types of actors. Like the more quantitative literature, the main point in the SIS approach is that the knowledge base, the pattern of interactions among the actors, and the institutions governing these interactions, are believed to differ across sectors and to constitute distinct innovation systems (see Malerba, 2005 for a review). Because of its focus on the more qualitative and historically rooted characteristics of sectors, the SIS approach is particularly relevant for the questions that we wish to investigate (the historical lock-in pattern of the Norwegian specialization). We refer the reader to sector specific studies on the aluminum industry, the aquaculture industry, the petroleum industry, the ICT sector and biotech sector by Moen (2007), Wiig Aslesen (2007), Engen (2007), Grønning (2007) and Sogner (2007) for an SIS-related approach to this issue from a Norwegian perspective.

While prior research has provided useful insights into the importance and significance of technological regimes and sectoral innovation systems, especially three issues remain unexplored. First of all, past empirical research in this tradition has not included service sectors in the analysis. Service industries are of increasing importance as sources of employment growth and innovation (Miles, 2005). By excluding these sectors, a rather narrow picture on the relationship between the nature of technology and the dynamics of market structure and industrial competition has been offered. The failure to include service industries in large scale innovation databases has arguably been the reason why no attempt has been made to explore whether technological regimes or sectoral innovation systems cut across manufacturing and service industries. A main ambition in this paper is thus to explore the extent to which firms in the manufacturing and service industries face similar technological environments or innovation systems.

Secondly, few details on the dynamics of market structure have been included in the analysis. Past research has mostly focused on entry, exit and survival dynamics, and largely neglected other sources of industrial dynamics such as for instance spin-outs and mergers, although this is a recommended avenue for further research (Winter, 1984). We will remedy this and include a richer set of industrial dynamics indicators. Thirdly, interactions between sectoral innovation systems and the national innovation system embedding innovative activity and industrial dynamics in sectors have not been well-researched. In our Norwegian case, as we discussed in the introduction, prior research has suggested that the Norwegian economy is "locked in" to a particular type of activities, mostly related to the large scale based pattern of industrialization (Narula, 2002). However, no large scale quantitative study has been undertaken to verify the existence of such patterns of sectoral specialization in Norway.

While the first two of these issues are addressed by the use of a new database, the third one requires us to link the idea of systemic lock-in (Narula, 2002) to the literature on technology regimes and sectoral taxonomies of innovation systems. At a broad and general level, the idea of systemic lock-in of an innovation system says that a particular institutional environment has emerged in which innovation thrives. If the lock-in is particularly strong, it may cause a lack of institutional diversity, because the inefficient regimes have been driven from the system. However, in a less drastic lock-in, we would expect that multiple institutional environments exist, but that these show different levels of efficiency with regard to innovation. Such a situation of some institutional variety, rather than a complete lock-in, seems to be the case for the Norwegian innovation system, as argued by Narula (2002).

The literature on technological regimes that we have briefly discussed above puts great emphasis on conditions of appropriability of knowledge as a determinant of the knowledge base. This is the main factor that determines the distinction between routinized and entrepreneurial innovation regimes. But obviously, the conditions underlying a technological regime are broader than just appropriability. Narula (2002, p. 802) lists three main categories of factors that have historically led to the lock-in: energy policy in Norway (that has favoured energy-intensive, large scale industry), protection of Norwegian industry from foreign direct investment, and industrial policy (including technology policy) targeting specific sectors. Our extension of Narula's lock-in hypothesis argues that these factors will have had an impact in two main dimensions: industrial market dynamics, and innovation. If the lock-in that Narula signals for the case of foreign activities of Norwegian firms has a broader implication for the Norwegian innovation system, we expect that our data analysis will reveal distinct patterns related to these two dimensions, i.e., that there will be a dichotomy between sectors both in the realm of industrial dynamics, and in the innovation realm. Moreover, in the case of a lock-in, we expect that these dimensions are related, i.e., that the likelihood that a sector falls in any of the categories in the industrial dynamics dimension, is related to its innovation performance (and vice versa).

Obviously, the nature of the lock-in that Narula proposes has implications for the nature of the regimes that we expect to find. With respect to the industrial dynamics regimes, we expect that the emphasis on scale economies and resource-intensity will have led to concentrated market structures, large firm size, and a low level of market turbulence in the dominating part of the Norwegian economy. On the other hand, we expect that a smaller part of the economy will be characterized by a more competitive and open market structure, particularly in economic sectors related to the 'third path' of science based industrialization. In addition, we expect that these two industrial dynamics regimes will be characterized by different technology and innovation dynamics. We expect that innovation in the closed and concentrated market regime will be based on process innovation, in-house R&D, and a low degree of cooperation with other firms (possibly higher levels of cooperation with universities and/or the institutes sector). In the more competitive market regime, innovation is expected to take a more open character (e.g., less dependence in in-house resources, less dependence on protection of intellectual property rights, and stronger patterns of cooperation), and we expect that more emphasis is put on product innovation.

If, on the other hand, the idea of lock-in does not extend to the broader context of the Norwegian innovation system, we expect that differences between sectors are still important, and hence that industrial dynamics regimes and innovation regimes are visible in the data. However, without a lock-in, we expect that the variety of possible outcomes is larger, and hence the correlation between industrial dynamics regimes and innovation regimes is much less strict.

## *Data and method*

Our database is a combination of two different sources. Information about R&D, innovation, the sources of innovation, and the like is derived from a combined R&D and innovation survey, where the innovation part constitutes the third Community Innovation Survey (CIS) for Norway. The combined survey contains large amounts of information about firms' innovation activities (CIS survey) and questions about how R&D activities are financed (R&D survey), and is answered by the firm manager. Apart from the fact that a few industrial sectors were excluded from the sampling frame, most notably Hotels and Restaurants, Retail Trade and some Financial Service industries like Real Estate, the combined survey was directed to a representative sample of the Norwegian enterprise population with 10 employees or more and is representative of an enterprise population of about 12000 firms. There was a random selection of units with 10 to 49 employees. All units with 50 employees or more were included in the sampling frame. The survey was further stratified according to industrial sectors using two digit NACE and size classes. In total, the questionnaire was returned by 3899 firms which constitute a response rate of 93 %, minimizing problems like sample selection. From this database the following indicators are constructed, measuring technology and innovation (see Table 1 for a summary of details): Innovation resources (formal R&D, total innovation expenditures), number of innovating firms; product and process innovators as a fraction of the population, ratio of product to process innovators, number of innovators with permanent R&D), innovation expenditures (spread over categories), hampering factors (spread over categories), and protection of innovation (different methods used).

[TABLE 1 ABOUT HERE]

The other data source is the business register of the entire enterprise and business unit population in Norway. This database contains information about 458,000 establishments belonging to some 415,000 enterprises, including self-employed entrepreneurs with zero employees. Information at the business unit level, such as employment and turnover, was aggregated to the enterprise level in order to provide as close a match as possible to the enterprises included in the combined R&D and innovation survey. A highly novel feature with this database is that it does not only contain information needed on entry and exit statistics at the industry level, but also records changes or vital events taking place among business units of multi-establishment enterprises. Thus, we are able to provide a rather detailed picture about the industrial dynamics taking place at the sectoral level and how this relates to underlying differences in the technology domain. From the industrial dynamics datasource the following indicators are constructed, measuring market concentration and industrial dynamics (see Table 2 for a summary): Concentration (size classes, C4, C20), market turbulence (different types of entry and exit), and the details of industrial dynamics taking place (various types of vital events).

[TABLE 2 ABOUT HERE]

The primary measure of entry and exit is defined in the usual way: the number of new entrants or exits (both defined as firms, i.e., at the enterprise level) as a percentage of all firms in the industry in 2001.[3] However, using the establishment level data in our database, we are able to go beyond this traditional measure of market turbulence. First, we identify a specific subset of entrants and exits as those enterprises that have no employees (i.e., self-employed entrepreneurs). We label this as "entrepreneurial" entry or exit, and express it again as a percentage of all firms in the industry (by definition, the entrepreneurial entry/exit rate is smaller, or in the limit equal to, the overall entry/exit rate). The non-entrepreneurial entry/exit rate is then defined as the overall entry/exit rate minus the entrepreneurial entry/exit rate. Firm survival is measured as the percentage of firms in the industry that were also in the industry 5 years ago.

Next, we are able to observe five distinct events that are related to the mobility of establishments and their relation to enterprises. We label these events as take-over, divesting, expansion, spin-out, and transformation. A *take-over* occurs when an existing establishment moves into a different enterprise than the one it belonged to, and the latter enterprise is closed down. Hence, a take-over is also an exit (of the enterprise that originally owned the establishment), and we do include it in the measurement of the exit rate. *Divesting* occurs when an establishment moves from one enterprise to another, and the original owner remains active in the sector. Thus, divesting is similar to a take-over, the only difference lies in the question of whether the original owner of the establishment remains in business. *Expansion* is defined as the birth of a new establishment, owned by an existing enterprise. A *spin-out* occurs when an existing establishment becomes an independent enterprise, and the old owner of the establishment survives as an enterprise. Hence, a spin-out is a form of entry, and we include it in the measurement of the entry rate. Finally, a *transformation* is similar to a spin-out, with the exception that the enterprise that owned the establishment goes out of the market (hence a transformation is both an entry and an exit, and we measure it as such). Table 3 summarizes the definitions of our detailed variables on industry dynamics. In the analysis, we always express the number of occurrences of take-over, divesting, expansion, spin-out or transformation as a percentage of the total population. Occurrence of any of these events is measured as the number of enterprises involved in an activity (e.g., when an enterprise takes over two distinct establishments, it is counted as a single take-over).

[TABLE 3 ABOUT HERE]

Table 4 provides summary statistics of the variables that we employ to measure industrial dynamics. The means of the entry and exit rates are rather close to each other, and the same holds for the entrepreneurial versions of these rates. Slightly less than half (unweighted average over sectors) of all entry and exit is entrepreneurial. For the detailed market dynamics events, we observe that the one that is most frequent is the combination of take-over, divesting and expansion, i.e., when an enterprise combines all these three forms in the single year. This is far more frequent than any of the individual events (including spin-out and transformation) on its own. On the other hand, these five events are all much less frequent than entry or exit. We decide to construct a new variable where we add the individual rates for take-overs, divesting and expansion together with the combined one. This is the variable that will be included in the factor analysis. We keep the two other events (transformation and spin-out) separate, because their nature is different from the other events, and from each other.

[TABLE 4 ABOUT HERE]

The two databases provide detailed information about the sectors in the Norwegian economy. Our theoretical framework, as discussed in the previous section, suggests that there are particular (causal) relationships between these variables and the underlying dimensions they capture, but we do not have a full model that outlines these relations in a precise way. Consequently, we take an explorative perspective, and apply a methodology that is aimed at outlining the major relations between the various indicators, rather than investigating their causal links. The first step in the explorative analysis is using Principals Components Factor Analysis on pre-selected groups of variables. The extracted factors are then used as input for the cluster analysis. This method can be described as a bottom-up approach to the identification of regimes as we define them, based upon the information available to us in our database. This is somewhat in contrast to prior studies in this tradition, which have mainly attempted to confirm existing taxonomies using new data sources (e.g., Marsili and Verspagen, 2002; Castellacci, 2007). To use an existing taxonomy was not an option for us because we want to confront the idea of systemic lock-in in Norway in an open-ended way, i.e., to see how this idea holds up if we subject it to a broad set of alternative taxonomies.

Our analysis is done at the level of sectors. We assign each firm in our database to an industrial sector and information is aggregated from the enterprise and business unit level to the sector level. Survey data from the R&D and innovation survey was aggregated to the sector level using weights generated by SSB in order to ensure that the industrial sectors data is representative. In total, we have 60 industrial sectors in our database which covers firms in both the manufacturing and service sectors, at the 3 or 4 digit NACE level. The sectors are listed in the appendix. They were defined as an ad hoc list that is very much specific to Norway. This specificity is first of all related to the existing Norwegian specialization pattern, and we try to include as separate entities sectors that have attracted attention before (e.g., we include fish-farming as a separate sector, which would not be useful for most other countries than Norway). Another way in which the list of sectors is specific to Norway is that we have only included a sector as a separate entity if we have enough coverage in the CIS database.[4]

## *Results*

### Factor analysis

We apply principal components analysis with varimax rotation order to reduce the number of dimensions in the data, and to extract empirical measures of latent factors believed to classify industrial sectors into different technological regimes or clusters. The number of factors is determined endogenously using an eigenvalue (>1) criterion. Following Marsili and Verspagen (2002) a number of variables have been grouped together on a priori grounds (according to Tables 1, 2 and 3), and rotated factor scores have been calculated. The first group of variables relates to the resources going into the innovation process. The variables entered and the factor loadings for each variable are listed in Table 5.

[TABLE 5 ABOUT HERE]

In Table 5, and in Principals Components Factor Analysis more generally, the principal assumption is that the pattern of correlations between the variables included in the analysis is caused by non-observable or latent factors such as the underlying technology at the level of industrial sectors. In the rotated factor solution each loading represents the partial correlation between the latent factor and the variables in the row to the left in the table. A high factor loading indicates that the factor is strongly influenced by the variable. The seven variables included in the factor analysis in Table 5 are thus able to measure the existence of three factors, and we can see that variables have different factor loading on the three factors. The three factors distinguish between sectors where formal R&D is important and embodiment in machinery is not (factor 1), where external non R&D based knowledge and training are important but where R&D is not (factor 2) and lastly where design and marketing of new products are more important, but where external R&D is not important (factor 3).

[TABLE 6 ABOUT HERE]

Table 6 reports the results for the group of variables that we use to measure technological opportunity. Variables measuring the intensity of R&D and innovation load high on the first factor, and variables which capture "innovation output" load high on the second factor. The first factor accounts for almost 70 % of the observed variance. According to our interpretation, the first factor is a measure of technological opportunity, and the second factor is a measure of persistent innovativeness.

In Table 7 we have tried to measure different aspects of the appropriability regime. All the included variables load high on the first factor, with the exception of copyright and trademarks, although these loadings are positive. As such, the first factor is a rather clear cut measure of appropriability instruments in the traditional technology domain, which distinguishes between industrial sectors where it is important to protect innovations using formal and informal methods, and sectors where this is not so important. The second factor loads high on copyrights and trademarks, which are the instruments that are used for a wider set of innovations than just those that rely on technology (e.g., business models, but also software).

[TABLE 7 ABOUT HERE]

[TABLE 8 ABOUT HERE]

In Table 8 we have attempted to measure properties of the knowledge base apart from R&D. This focuses on the sources of knowledge/information that are rated as important by the responding firms. A rather complex picture with four factors emerges, suggesting that the knowledge bases differ strongly across sectors. Customers, competitors and suppliers as important knowledge sources all load rather high on the first factor. Hence, this factor distinguishes between sectors where market based knowledge is important, and those where it is not. Institutional actors, such as R&D enterprises, universities, and public research organizations load high on the second factor. As such, this factor captures vital elements of the national innovation system, and identifies sectors where such institutional actors constitute an important knowledge source. The third factor combines a high loading on consultancy enterprises with one on exhibitions, trade shows etc. The fourth factor is a rather clear measure of firm internal knowledge.

[TABLE 9 ABOUT HERE]

In Table 9 we entered various variables perceived by firms to be hampering factors in the innovation process. The outcome of the factor analysis is pretty clear, as the first factor is a measure of economic and financial obstacles, combined with regulation, while the second factor measures the presence of organizational and technological obstacles. It is interesting to note that organizational and technological obstacles go together and seem to form a distinct hampering factor. Lack of qualified personnel and market information both load high on the third factor.

[TABLE 10 ABOUT HERE]

Table 10 makes a further distinction between types of R&D: product vs. process R&D, and basic-applied-development R&D. We extract only one factor for this set of variables, which loads high on four of the five variables. The one variable that loads (relatively) low is basic R&D, so that this factor essentially captures R&D intensiveness, with the exception of basic R&D.

[TABLE 11 ABOUT HERE]

Table 11 measures non-technological innovation, and distinguishes five forms of this. Essentially, we see that all of these load high together, suggesting that the occurrence of non-technological innovations can be reduced to a single dimension.

[TABLE 12 ABOUT HERE]

The final[5] set of variables that we use in the innovation domain relates to the share of firms' turnover that is related to product innovations. The CIS questionnaire asks for the firm's share of turnover for products new to the market ('radical innovations') and products new to the firm. We also include the share of turnover of unchanged products. Table 12 presents the results for this factor analysis. We have one factor, on which both innovations definitions load high, implying that the factor captures the importance of product innovation (in general) in turnover of the sectors.

Having captured and measured the main variables describing innovation and technology at the sectoral level, we move on to measure variables related to market structure and industrial dynamics. This is done in tables 13 and 14.

[TABLE 13 ABOUT HERE]

In Table 13 variables measuring the (static) competitive structure in the 60 industries are included. This involves variables capturing the distribution of firms over size classes, as well as concentration ratios (C4 and C20). The first factor captures essentially the absence of micro enterprises (<10 employees), as it loads high on all the size classes with 10 or more employees, and strongly negative on the zero employees variable. The concentration ratios load high on the second factor, which thus distinguishes between sectors according to concentration levels. The third factor provides more nuance to this picture, and identifies sectors where employment is concentrated in large firms (in a Norwegian standard), while not necessarily leading to high concentration (the concentration ratios have low factor loadings).

[TABLE 14 ABOUT HERE]

In Table 14 we have entered the variables that capture vital elements of industrial dynamics, as opposed to the static picture of the previous table. These are the variables covered in Table 4 above. The first factor in Table 14 captures general turbulence in a sector, with high factor loadings on total entry and exit rates, and a strongly negative loading on survival of entrants. But entry in this factor is mainly non-entrepreneurial. The second factor captures entrepreneurial (self-employed) entry, and loads high on both entry and exit rates of this type, but low on the "takeovers, moves and expansion" events that involve incumbent firms. The final third factor loads high on spin-outs and transformations.

### Cluster analysis

The aim of our cluster analysis is to obtain groups of sectors, or regimes, which are relatively homogenous in terms of the variables that we put into the clustering procedure, but are different from the sectors found in the other regimes. We use the two-step clustering algorithm in SPSS to obtain groups of sectors, based on the factor scores obtained using Tables 5 – 14. The two-step clustering algorithm has the important advantage that the number of clusters is determined on the basis of an objective criterion (we use Akaike's information criterion for this purpose). The algorithm works by first forming a number of pre-clustering groups, and then merging these groups in a more-or-less traditional hierarchical clustering method.[6] We perform the clustering both for the factors in the innovation domain (Tables 5 – 12), and for the industrial domain (Tables 13 – 14). We start by entering all factors into the analysis, and perform a Bonferroni adjusted *t*-test for differences of the clusters (centroids) relative to the total sample mean. When a variable (factor) turns up for which none of the clusters is significantly different from the sample mean (we use a 10% significance threshold), we omit this factor and run the cluster analysis again, until all variables have at least one cluster that is significantly different from the sample mean. In this way, we ensure that variables that do not distinguish between clusters (regimes) do not influence the results.

Table 15 presents the results of the cluster analysis for the innovation variables, or, in other words, the innovation regimes that we find for the Norwegian economy.[7] We have two regimes (clusters), which are fairly equally divided in terms of the number of sectors (24 and 36). In terms of the differences between the clusters, the interpretation of the results is fairly straightforward: the large cluster (36 industries, cluster 2) tends to score high on the innovation-related variables, and the smaller cluster (24 industries, cluster 1) scores low. In other words, the distinction into two regimes that we find can be interpreted as a low- and high-innovation intensive dichotomy. Note, however, that using these labels, the high innovation intensive share of the economy includes a relatively large number of sectors, including sectors that would traditionally classify as low innovation intensity sectors. Examples of the latter are 'knitted fabrics and products' and 'ships and boats'. Two of the most internationally visible Norwegian sectors, fish farming and extraction of crude oil and gas, are also classified in the high innovation intensity regime.

[TABLE 15 ABOUT HERE]

One, two and three starts indicate significant differences (at the 10%, 5% and 1% level, respectively) of the cluster centroids from the total sample mean in a *t*-test with Bonferroni adjustment.

These high innovation intensity sectors score high on the importance of formal R&D, on R&D intensity, on persistence of innovation, on the use of appropriability instruments, on internal knowledge sources, on non-technological innovation, and on the importance of new products in turnover. The low innovation intensity sectors, on the other hand, score relatively low in all variables in the table, except the use of non-R&D external knowledge and training (this is higher in the non-innovation intensive sectors).

In the domain of industrial structure and dynamics, we have a total of six factors from Tables 13 and 14. In the cluster analysis, all these factors contribute significantly to the distinction between the clusters. We obtain four clusters for these five factors. Table 16 shows the details (cluster centroids and number of members) for the four clusters.

[TABLE 16 ABOUT HERE]

One, two and three starts indicate significant differences (at the 10%, 5% and 1% level, respectively) of the cluster centroids from the total sample mean in a *t*-test with Bonferroni adjustment.

We obtain two small (one and two) clusters, and two larger ones (three and four). In the domain of the static market structure variables (i.e., the first three factors), cluster number two is the only one that does not distinguish itself from the mean total sample values. In this domain, cluster one is the least competitive one. It shows significantly higher market concentration than the average, and also scores significantly higher on "absence of microfirms". The two other clusters are somewhat paradoxical in the static domain. Cluster three has few microfirms (significantly higher on the "absence of microfirms" factor), but also few large firms (significantly lower on this factor), and hence consists of sectors with many small (but not very small) and medium-sized firms. Cluster four is the exact opposite: it scores significantly higher on large firms, but also on microfirms (i.e., significantly lower on "absence of microfirms").

In the dynamic market structure domain, perhaps the most obvious result is that in the non-competitive cluster one, we find significantly lower than average entrepreneurial entry and transformations/spin-outs. On the whole then, cluster one seems to be a set of rather *stable and concentrated sectors*. Cluster two just shows *high turbulence*, and does not score significantly different from the average in any other way. Cluster number three, with its stress on medium-sized firms, distinguishes itself in the domain of the dynamic market structure variables by relatively high spin-out and transformations. *Incumbent firms* in this cluster are the only ones that show higher than average restructuring events (spin-outs and transformation). Finally, cluster four is the *entrepreneurial* one, although it is somewhat surprising that this comes with lower general turbulence.

## Discussion

The starting point of our theoretical interpretation of the lock-in argument has been the idea that we can discern clear differences in terms of both industrial dynamics regimes, and innovation regimes. The cluster analysis seems to confirm that this is indeed the case. In the industrial dynamics domain, it is especially the *stable and concentrated* industrial regime, and, to a somewhat lesser extent, the *incumbent dynamics* regime, that answer to the picture of a scale dominated environment that offers little opportunities for potential entrants and outsiders in general. These two regimes correspond quite intuitively to the environments in which Narula's (2002) Type A firms operate.

However, in terms of the distinction between a resource-based and scale intensive nature on the one hand, and a science based nature on the other hand, the results are not so clear-cut. The first of the two regimes in the Type A group, *stable and concentrated*, is in fact a mix of natural resource-based sectors and science-based sectors, whereas the lock-in argument would imply that science-based sectors are largely absent from this regime. The natural resource-based sectors in this regime are 'production and distribution of electricity', 'pulp and paper', 'basic chemicals', 'ferrous basic metals', and 'non-ferrous basic metals' (i.e., five of the eight sectors in this regime). The science-based sectors in this regime are 'pharmaceuticals' and ‘electronic valves and tubes’. In total, six of the eight sectors in this regime rank under the high innovation intensity class, and this includes four of the five industries that are resource-based (Table 17 provides details of the cross-tabulation of the innovation and industrial dynamics regimes).

In the *incumbent dynamics* regime, the majority of sectors also fall under the high innovation intensity regime. Again, there are a number of resource-intensive industries here, but the dominance is less strong than in the *stable and concentrated* regime. Typical resource-intensive industries in this regime are food industries such as meat- fish- and bakery- products, and construction materials such as ‘saw mills’, ‘builders carpentry’ and ‘bricks, cement, concrete and stone’. All these resource intensive industries in this regime are also classified as low innovation intensity. The high innovation intensity industries in the *incumbent dynamics* regime, on the other hand, are what Pavitt (1984) calls specialized supplier industries, such as ‘power generating equipment’, ‘machine tools’ and ‘electric motors’, as well as the science-based industries such as ‘instruments and medical equipment’, and transport equipment industries such as ‘motor vehicles’ and ‘ships and boats’.

[TABLE 17 ABOUT HERE]

In the *high turbulence* regime (only 6 sectors), we have ‘water transport’ and ‘financial services’, which both fall under the low innovation intensity regime, as well as ‘fish farming’, ‘extraction of crude oil and gas’, ‘telecom services’ and ‘computer services’, which fall in the innovation intensive category. These four sectors account for almost 30 % of the total internal R&D efforts in the Norwegian economy. A closer look at the composition of internal R&D in the innovation intensive high turbulence regime reveals an interesting pattern, most notably that the majority of R&D done in the oil and fish-farming sectors is applied research (70 % and 50 % accordingly). In the larger group of the *entrepreneurial* regime, we also find a number of resource-intensive industries ('mining, other than oil and gas', 'wood and products'), but also the science-based industries 'computers and office machines', 'radio and TV transmitters and receivers', and 'R&D and engineering services'.

In summary, we do find somewhat of a weak correlation between resource-intensity and the closed nature of industrial dynamics on the one hand, or a science-based nature and more open market structures on the other hand, but there are important exceptions to this correlation. In particular, our analysis suggests that important resource-based Norwegian sectors such as fish farming and the oil sector do not have a concentrated and closed industrial structure. Rather, these sectors appear in our analysis as industries in which market dynamics are more turbulent than the average, and also they seem to belong to the high innovation intensive part of the Norwegian economy.

This may be a surprising result especially for the oil sector, since this sector is traditionally seen as dominated by a couple of very large firms (but note that we also include firms that deliver to the oil drillers, and the dominance of large firms is less obvious here). Our impression, based on anecdotal evidence, is that although the oil sector could have been described as a stable and concentrated regime up to the 1990s, this is no longer the case. In the 1990s, and the decades before, the oil sector in Norway was dominated by around 20 giant corporations. Since 2000, more than 50 new oil companies have entered the sector. This rather revolutionary change has been partly due to a high oil price, but also due to changes in legislation and policy support of smaller oil firms which were introduced in 2000 (OD, 2007). Smaller firms have been encouraged by policymakers to develop the high number of smaller oil fields on the

Norwegian continental shelf, in order to maximize oil production, as the bigger oil fields are reaching, or have gone beyond, maturity. Smaller companies are thus in the business of developing smaller oil fields not developed by the giant corporations as specialized oil producers. As such it is important to understand the interactions between the oil sector and the Norwegian NIS, especially the institutional domain, as these two levels co-evolve. The revolutionary change in the oil sector has further been facilitated by the introduction of new technologies such as floating oil production and subsea oil exploration and production technologies (see Engen, 2007 for an elaborated view).

Table 17 also provides information about the importance of the various regimes for the Norwegian economy, in terms of the regimes' share in R&D, employment and turnover (sales).[8] In light of the previous discussion, an obvious way of cutting across the eight detailed regimes is to look at the totals of the concentrated and stable and the incumbent dynamics regimes on the one hand, and the high turbulence and entrepreneurial regimes on the other hand. Although the distribution of especially employment is fairly even between those two groups, the stable and incumbent dynamics regimes account for the smaller share of the Norwegian economy. Thus, we do not have much evidence for a lock-in into those regimes.

Looking at the detailed level, the *incumbent dynamics* and low innovation intensity combination is the largest category of the eight possible combinations. This accounts for about one third of total turnover (sales), although only 23% of employment. The runner-up in this respect is the four sectors combination of high innovation intensity and *high turbulence*. This combination accounts for almost 30% of total turnover, although only for about 10% of employment. In terms of R&D, this is the largest group, with almost 30%. If we interpret these two groups as the dominant regimes found in the Norwegian innovation system, than we have a picture that diverges somewhat from the idea of a locked-in system. Our picture is one in which there is indeed an 'inert' sector in the Norwegian economy, in which market dynamics are slow, typically related to incumbent firms, and where innovation is generally at a low level. But part of this inert set of sectors is also innovation-intensive. On the other hand, there is also a part of the Norwegian economy where market turbulence and innovation are both high. This part includes the oil sector, which obviously carries a lot of weight in Norway, and fish-farming. Our data clearly suggest that this sector falls in a high innovation intensity – turbulent markets regime, but this may be a conclusion that is challenged by some who take a more qualitative perspective.

It is further interesting to note that the pattern of sectoral specialization in Norway, when it comes to the nature of technology and knowledge underlying industrial innovation on the one hand, and the dynamics of market structure on the other hand, partly cuts across the manufacturing and services distinction. Most notably, R&D engineering services go together with certain manufacturing industrial sectors, such as machinery industries and production of computers, and seem to form a distinct innovation intensive entrepreneurial regime. Computers and telecom services form, in addition to the oil and gas and fish-farming, a distinct innovation intensive turbulent regime. Hence, there exist rather close similarities between certain manufacturing and services industries in Norway, which have important implications for the understanding of the origin and evolution of technological change in the Norwegian economy.

With regard to services, our results suggest that the majority (7 of the 10 services sectors that we have) belong to the low innovation intensive group. The three high innovation intensive services are Telecom services, Computer services, and R&D, engineering, architecture and design. With regard to the industrial dynamics regimes, all four regimes that we identified contain at least one services sector, which implies that services as a whole are rather heterogeneous with regard to industrial dynamics.

## *Conclusions*

We have investigated in a quantitative and data-intensive way the idea that the Norwegian innovation system is locked-in to a specialization pattern of resource- and scale-intensive industries, associated with the large scale industrialization path discussed by Wicken (2007), and that the system selects against entrepreneurial initiatives and science-based technology-intensive sectors. Our conclusions are that resource-and scale intensity is indeed important in a part of the Norwegian economy, and also that there are sectors in Norway that can be characterized as inert in terms of their industrial dynamics. But we do not find particularly strong evidence that innovation performance is strongly correlated with closed market structures. Rather, the set of inert sectors in terms of market structures includes both innovation-intensive and science-based sectors, and non-innovation intensive and resource based sectors. Thus, our results indicate that the inert market structure in some sectors does not seem to have particularly negative implications for innovation in Norway, since many of the individual industries that appear to belong to the relatively closed, resource-based and inert part of the economy are still rather innovation intensive. The general absence of a strong relationship between industrial market dynamics regimes and innovation performance suggests that no strong pattern of innovation related lock-in exists in the Norwegian economy.

As a natural result of the characteristics of the Norwegian economy, these conclusions depend to a large extent on individual sectors. In particular, we find that the basic chemicals and basic metals industries indeed belong to a broader group of sectors that are relatively concentrated and stable (but this is something that is shared with, e.g., pharmaceuticals), but that the oil sector and fish farming belong instead to a much more open regime.

## Notes

[1] We gratefully acknowledge funding from the Norwegian Research Council, The Ruhrgas Foundation and the P.M Røwdes Foundation. We thank Keith Smith, Bo Carlsson, Fulvio Castellacci, Jan Fagerberg, and Ole Andreas Engen for helpful comments.

[2] This literature revolves around the so-called Schumpeterian Hypotheses of increasing returns to firm size and market concentration in innovation, see Kamien and Schwartz (1982) Cohen (1995), Cohen and Levin (1989), Van Cayseele (1998) for reviews. We regard the recent folly around Aghion et al. (2005) results largely as a repetition of this literature.

[3] 2001 is the year we use to measure all industrial dynamics variables.

[4] In particular, we compared the sum of weights in a sector to the sum of firms. If the discrepancy is large, this implies that our coverage is not very large, and we tend to aggregate the sector into a larger whole. No fixed rules where used to decide on this, and we cannot provide full details of the procedure for reasons of confidentiality of the data.

[5] We also experimented with a factor analysis on cooperation in innovation, using the variables on the importance of several partner categories. However, since these variables do not show up significantly in the cluster analysis below, we do not present these results here.

[6] The pre-clustering step is especially useful in the case of a large number of observations, since it reduces the number of units entered into the hierarchical clustering. This is not very important in our case, where we only have 60 sectors.

[7] The appendix shows full details of which industries are classified into the regimes.

[8] The R&D performed in our 60 sectors is equal to total business R&D in Norway, but the 60 sectors do not cover total production or employment. However, we scaled the shares in such a way that they all sum to 100%, i.e., we disregard here the employment and turnover shares of firms that do not belong to one of 60 sectors.

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Table 1. Variables in the technology and innovation database

| Group | ***Variables*** |
|---|---|
| Innovation expenditures | Spread over several categories of expenditures |
| Number of innovators | Share of innovators; share of firms with product and process innovation, fraction of firms with permanent R&D activity. |
| Access to knowledge | Importance of internal and external information sources relevant to innovation |
| Protection of innovation | Different methods to protect innovations |
| R&D expenditures | Spread over several categories in relation to sales |
| Hampering factors | Importance of obstacles in the innovation process |

Table 2. Variables in the market structure and dynamics database

| Group | ***Variables*** |
|---|---|
| Concentration | Size classes, C4, C20 |
| Market turbulence | Entry and exit, entrepreneurial (self-employed) entry and exit, survival rates |
| Details of industrial dynamics | No change, transformation, takeover, move, spin-out, entrepreneurial new, new by expansion |

Table 3. Source of industrial dynamics according to changes between enterprise and establishment level.

| **Source of industrial dynamics** | |
|---|---|
| **No change** | An existing establishment continues within the same existing enterprise |
| **Transformation** | An existing establishment continues and becomes a new independent enterprise, and the old enterprise is closed down |
| **Take-over** | An existing establishment continues within another existing enterprise, and the old enterprise is closed down |
| **Divesting** | An existing establishment continues within another existing enterprise, and the old enterprise survives |
| **Spin-out** | An existing establishment continues and becomes a new independent enterprise, and the old enterprise survives |
| **Entrepreneurial new** | A new establishment comes into existence as a new independent enterprise |
| **New by expansion** | A new establishment comes into existence within an existing enterprise |
| **Complete closure** | An establishment is closed down and the enterprise it belongs to is also closed down |
| **Partial closure** | An establishment is closed down but the enterprise it belongs to survives |

Table 4. Summary statistics for market dynamics variables

| **Variable** | **Mean** | **Standard deviation** |
|---|---|---|
| **Entry rate** | 10.60 | 4.51 |
| **Exit rate** | 11.02 | 3.54 |
| **Entrepreneurial entry** | 4.23 | 3.57 |
| **Entrepreneurial exit** | 5.01 | 3.36 |
| **Non-entrepreneurial entry rate** | 5.68 | 3.89 |
| **Survival rate** | 63.4 | 7.35 |
| **Take-over rate** | 0.228 | 0.406 |
| **Divesting rate** | 0.085 | 0.258 |
| **Expansion rate** | 0.200 | 0.367 |
| **Take-over, divesting and expansion rate** | 1.558 | 1.994 |
| **Spin-out rate** | 0.127 | 0.228 |
| **Transformation rate** | 0.493 | 0.465 |

Table 5: Measuring distribution of innovation expenditures

| Share of total innovation expenditures | ***Factor loadings*** | | |
|---|---|---|---|
| | First factor | Second factor | Third factor |
| Internal R&D | 0,765 | -0,528 | 0,077 |
| Machinery | -0,990 | 0,013 | -0,071 |
| Marketing of new products | 0,036 | 0,054 | 0,796 |
| External acquisition of knowledge | 0,015 | 0,874 | 0,011 |
| Design | 0,081 | 0,281 | 0,623 |
| External R&D | 0,520 | 0,238 | -0,542 |
| Training | -0,167 | 0,719 | 0,295 |
| Cumulative % of explained variance | 32 % | 53,5 % | 71,2 % |

Table 6. Measuring technological opportunity

| | ***Factor loadings*** | |
|---|---|---|
| | First factor | Second factor |
| R&D expenditure as a fraction of sales | 0,961 | 0,194 |
| R&D personnel as a fraction of total employment | 0,903 | 0,356 |
| Research expenditure as a fraction of total sales | 0,907 | -0,021 |
| Total innovation expenditure as a fraction of sales | 0,916 | 0,176 |
| % of innovating firms | 0,455 | 0,856 |
| % of firms with a product innovation | 0,500 | 0,827 |
| % of firms with a process innovation | 0,331 | 0,871 |
| Fraction of firms with permanent R&D activities | -0,207 | 0,695 |
| Cumulative proportion of explained variance | 0,67 | 0, 87 |

Table 7. Measuring appropriability conditions

| Fraction of firms within an industry which use: | ***Factor loadings*** | |
|---|---|---|
| | First factor | Second factor |
| Patent application to protect an innovation | 0,837 | -0,113 |
| Design patent to protect an innovation | 0,580 | 0,230 |
| Trademark to protect an innovation | 0,218 | 0,794 |
| Copyright to protect an innovation | 0,08 | 0,786 |
| Secrecy to protect an innovation. | 0,647 | 0,247 |
| Complex design to protect an innovation. | 0,767 | 0,211 |
| Lead time to protect an innovation. | 0,788 | 0,172 |
| Cumulative % of explained variance | 0,44 | 0,60 |

Table 8. Measuring sources of information for innovation

| % Firms that rate the following sources of information as important for their innovations: | ***Factor loadings*** | | | |
|---|---|---|---|---|
| | First factor | Second factor | Third factor | Fourth factor |
| Consultancy enterprise | -0,41 | 0,34 | 0,69 | 0,12 |
| R&D enterprise | -0,38 | 0,75 | 0,17 | 0,22 |
| Within enterprise group | 0,02 | -0,05 | -0,11 | 0,86 |
| Suppliers | 0,46 | -0,13 | 0,26 | -0,05 |
| Customers | 0,80 | -0,19 | 0,09 | 0,14 |
| Competitors | 0,82 | 0,25 | -0,08 | 0,18 |
| Universities | 0,18 | 0,85 | 0,13 | 0,06 |
| Public research organizations | -0,07 | 0,75 | 0,11 | -0,28 |
| Meetings and journals | 0,23 | 0,19 | 0,51 | 0,37 |
| Exhibitions | 0,23 | 0,11 | 0,75 | -0,17 |
| Within the enterprise | 0,44 | -0,01 | 0,39 | 0,58 |
| Cumulative % of explained variance | 24 % | 47 % | 57 % | 67 % |

Table 9. Measuring hampering factors for innovation

| % Firms that rate the following hampering factors as important in their innovation processes: | ***Factor loadings*** | | |
|---|---|---|---|
| | First factor | Second factor | Third factor |
| Too high economic risk | 0,83 | 0,29 | 0,05 |
| Too high innovation costs | 0,80 | 0,23 | 0,18 |
| Lack of finance | 0,62 | 0,52 | 0,13 |
| Organizational rigidities | -0,12 | 0,78 | 0,17 |
| Lack of qualified personnel | 0,28 | 0,10 | 0,80 |
| Lack of technological information | 0,15 | 0,81 | 0,06 |
| Lack of market information | 0,02 | 0,13 | 0,85 |
| Too strong regulation | 0,71 | -0,11 | 0,08 |
| Lack of interest among costumers | 0,31 | -0,09 | 0,04 |
| Cumulative % of explained variance | 36 % | 50 % | 63 % |

Table 10. Measuring the nature of R&D in sectors

| % share of the following R&D types in total sales in a sector: | ***Factor loadings*** |
|---|---|
| | First factor |
| Process-related R&D | 0,81 |
| Product-related R&D | 0,95 |
| Basic R&D | 0,50 |
| Applied R&D | 0,81 |
| Development R&D | 0,87 |
| Cumulative % of explained variance | 64 % |

Table 11. Measuring non-technological innovations

| % share of firms with the following innovations: | ***Factor loadings*** |
|---|---|
| | First factor |
| Innovation in strategy | 0.91 |
| Management innovation | 0.83 |
| Organizational innovation | 0.87 |
| Marketing innovation | 0.87 |
| Esthetic innovations in products | 0.76 |
| Cumulative % of explained variance | 71 % |

Table 12. Measuring importance of new products for turnover

| % share of product categories in sectoral turnover: | ***Factor loadings*** |
|---|---|
| | First factor |
| Unchanged products | -0.98 |
| Products new to the firm | 0.98 |
| Products new to the market | 0.92 |
| Cumulative % of explained variance | 92 % |

Table 13. Measuring market concentration

| Market concentration | ***Factor loadings*** | | |
|---|---|---|---|
| | First factor | Second factor | Third factor |
| Share of firms with 0 employees | -0,95 | -0,13 | 0,29 |
| Share of emp. in firms with 1-10 employees | 0,20 | -0,11 | -0,94 |
| Share of emp. in firms with 11-50 employees | 0,87 | -0,07 | -0,02 |
| Share of emp. in firms with 51– 200 employees | 0,73 | 0,36 | 0,49 |
| Share of emp. in firms with > 200 employees | 0,52 | 0,46 | 0,54 |
| Concentration ratio – C4 | 0,03 | 0,97 | 0,09 |
| Concentration ratio – C20 | 0,10 | 0,94 | 0,17 |
| Cumulative proportion of explained variance | 47 % | 75 % | 89 % |

Table 14. Measuring industrial dynamics

| | Factor loadings | | |
|---|---|---|---|
| Market dynamics | First factor | Second factor | Third factor |
| Exit rate | 0.73 | 0.44 | -0.24 |
| Entry rate | 0.86 | 0.31 | -0.13 |
| Entrepreneurial exit rate | 0.11 | 0.91 | -0.08 |
| Entrepreneurial entry rate | 0.20 | 0.89 | -0.08 |
| Survival rate | -0.85 | -0.19 | -0.08 |
| Non-entrepreneurial entry rate | 0.82 | -0.46 | -0.21 |
| Takeovers, moves, expansion | -0.06 | -0.56 | -0.08 |
| Spin-out | 0.04 | -0.04 | 0.80 |
| Transformation | -0.21 | 0.02 | 0.68 |
| Cumulative proportion of explained variance | 38% | 60% | 72% |

Table 15. Innovation regimes in the Norwegian economy

| **Factor label** | **Table from which the factor is drawn** | **Factor number in Table** | | Cluster 1 | Cluster 2 |
|---|---|---|---|---|---|
| | | | N | 24 | 36 |
| Formal R&D | 5 | 1 | Mean | -0.71 | 1.16 |
| | | | Std. Dev. | 0.47 | 0.47 |
| | | | | ** | *** |
| Non-R&D external knowledge and training | 5 | 2 | Mean | 0.55 | -0.37 |
| | | | Std. Dev. | 1.24 | 0.58 |
| | | | | * | *** |
| Technological opportunity | 6 | 1 | Mean | -0.36 | 0.23 |
| | | | Std. Dev. | 0.14 | 1.24 |
| | | | | *** | |
| Persistence | 6 | 2 | Mean | -0.81 | 0.54 |
| | | | Std. Dev. | 0.56 | 0.85 |
| | | | | *** | *** |
| Appropriability use | 7 | 1 | Mean | -0.87 | 0.58 |
| | | | Std. Dev. | 0.66 | 0.73 |
| | | | | *** | *** |
| Market-based knowledge sources | 8 | 1 | Mean | -0.52 | 0.34 |
| | | | Std. Dev. | 0.56 | 1.09 |
| | | | | *** | |
| Internal knowledge sources | 8 | 4 | Mean | -0.56 | 0.95 |
| | | | Std. Dev. | 0.37 | 0.86 |
| | | | | ** | ** |
| Economic and financial obstacles | 9 | 1 | Mean | -0.39 | 0.70 |
| | | | Std. Dev. | 0.26 | 1.09 |
| | | | | ** | |
| Organizational and technological obstacles | 9 | 2 | Mean | -0.34 | 0.59 |
| | | | Std. Dev. | 0.23 | 1.15 |
| | | | | ** | |
| R&D intensity | 10 | 1 | Mean | -0.58 | 0.38 |
| | | | Std. Dev. | 0.39 | 1.13 |
| | | | | *** | * |
| Non-technological innovation | 11 | 1 | Mean | -0.58 | 0.38 |
| | | | Std. Dev. | 0.38 | 0.93 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | *** | * |
| Importance of new products for turnover | 12 | 1 | Mean | -0.61 | 0.41 |
| | | | Std. Dev. | 0.17 | 1.11 |
| | | | | *** | * |

Table 16. Industrial dynamics regimes in the Norwegian economy

| **Factor label** | **Table from which the factor is drawn** | **Factor number in Table** | | Cluster 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|
| | | | N | 8 | 6 | 25 | 21 |
| No microfirms | 13 | 1 | Mean | 1.35 | -0.12 | 0.37 | -0.92 |
| | | | Std. Dev. | 0.56 | 0.33 | 0.74 | 0.61 |
| | | | | *** | | * | *** |
| Concentration | 13 | 2 | Mean | 0.93 | 0.32 | -0.24 | -0.16 |
| | | | Std. Dev. | 0.63 | 1.20 | 0.83 | 1.07 |
| | | | | ** | | | |
| Large firms | 13 | 3 | Mean | 0.93 | -0.63 | -0.47 | 0.39 |
| | | | Std. Dev. | 1.54 | 0.65 | 0.78 | 0.62 |
| | | | | | | ** | ** |
| Turbulence | 14 | 1 | Mean | -0.13 | 2.31 | -0.25 | -0.32 |
| | | | Std. Dev. | 0.74 | 0.39 | 0.72 | 0.55 |
| | | | | | *** | | * |
| Entrepreneurial | 14 | 2 | Mean | -1.16 | -0.19 | -0.21 | 0.74 |
| | | | Std. Dev. | 0.74 | 1.75 | 0.48 | 0.73 |
| | | | | ** | | | *** |
| Transformation/spinout | 14 | 3 | Mean | -1.12 | -0.29 | 0.79 | -0.43 |
| | | | Std. Dev. | 0.46 | 0.25 | 0.95 | 0.50 |
| | | | | *** | | *** | *** |

Table 17. Innovation and Industrial regimes in the Norwegian economy

| | **Low innovation intensive regime** | **High innovation intensive regime** | **Total** |
|---|---|---|---|
| **Stable and concentrated regime** | n = 2<br>Internal R&D = 0.7%<br>Turnover = 3.3%<br>Employment = 3.6% | n = 6<br>Internal R&D = 13.4%<br>Turnover = 4.9%<br>Employment = 5.1% | n = 8<br>Internal R&D = 14.2%<br>Turnover = 8.3%<br>Employment = 8.7% |
| **High turbulence regime** | n = 2<br>Internal R&D = 3.9%<br>Turnover = 5.0%<br>Employment = 8.5% | n = 4<br>Internal R&D = 28.6%<br>Turnover = 29.8%<br>Employment = 9.8% | n = 6<br>Internal R&D = 32.5%<br>Turnover = 34.8%<br>Employment = 18.3% |
| **Incumbent dynamics regime** | n = 11<br>Internal R&D = 4.8%<br>Turnover = 32.0%<br>Employment = 23.0% | n = 14<br>Internal R&D = 19.6%<br>Turnover = 8.8%<br>Employment = 11.8% | n = 25<br>Internal R&D = 24.4%<br>Turnover = 40.8%<br>Employment = 34.8% |
| **Entrepreneurial regime** | n = 9<br>Internal R&D = 2.9%<br>Turnover = 11.1%<br>Employment = 28.2% | N = 12<br>Internal R&D = 25.6%<br>Turnover = 5.0%<br>Employment = 9.9% | n = 21<br>Internal R&D = 28.9%<br>Turnover = 16.2%<br>Employment = 38.2% |
| **Total** | n = 24<br>Internal R&D = 12.4%<br>Turnover = 51.4%<br>Employment = 63.5% | N = 36<br>Internal R&D = 87.6%<br>Turnover = 48.6%<br>Employment = 36.5% | n = 60<br>All percentages equal to 100 |

## Appendix. Sectors and the assignment to regimes

| No. | Description | Innovation Cluster | Industrial dynamics cluster |
|---|---|---|---|
| 1 | Fish farming | 2 | 2 |
| 2 | Mining and quarrying, ex. oil and gas | 1 | 4 |
| 3 | Extraction of crude oil and natural gas, services delivered to this sector | 2 | 2 |
| 4 | Meat products | 1 | 3 |
| 5 | Fish products | 1 | 3 |
| 6 | Bakery products | 1 | 3 |
| 7 | Other food products, beverages, tobacco | 2 | 3 |
| 8 | Spinning, weaving and textiles | 1 | 4 |
| 9 | Carpets, rugs, rope, etc. | 1 | 3 |
| 10 | Knitted fabrics and products, other wearing apparel | 2 | 4 |
| 11 | Fur, leather, articles thereof | 2 | 3 |
| 12 | Saw mills | 1 | 3 |
| 13 | Wood, wooden products | 2 | 4 |
| 14 | Builders carpentry | 1 | 3 |
| 15 | Pulp, paper, paper products | 2 | 1 |
| 16 | Publishing | 1 | 4 |
| 17 | Printing | 1 | 4 |
| 18 | Basic chemicals | 2 | 1 |
| 19 | Other chemicals | 2 | 3 |
| 20 | Pharmaceuticals | 2 | 1 |
| 21 | Rubber and plastic products | 2 | 3 |
| 22 | Glass, glass products, ceramics, other minerals products | 2 | 4 |
| 23 | Bricks, cement, concrete, stone | 1 | 3 |
| 24 | Ferrous basic metals | 2 | 1 |
| 25 | Non-ferrous basic metals | 2 | 1 |
| 26 | Casting, forging, pressing of metals, tanks, containers, boilers | 2 | 3 |
| 27 | Structural metal products | 1 | 3 |
| 28 | Treatment and coating of metals | 1 | 4 |
| 29 | Cutlery, tools, crafts, other metal products | 2 | 3 |
| 30 | Power generating equipment | 2 | 3 |
| 31 | Other general purpose machinery | 2 | 4 |
| 32 | Agriculture and forestry machinery | 2 | 4 |
| 33 | Machine tools and other special purpose machinery | 2 | 3 |
| 34 | Domestic appliances | 2 | 4 |
| 35 | Computers and office machines | 2 | 4 |
| 36 | Electric motors, generators, electrical distribution | 2 | 3 |
| 37 | Wire and cable, batteries, other electric equipment | 2 | 3 |
| 38 | Electronic valves, tubes, etc. | 2 | 1 |
| 39 | Radio and tv transmitters and receivers | 2 | 4 |
| 40 | Instruments, medical equipment | 2 | 3 |
| 41 | Motor vehicles, parts | 2 | 3 |
| 42 | Ships and boats | 2 | 3 |
| 43 | Other transportation equipment | 2 | 4 |
| 44 | Furniture | 2 | 4 |
| 45 | Other manufacturing | 2 | 4 |
| 46 | Waste metal and scrap, recycling thereof | 2 | 3 |
| 47 | Production and distribution of electricity | 1 | 1 |
| 48 | Steam, hot water, purification and distribution of water | 1 | 4 |
| 49 | Building and construction of buildings, installation, finishing | 1 | 4 |
| 50 | Building of roads, other building | 1 | 4 |

| No. | Description | Innovation Cluster | Industrial dynamics cluster |
|---|---|---|---|
| 51 | Wholesale | 1 | 3 |
| 52 | Land transport | 1 | 4 |
| 53 | Water transport | 1 | 2 |
| 54 | Air transport | 1 | 1 |
| 55 | Transportation support, cargo storage | 1 | 3 |
| 56 | Transportation and travel agents | 1 | 3 |
| 57 | Telecom services | 2 | 2 |
| 58 | Financial services | 1 | 2 |
| 59 | Computer services | 2 | 2 |
| 60 | R&D, engineering, architecture and design | 2 | 4 |