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Innovation in Norwegian industries – testing a new taxonomy

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Executive summary

Recent innovation literature has emphasised several aspects in company innovation processes: Innovation processes are *systemic*, innovation processes are *market-specific*, *learning* plays an important role in innovation and *technological change* is a major issue in innovation and economic development processes.

This paper introduces a company classification rooted in these dimensions. We divide industries by engineer density (high/low) and probability to have innovation collaboration (high/low). This gives us four industry groups;

- *Systemic* industries (low engineering intensity, often innovation collaboration),
- *Craft-based* industries (low engineering, less often collaboration),
- *Complex technological systems* industries (high engineering, less often collaboration) and
- *Research-oriented* industries (high engineering, less often collaboration).

Using these groups as independent variable, we investigate variation in innovative activity (process vs products, innovation barriers, innovation objectives, ICT orientation, R&D intensity etc.)

The Norwegian economy is dominated by *systemic* industries; about 50 percent of the private sector employees work in such industries. For these industries, we find that there are indications of a relation between size and innovativity. We also find that *systemic* innovators tend to have in general lower expenditure costs than for example *craft-based* industries, but slightly higher innovation rates. *Systemic* industries have more often more informal innovation processes, with the exception of one (Mining). These industries tend to be low on the process innovation axis, but quite spread on the product innovation axis.

We find that *Craft-based* industries have less often innovation as output from the same share of innovation expenditures than other industry groups. These industries are in average recognised by small companies and with a dominantly low innovation rate. About 25 percent of the Norwegian private sector workforce work in these industries. *Craft-based* industries are in general higher on process innovations than other industries, and they are also lower on product innovation. All but *craft-based* industries introduce more often completely new products to the market.

Complex technology systems companies are in general more innovative than the two other large groups. Particularly seem *complex technology system* innovators to have innovation more often than other industry groups, when holding innovation expenditures constant. For *complex technology system* industries, we find a general high share of innovative industries with new-to-market products, but with transport services as a clear exception. These industries also have higher ICT intnsity than other industries.

Research-oriented industries cover only one industry; the Machinery industry. This is a weakness with our typology. Our *research-oriented* industry has lower R&D intensity than most *Complex technology system* industries, and is also slightly probable to have more informal innovation processes, with modest average innovation costs and innovativity beyond average. Our *research-oriented* industry keeps a quite high focus on product innovation and quite low on process innovation.

Compaines in both *craft-based* and *research-oriented* industries mention much more often than the other two groups that increased flexibility is a major objective for innovation. Reducing labour costs is also a factor that divides industries with innovation collaboration from industries without innovation collaboration, although the difference is slightly less than what we found for flexibility. It is dominantly industries with high engineer density that report on replacing existing products as major objective. Industries with low engineer density have a much higher probability to focus on reducing use of energy and materials. Industries with often innovation collaboration also slightly more often report opening up new markets as an objective to innovation than those that has less often innovation collaboration.

We see that industry-groups reckognised by high engineer density more often report lack of finance as a relevant barrier to innovation. The same difference applies to similar factors like economic risk and too high innovation costs, but not so strong.

Craft-based industries more often report lack of technological information as a barrier to innovation. However, there is no relation between low engineer density and probability of reporting lack of technological information as a barrier. *Systemic* industries report this barrier least often; in fact, we see that industry-groups reckognised by more frequent innovation cooperation report (*Systemic* and *Complex technology systems*) less often lack of technological information as a barrier.

We also found a general relation between engineer intensity and R&D intensity on industry-level. We have suggested using this approach as a good alternative gateway to find industries with R&D discrepancies – compared to the often-used argument that R&D levels need to be increased whatsoever. We claim that a good starting point to increase Norwegian R&D levels could be to find industries with low R&D compared to engineer density. We find that this is particularly true for two *Complex technological systems* industries; Business services/computing and Recycling/el/water power.

There exist other methods than increased R&D to stimulate to innovation. One way to increase the complexity of innovation activities could therefore be to stimulate innovation collaboration, rather than focus on tax-incentives to increase R&D alone. This would be a just as relevant goal for innovation policy, in industries belonging to *craft-based* group in particular, as would be increasing R&D or engineering density.

Table of contents

Innovation in Norwegian industries – testing a new taxonomy

The need to classify objects

In *Les mots et les choses*, Foucault refers to the Chinese encyclopaedia of Borges, dividing animals into a) belonging to the Emperor, b) embalmed, c) tame, d) sucking pigs, e) sirens, f) fabulous, g) stray dogs, h) included in the present classification, i) frenzied, j) innumerable, k) drawn with a very fine camelhair brush, l) *et cetera*, m) having just broken the water pitcher and n) that from a long way off look like flies…[1].

Although humourous, and with some lack of internal consistency, to say it least, this taxonomy illustrates how mankind finds a profound interest in looking for order in a multitude of variety, by putting variety into organised, collective categories.

A more consistent taxonomy is Linneaus' classical naturalist categorisation system for living species, focussing on physiognomy as a determining factor for classification. What defines a species, says Linneaus, is common physiology of organs, body, limbs, etc. In Linneaus' view, there is a relationship between man and monkeys, as they have close similarities in the physical build-up of the body. But while Linneaus separated species by how they looked, Damuth (1985)[2] and van Valen (1992)[3] provide an alternative taxonomy, suggesting that animals should be separated by their 'ability to use same ecological resources'[4], hence focussing on habitats and food as definition on what separates living species.

As these two last examples show, the drawback of classifications is that all taxonomies are built on certain aspects we find important in the study objects. The two taxonomies illustrate that our perception of reality is strongly related to how we categorise and order the very same reality: Behind every mapping and logging of study objects (be it companies, regions or animals) lies tacit, but deciding considerations on what we regard as important to the objects.

Therefore, any categorisation is somewhat 'dangerous', because it leads us to think in certain direction, it leads us to focus on particular phenomena to the studied objects; what we look for is always a question of what we believe there is to find; epistemology is always a question of ontology. The backside of categorisations is that such generalisations tend to ignore important differences between objects apart from those tacitly regarded as important for the taxonomy.

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[1] English version: Foucault, M (1970), *The order of things* (1994 reprint), Routledge, page xv

[2] J. Damuth (1985) Selection among 'Species': A Formulation in Terms of Natural Functional Units, in Evolution 39:1132-46

[3] L. van Valen (1992) *Ecological species, multispecies, and oaks*, in The Units of Evolution: Essays on the Nature of Species 69-77, ed. M. Ereshefsky, MIT Press, Cambridge MA

[4] Wilkins, John S. (1997) *A Taxonomy of Species Definition*, (work in progress), from http://wehiz.wehi.edu.au/~wilkins/metatax/metataxo.htm

These issues are also important for how we understand *industrial* ecology. It is common to classify companies; the most common classifications are by size or industry. But when we divide companies into different classes, we do this because we think that such classes touch upon some fundamental characteristics of the company. In this paper, however, we claim that most ways of classifying companies stand in sharp contrasts to recent innovation theories. In our view, a company classification must start with what we regard as important features with the *innovation process* of the company; relations like ways of organising innovation processes, the role of technology, the intensity and direction of internal skills, and markets.

The following sections look closer at different common ways of distinguishing between companies, what the policy implications are from such a classification, and what the drawbacks of such a classification are. This section founds a basis for our attempt to introduce a new company classification based on fundamental innovation characterisitics: Systemity, learning and technological knowledge.

Size classifications

A common way of classifying companies is to look at mere size, measured for example by employment. The reason why this categorisation is important is – in an evolutionary perspective – that large and small companies have different technological 'roles'. Small companies are often said to be more flexible and therefore capable of exploiting emerging technologies or new niche markets more rapidly[5]. Large companies, on the other hand, are often regarded as heavy export-oriented technological and economical locomotives that have better access to capital and perform systematic research.[6]

The policy implication from this categorisation is that one should pursue different strategies for small and large companies. Small companies are structurally in need of capital, export support and access to technological surveillance. Large companies structurally need access to researchers and equipment.

The drawback from this classification is that it does not take into consideration factors like locality or production technology. There are differences with regard to whether the company is a little grocery store or a newly set up pulp and paper plant, and there are differences in company performance with respect to geography (the same rules do not apply to a small company in Norway and a small company in London). These measures are ignored in a pure size-based classification.

Classifications by location

Companies in rural and urban areas may act or perform differently, and several lines of economic theory have argued that there is a difference to company development with respect to location and space. Regional cluster theory argue for example that companies within same production filière located within the same region tend to

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[5] E.g. Schumpeter mark 1

[6] E.g. Schumpeter mark 2

perform better than single companies[7]. Some theorists argue that space in itself has some qualitative features; for example that cities are more innovative than rural areas, because of the cultural mix, the speed of information and the pool of skilled persons[8]. Thirdly, some theorists argue that the global division of labour depend upon the production activity’s place on the technological trajectory: New and emerging industries are engineering- and R&D-intensive, and therefore located to areas with high access to such resources. Standardised routine production is located to areas where access to cheap labour is high[9].

The policy implication from this taxonomy is that policies must be time- and space (culture) contingent, and aimed at localised company development, dominantly focussing on developing or stimulating innovative clusters or innovative urban-industrial environments[10].

A company taxonomy based on location can be criticised on several levels. Firstly, the concept of ‘region’ or ‘space’ is often vaguely defined, and normally interpreted on a level that suits the actual study. Secondly, and in relation to this, the concept of ‘space’ is often used so wide that it include all regional factors that the researcher find relevant (from political, cultural and economic history to family structure and birth rates). Thirdly, regional studies are criticised for giving ‘space’ (culture) explanatory powers, although it is not evident that companies are a result of space (culture), instead of space (culture) being a result of companies (technology). It is for example unlikely that a successful regional cluster on for example metals would survive if their customers gradually switch to plastics.

The NACE classification

One way to include technology and markets into company classification has been to separate companies by their main product in branches. International industrial statistics are collected and sorted by using a UN classification standard (NACE[11]), sorting companies by what they produce: All companies producing clothing belong to one industry, all companies selling cars belong to one industry and companies producing petroleum are categorised as one industry etc.

The policy implication for this classification is that each industry or branch have their own technological set-up, employment and skill demand and technological and productivity trajectory, and therefore demands unique policy design.

Although this approach includes ‘technology’ in terms of some common aspects in the final product, the approach is criticised for ignoring knowledge content in the industrial production process. For example, many different industries, like services,

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[7] See for example Saxenian, A. (1994); *Regional Advantage*, Harvard University Press, Cambridge and London.

[8] See for example Friedmann, J. (1972), *A general Theory of Polarized Development*, in Hansen, N. M. (ed.), Growth Centers in Regional Economic Development, New York.

[9] See for example Rothwell, R. and W. Zegveld (1985), *Reindustrialisation and technology*, Longman, p. 21

[10] Michael Porter, *The competitive advantage of nations*, MacMillan, 1985

[11] Nomenclature générale des Activités économiques dans les Communautés Européennes

food production and manufacturing of metals innovate through investment in physical equipment. Important common innovative activities are test production, learning processes, technological surveillance etc., but this common knowledge component is ignored in such NACE-based overviews.

The Pavitt taxonomy

A response to the critique of the NACE-based categorisation classical categorisation of companies is constructed by Keith Pavitt, who used innovative patterns in British industries to distinguish companies into one of four groups: Supplier dominated industries (like services and agriculture), Scale intensive industries (like food production and man. of automobiles), Specialised suppliers (like small engineering companies) and Science based industries (like pharmaceuticals and electronics)[12].

The policy implication is that although some industries produce different products they may have common innovation process features and therefore common innovative needs[13].

The classification is a good attempt to map common internal innovation processes among companies, despite large differences in final products. It also indicates various common learning processes among companies in different industries. The taxonomy is however criticised for not distinguishing enough between various forms for private services. Secondly, the taxonomy is criticised for being an attempt to generalise some kind of ‘laws’ based on quite time- and space-specific results from England. Thirdly, it is critisised for using industries and not companies as the smalles entity[14].

The OECD high-tech / low-tech classification

At the same time as Pavitt introduced his taxonomy (mid-eighties), OECD started categorising companies into three groups; high-tech, medium-tech and low-tech companies, based on the R&D “intensity”. The R&D intensity was defined as the share of “internal R&D” of sales or value added. Industrial sectors with a four percent R&D intensity or higher were labelled hi-tech, between one and four percent medium-tech and below one percent low-tech. This classifying scheme was then applied and there emerged a list of hi-tech sectors that to a wide extent became canonical (Appendix)[15].

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[12] Pavitt, Keith (1984), *Sectoral patterns of technical change: Towards a taxonomy and a theory*, in Research Policy 13 (1984), Elsevier Science Publishers B.V. (North Holland)

[13] For a Norwegian innovation study using this taxonomy, see Braadland (2001)

[14] Archibugi, D. (2001), *Pavitt’s Taxonomy sizteen years on: A review article*, in Economics of Innovation and New Technology, Vol. 10, No. 5, 2001

[15] OECD also developed two other taxonomies in this period; one that was called ‘orientation based industry groups’, dividing industries into groups based on the primary factors that affect the competitive processes; respectively *resource intensive industries; labour intensive industries, scale-intensive industries, specialised supplier industries and science based industries* – in other word quite similar to the Pavitt taxonomy. The other taxonomy was a ‘wage-based’ taxonomy, dividing industries into *high wage, medium wage* and *low wage industries.*

The policy implications from this taxonomy have more or less implicitly been that one should support innovative, high technology industries, and simultaneously let low-tech industries gradually die out.

There are two major critiques against this perspective. Firstly, it completely ignores the role of markets: Although there is no obvious relation between high R&D intensity on the one side and size or development of markets on the other, the distinction tacitly argues that R&D intense industries are more important than others. This is clearly a debatable approach.

Secondly, and in relation to the first, it has been increasingly argued that industrial R&D intensity is a too simple measure to grasp the complexity and systemity of company behaviour in innovation processes[16]. The basic problem is that the R&D intensity has the “car factory” as its archetype; an integrated firm with routine industrial production – and a research lab developing the new models. The R&D intensity indicator ignores that industries may use a rather complex knowledge base in the innovation process – and being quite innovative – without spending large shares of turnover on R&D.

Let’s show this empirically[17]. The figure below shows R&D intensity on industrial level (x-axis) and share of innovative companies in industries in Norway (y-axis). There *is* a slight log correlation between R&D and innovativity (R^2 = 0,4477). Industries with high R&D intensity are never less than 40 % innovative.

However – as we also have emphasised graphically in the figure – there are two other aspects that are equally interesting. Firstly, there is a large group of industries with more or less same R&D intensity (less than 20.000 NOK per employee) that vary quite much in innovativity rates (from 10 to 55 percent). Secondly, there is group of industries with quite varying R&D intensity (from 25.000 to 110.000 NOK per employee) but with more or less same innovativity rates (from 40 to 55 percent).

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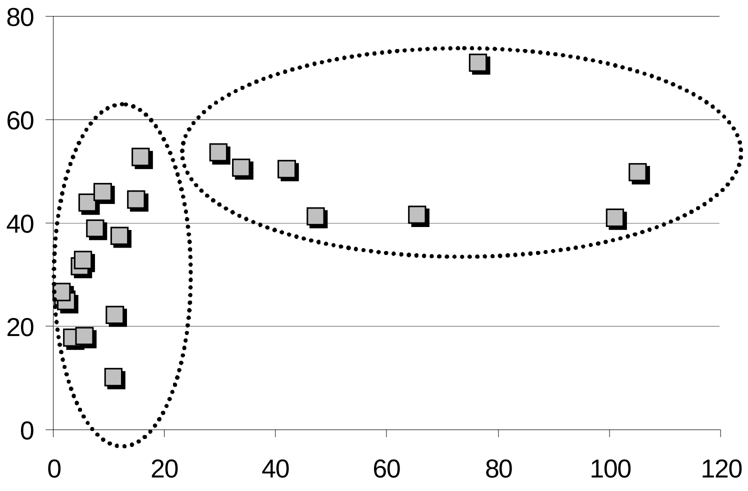
[16] See for example Smith, K. (1999), *What is the ’knowledge economy’? Knowledge-intensive industries and distributed knowledge bases*, paper presented to DRUID Summer Conference on the Learning Economy – Firms, Regions and National Specific Institutions, June 2000

[17] The following work is based on combination of three data sets for Norway. The Community innovation survey (CIS) is a survey on innovation activities in about 2.800 companies (weighted), performed in 1997. The employee/employer data set is a register database with information on employment, company size, industry and each employee’s highest education, to mention the most relevant variables. Here, we use data for 1999. The R&D data set is a survey from about 4.000 companies (weighted) on R&D volume. R&D data were collected in 1999. R&D includes both internal and external R&D, financed by the industry. We dominantly aggregate companies in NACE 2-level industries, with some exceptions. An overview is presented in the Appendix.

Figure 1: R&D intensity (1.000 NOK per employee, x-axis) and share of innovative companies, by industry (y-axis).



Summing up

We have presented different kinds of often-used company taxonomies, their inherent policy implications, and their weaknesses. We have put particular emphasis on discussing the famous and widely used OECD taxonomy, dividing industries into high-, medium- or low-tech industries depending on their R&D intensity. The two major critiques against this taxonomy are, firstly, that it does not take into consideration markets, and, secondly, that it is based on a quite simple view on the innovation process.

On the basis of these discussions, one could argue that there is need for more sophisticated company taxonomies. Such a new taxonomy should take into consideration newer theoretical and empirical evidence from the economic literature; that innovation is market-specific, systemic, knowledge-driven and technological. In the next section, we introduce a new approach to company categorisation that satisfies these demands.

Introducing a new company taxonomy

Classification by way of organizing the innovation process

Recent innovation literature has emphasised three empirical facts around innovation processes. The first is that innovation processes are *systemic*[18]. That is to say that innovation processes are not sequential processes where R&D enters in the one end and new products and processes come out in the other. Innovation is increasingly understood as an interactive development process involving several knowledge bases. Such knowledge bases include for example suppliers, customers, research departments, universities, market knowledge etc.

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[18] See for example *Technology and the Economy – the key relationships*, OECD 1992, Paris

This variety in the direction and complexity of how the innovation process is configured can be seen as a critique of the sequential and one-dimensional axis of the high-tech / low-tech approach, where research input almost by nature leads to innovation output. Surely, there are industries where R&D is important to innovation, like chemicals or electronics. But in industries like food and beverages, metals and pulp and paper, we know that respectively branding, material technologies and machinery may be other and equally important sources to innovation and economic development.

Secondly, the role of learning has been increasingly emphasised as important to innovation[19]. Learning and knowledge are person-specific attributes, contained in companies. Knowledge influence profoundly on how companies respond or act to changed environments, but is neglected in large parts of economic literature, where *information* (and not knowledge) is regarded as given. Learning is important in economic development, for many reasons. Firstly, learning is tightly related to the evolutionary aspect of economics: New ways of doing things, new knowledges, or combining existing knowledges are at the core of economic development. And it is often argued that innovation cannot be separated from learning at all, as innovation per definition involves doing something new, something one didn't do before.

Thirdly, economic literature points to *technological change* as a major factor for economic development[20]. However, that economics is about change and not about statics has actually never struck the major bulk of economists; equilibrium-based theories still found the basis for a large share of economic analysis.

The basic purpose of our taxonomy will be to challenge the simple R&D indicator taxonomy by bringing these three aspects – systemity, learning and technological development – into a new company taxonomy. We also want to include markets as a factor. We therefor look at the economy at industry-level, and not company-level. We have therefore distributed industries along two axes. The first axis concerns the degree of systemic dimension to the innovation process. Here we use share of companies in industry with innovation collaboration. Low collaboration shares in an industry indicate on dominantly internal organised innovation processes, while – conversely – high shares indicate on systemic ways of organsising the innovation process. The second axis concerns internal technical capabilities, including both the 'learning' dimension and the 'technological' dimension. This axis is constructed by dividing the number of engineers working in industry by total workers in the industry.

The two axes divide industries into four broad groups, according to how they organise their innovation process; *Systemic; Craft-based; Complex technology systems* and *Research-oriented.*

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[19] See for example I. Nonaka, R. Toyama and A. Nagate (2000), *A firm as a Knowledge-creating entity: A new perspective on the theory of the firm,* in Industrial and Corporate Change vol 9 no 1 March 2000.

[20] See for example J. Fagerberg (1994), *Technology and International Differences in Growth Rates*, Journal of Economic literature, vol XXXII (September 1994), pp. 1147-1175.

Figure 2: A new industry taxonomy based on skills and systemity

	Low degree of formal skills	High degree of formal skills
Systemic organised innovation process	Systemic	Complex technological systems
Internal organised innovation process	Craft-based	Research-oriented

In the following, we will use this matrix to do two things: First, we determine how different Norwegian industries locate themselves in this scheme. Second, we test this division of industries against other variables, like innovativity, industry size, informal vs formal innovation processes, innovative orientation (product vs process), objectives to innovation, barriers to innovation and R&D intensity.

Categorising the industries

From the CIS survey data we find that about 50 percent of all companies had innovation collaboration (1455 of 2857 companies, weighted, only companies with innovation activities accounted for)[21]. Some industries had more often innovation collaboration than others. Oil companies, chemical products, mining and Metals reported most often innovation collaboration with other external units. Printing and publishing, furniture, wood products and textiles were industries that most rarely reported innovation collaboration. This is shown in the figure below.

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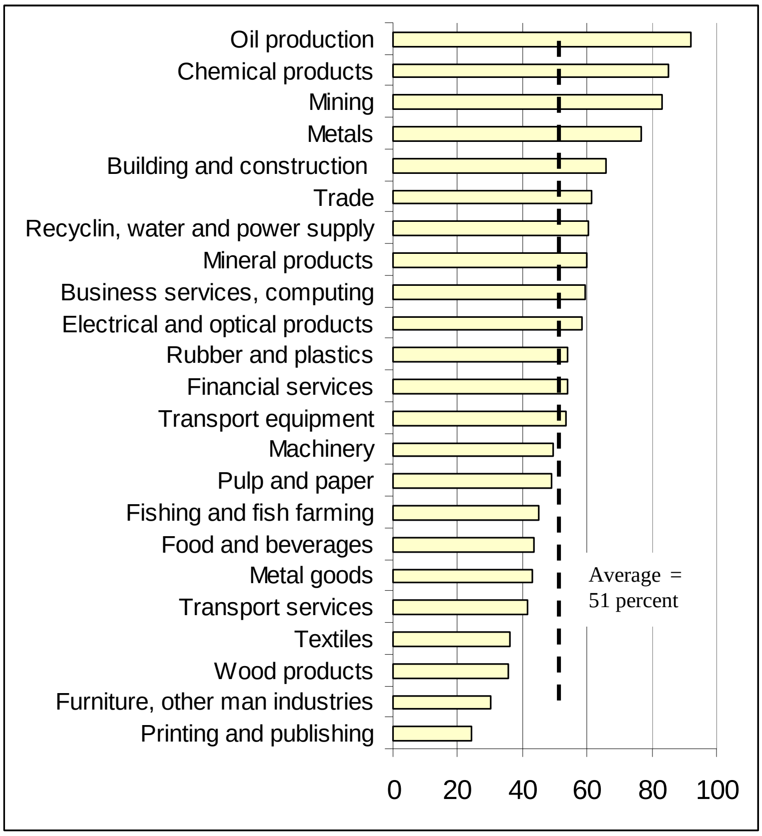
[21] Innovation collaboration referr to Q11 in the questionnaire, asking *"Did your enterprise have any cooperation arrangements on innovation activities with other enterprises or institutions in 1994-1996?"* By innovation cooperation means *"active participation in joint R&D and other innovation projects with other oragnisations. It does not necessarily imply that both partners derive commercial benefit from the venture. Pure contracting out work, where there is no active participation, is not regarded as cooperation"*. The responding companies could answer Yes or No.

Figure 3: Share of companies reporting innovation collaboration with external units, CIS Norway 1997. N = 2.857 (weighted), 1.363 (unweighted).



From the employee register database, we find that average engineering intensity – which is our second denominator – is about four percent[22]. Oil companies, Business services and Electronics come out as the most intense industries, while Wood products, Textiles and Trade are among those industries with low shares of engineers.

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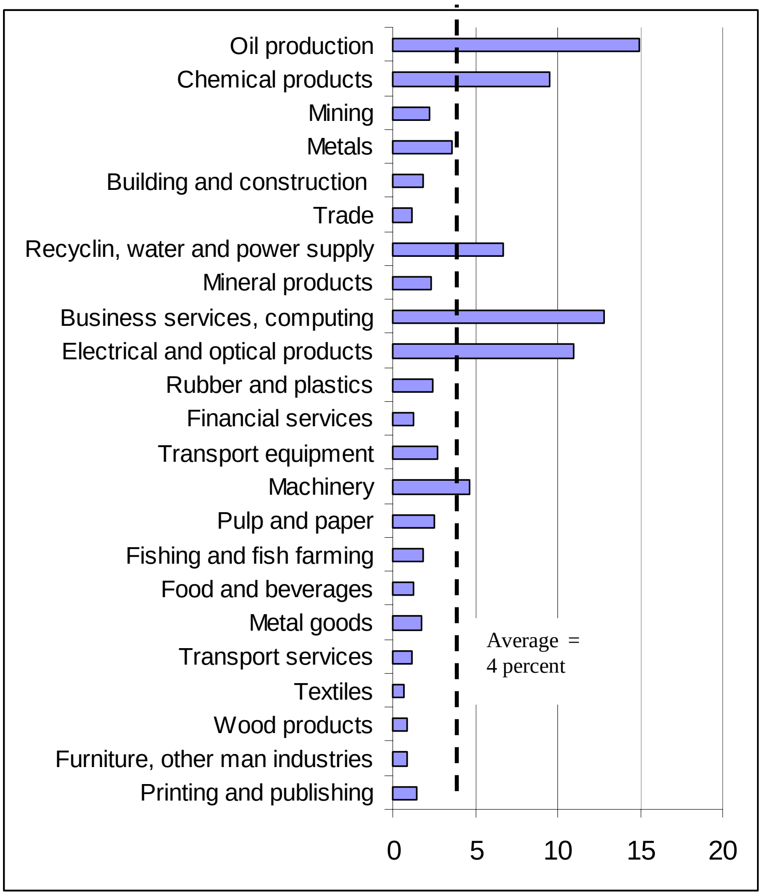
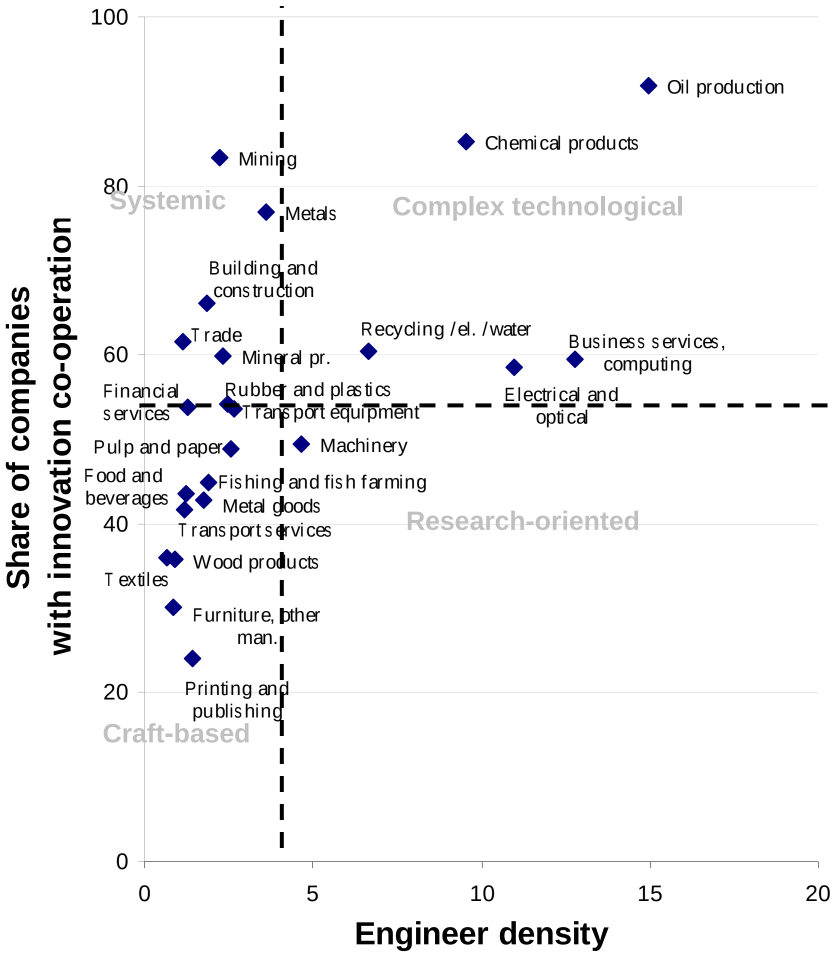
[22] Unweighted average, which means that we use average company density in each industry rather than total average for each industry, where density in large companies play a relatively larger role. Employment is here defined as all persons registered as working in a company with organsation number, regardless of income. This includes part-time workers and students working parallelly with studies. Other private services (NACE 75-99) are not included in our data, as the CIS survey did not over these industries.

Figure 4: Engineering density in Norwegian industries. Source: Employment register, STEP / Statistics Norway, 1999. N = 24.241 (register data), unweighted averages



When we put these two figures together, we get the following scatter plot (lines = Norwegian average).

Figure 5: Norwegian industries plot by engineer density and innovation collaboration.



The figure illustrates a couple of interesting things. Firstly, it shows that there is a log correlation between increased engineering density and increased probability to have innovation collaboration[23]. This result confirms previous findings[24].

Secondly, we find that the Norwegian economy is dominated by *craft-based* industries; that is industries with lower-than-average probability to have innovation collaboration and lower-than-average engineering density. However, these are in general small industries. Looking at number of employees, systemic industries are dominating (see Table 1 below).

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[23] $y = 12{,}848\mathrm{Ln}(x) + 42{,}924$, $R^2 = 0{,}44$

[24] NUTEK (1996), *Maskinindustrin i Sverige – teckologiutveckling, konkurrens och tilväxt*, R 1996:43

Thirdly, we find that almost all of the most knowledge-intensive industries (measured by engineering density) have a high degree of innovation collaboration, with one exception; the machinery industry. This industry is the only one with higher-than- average engineer density and lower-than-average innovation collaboration, and it differs only slightly from average on both axes. This is both an interesting result *and* a problem for the further work. We will keep the division like it is to see if the division can provide us with some fruitful insight.

The following table provides an overview of the results and the size of the groups in the Norwegian economy.

Table 1: Company categories, industries and signs of recognition.

Category	**Industries**	**Signs of recognition**	**Number and share of employees** [25]
Systemic	Mining, Metals, Building and construction, Trade, Mineral products, Rubber and plastics, Financial services, Transport equipment	*More often than average innovation collaboration; average or less engineering density*	426.308 **46 %**
Craft-based	Pulp and paper, Fishing and fish farming, Food and beverages, Metal goods, Transport services, Textiles, Wood products, Furniture/other man. industries, Printing and publishing	*Average or less often innovation collaboration; average or less engineering density*	261.023 **28 %**
Complex technological systems	Oil production, Chemical products, Recycling/water/el-power, Business services/computing, Electrical and optical	*More often than average innovation collaboration; higher than average engineering density*	209.476 **23 %**
Research-oriented	Machinery	*Average or less often innovation collaboration; higher than average engineering density*	20.471 **2 %**

Measured as share of employment, *systemic industries* cover about half of employment in private industries. *Craft-based* organised industries like pulp and paper, food and beverages and textiles represent about 30 percent of private sector, while *Complex technological systems* industries represent about one fourth. The only *research-oriented* industry (Machinery) represents about two percent of total employment in private sector.

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[25] Public sector (education, defence, public administration and social services) not included. Likewise, Other services (73.786 employees in 1999) are not included, as these industries were not included in the CIS survey.

Industry groups and innovation patterns

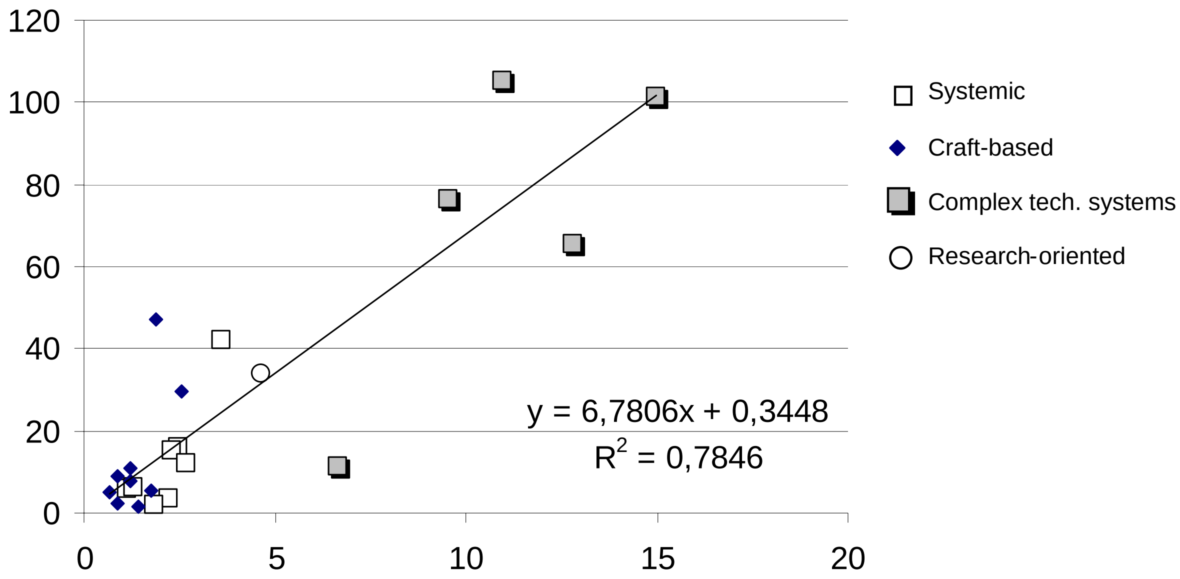
Engineering density and research and development

An often-used key to company taxonomy has been R&D intensity, as we saw for example in the OECD taxonomy, presented above. The R&D intensity indicator has in our view often been misused to emphasise two points; i) that important industries are those with high R&D intensities, and ii) that all industries should strive to increase their R&D intensity level.

In our opinion this is a method that slightly jumps the conclusions. We have shown that many industries have varying R&D intensities, but the same innovation frequency. Also, we have shown that many industries have the same R&D intensity with strongly varying innovatio frequencies. In a systemic approach, one would clearly emphasise that each industry has a unique technological set-up, and that in this setup R&D as innovation source must be weighted in relation to other innovation sources, like market domination, access to knowledge and information, design, customer relations etc.

Therefor, one needs to find other ways to increase R&D than arguing that we need a general increase. Another way to find R&D potential could be to compare R&D intensity with engineer intensity, to see where we find discrepancies in one or the other way. Industries with high engineer density and low R&D intensity would perhaps be easier to target for increased R&D policy? The following figure shows this alterative approach graphically. We have plotted engineer intensity on the x-axis and R&D intensity on the y-axis.

Figure 6: Engineer intensity (x-axis) and R&D intensity (R&D per employee, in 1.000 NOK), (y-axis).



As expected, the figure shows a strong, liner relation between the two, with R squared on 0.7846. The diagonal line represents in other words average relation between engineer intensity and R&D intensity. Industries above the line have more R&D than expected, relative to engineer intensity. Industries below the line have less R&D than expected, relative to number of engineers.

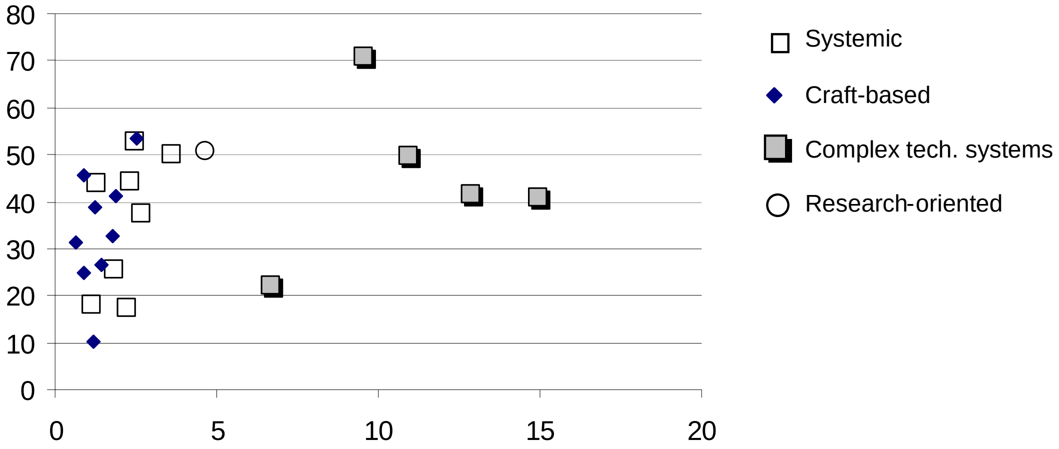
We find that most *systemic* industries are located under the line, with Metals as the only exception. For *complex technology system* industries, we find that two of five industries clearly have an R&D potential; Business services / computing and Recycling/electricity/water. Our *research-oriented* industry is quite on average, while the *craft-based* industry group includes a couple of industries with quite high R&D intensities; Pulp and paper, and Fishing and fish farming.

Engineering density and innovativity

We have seen that there is a relation between engineering intensity and R&D. We are interested in finding out how the different company groups behave with respect to innovativity. Do we find the same relation?

The following figure shows engineering density against innovativity rates, by industry[26].

Figure 7: Engineer density (x-axis) vs share of innovative companies (y-axis)



We find that there is no immediate relation between the two variables. Among *systemic* industries, for example, we see that the share of innovative companies within each industry vary quite much, from below 20 percent up to above 50 percent. The same goes for *craft-based* industries. Similarly, for *complex technology systems* industries, share of innovative companies vary from 20 to 70 percent.

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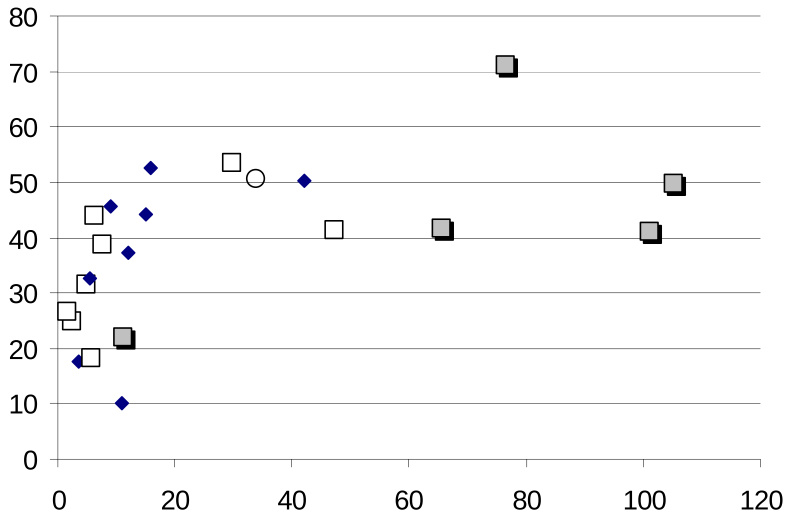
[26] Remember that engineer density was one of the determinants in our taxonomy.

R&D intensity and innovation

We have shown above that the relation between R&D intensity and innovation is quite ambiguous (Figure 1). How does our industry groups distribute in this scheme? This is shown in the following figure.

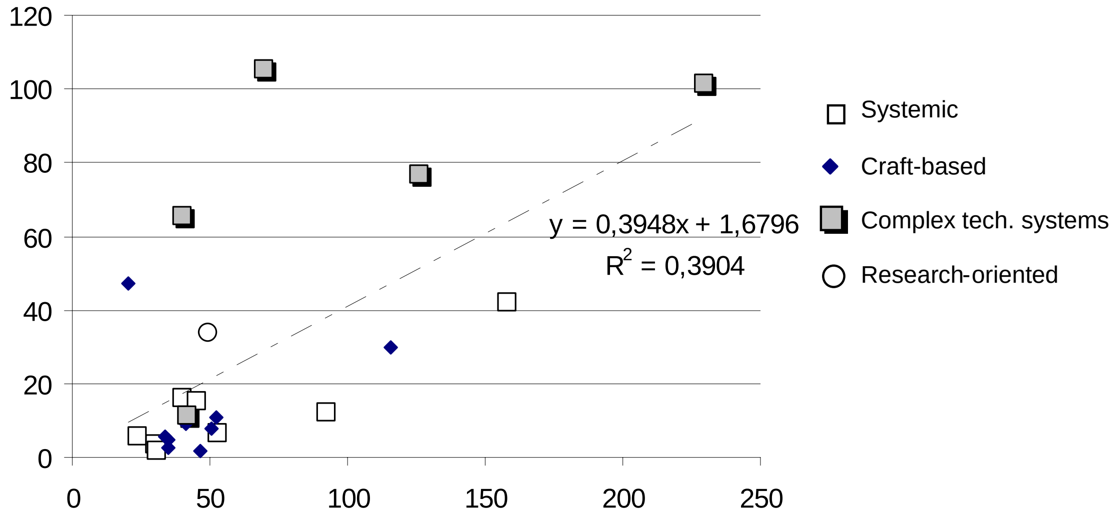
Figure 8: R&D intensity (1.000 NOK per employee, x-axis) and share of innovative companies, by industry (y-axis).



We find no particular pattern here above what we have already commented on: Engineer dense industries – and *complex technological system* industries in particular – have in general high R&D intensities.

We will check whether size is a more important role in R&D intensity. The following plot shows average size (x-axis) and R&D intensity (y-axis).

Figure 9: Average size (x-axis) and R&D intensity (y-axis)



There is a slight correlation, but not much. Outliers belonging to one particular group disturb the pattern: It is dominantly in *complex technological system* industries we find that R&D intensity is higher, compared to average company size.

Innovation objectives

There are many theoretical strands concerning why companies innovate. They are all linked to how innovation is defined. Michael Porter (op. cit.), for example, regards innovation as ‘a way of doing things better than before’. This definition implies that innovation is mainly targeted on *improving* something that was *done before*, e.g. that there must be some kind of qualitative development in a given, existing production process. His definition is problematic, however, for two reasons. It is up to others to define what kind of changes is regarded as ‘better’ and what kind of changes are not; should the criterion be economical more profitable innovations, environmental-friendly processes, how can we know if an organisational change is a ‘better way’, how can we know if changing ownership is ‘good’ or ‘bad’? Secondly, his definition has no room for completely new processes or products emerging for example in a completely new company.

Another perspective is therefore to see innovation as a first commercial use of a product or a process that hasn't previously been exploited. This definition includes only what is often described as ‘radical innovations’, including brand new products or processes only. As opposed to Porter, this definition does not (necessarily) include improvements of existing products or processes, but it emphasis completely new products and processes, an aspect that is neglected by Porter.

With increasing environmental awareness, it has been increasingly important to look for not only innovation pace, but also direction, in innovation analysis. However, the above-mentioned definitions are quite ‘neutral’ to innovation direction; Porter’s definition leaves it to the reader to put any normative value in the innovations. The radical innovation definition is mostly concerned with whether this is a completely new product/process or not.

With these strands as theoretical background, let’s turn to see if there are any significant differences between the industry groups in what objectives they have to innovation. The following figure shows an index for each industry group to report named objective as being of high importance to the innovation[27].

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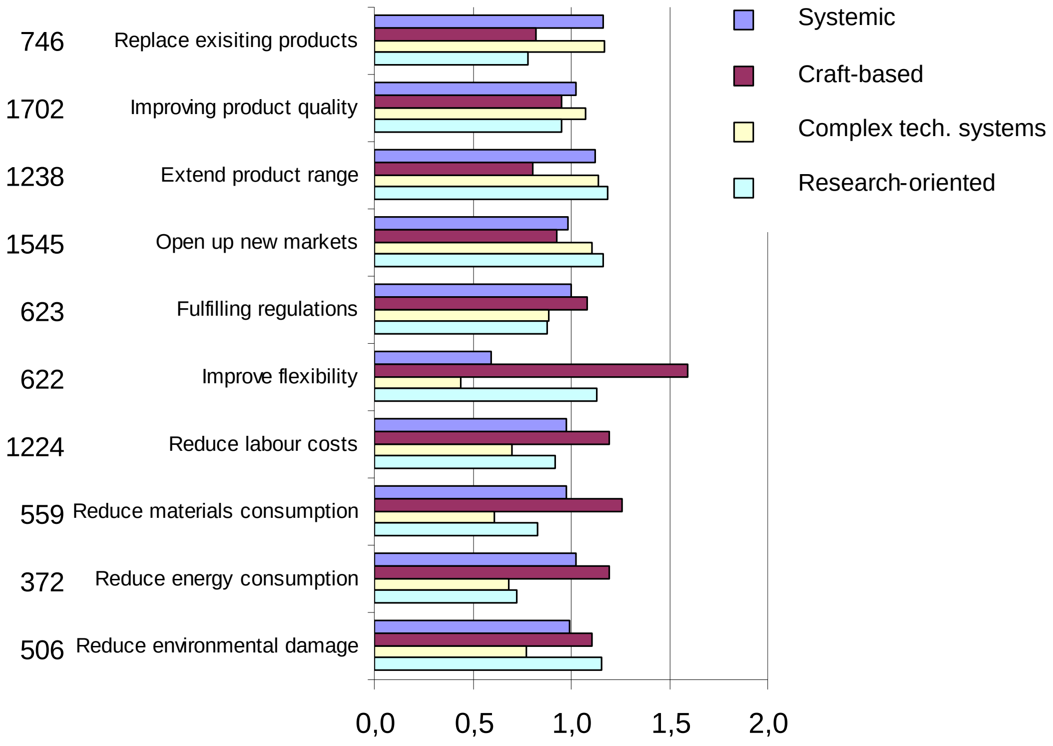
[27] We have used an RCA measure. The x-axis value represents (number of companies in group reporting this objective as important / all companies reporting this objective as important) / (total number of companies in group / total number of companies). The questionnaire asked innovating companies to range the given objectives from 0 to 3, where 3 represented high importance.

Figure 10: Index of how different industry groups report different objectives to innovation as important. N=2755 (weighted). Coloum to the left shows the relative importance of each objective; e.g. how many respondents that confirmed this objective as important.



Improving products quality, opening up new markets and reducing labour costs are the three most often reported objectives to innovation (coloumn to the left shows number of respondents reporting the respective object as important). Regarding improving product quality, there is no large difference between the four industry groups. Opening up new markets seems a bit more important to engineer intens industries. Reducing labor costs is more important to industries with low engineer density.

The major difference is how companies in different groups emphasis increased flexibility. Both *craft-based* and *research-oriented* industries mention much more often than the other two groups that increased flexibility is a major objective for innovation. Both these industry groups are defined as consisting of industries with less often innovation collaboration than other industries. How we should interpret this is a bit uncertain. Perhaps industries with less probability to external relations also emphasis the ability to be flexible in terms of markets and what customers they serve?

We also find that it is dominantly industries with high engineer density that report on replacing existing products as major objective. *Craft-based* industries are less apt to report extend product range.

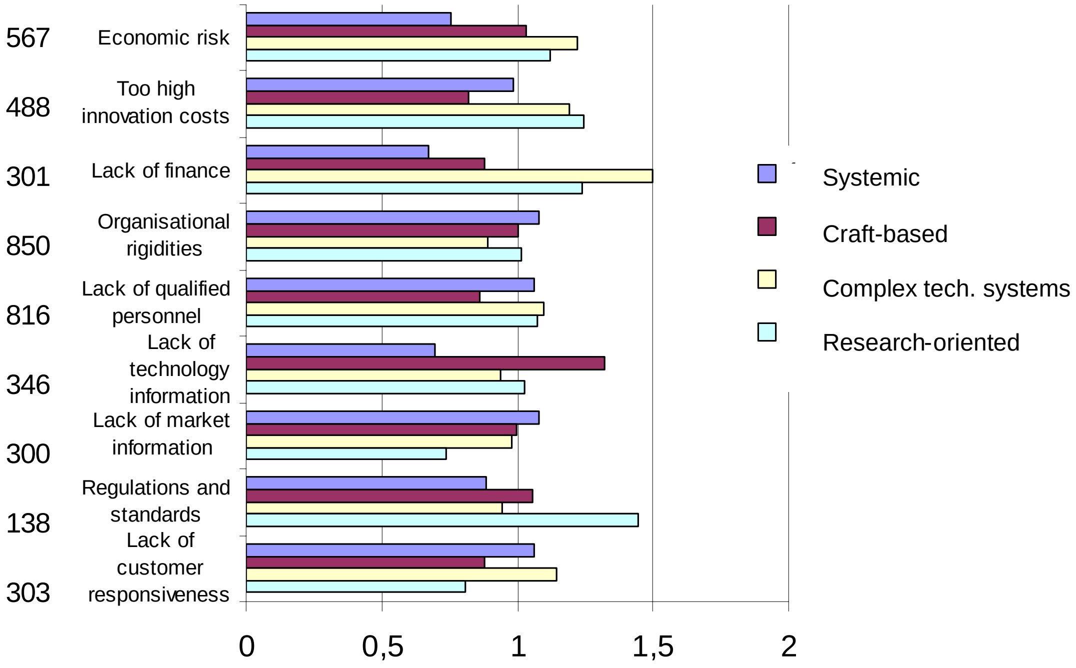
We also see an interesting difference with respect to energy- and materials saving innovation. Industries with low engineer density have a much higher probability to focus on reducing use of energy and materials.

Industries with often innovation collaboration also slightly more often report opening up new markets as an objective to innovation than those that has less often innovation collaboration.

Innovation barriers

The following figure shows an indexed overview of how different industry groups respond with respect to innovation barriers.

Figure 11: Index of how different industry groups report different barriers to innovation as important. N=1500 (weighted). Coloum to the left shows the relative importance of each barrier; e.g. how many respondents that confirmed this barrier as important.



The most important barriers in Norway are Organisational rigidities and Lack of qualified personnel. For our four company groups there are no large differences between them. Interestingly, *Complex technological systems* industries report slightly less often that organisational rigidites are important barrier to innovation. *Craft-based* industries, with little innovation collaboration and low engineer density, report slightly less than other groups that lack of qualified personnel represent an important barrier to innovation.

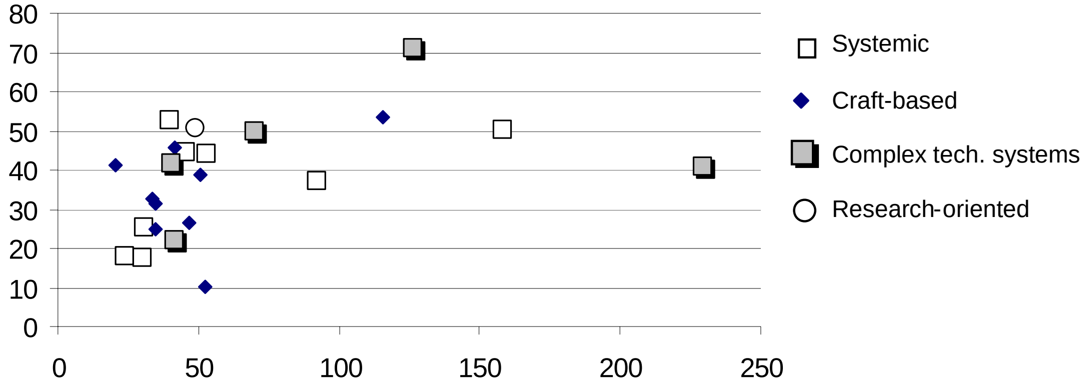
We find the largest differences in Lack of finance. We see that industry-groups reckognised by high engineer density (and therefor high R&D intensity) more often report lack of finance as a relevant barrier to innovation. The same difference applies to similar factors like Economic risk and Too high innovation costs, but not so strong.

Craft-based industries more often report Lack of technological information as a barrier to innovation. However, there is no relation between engineer density and probability of reporting Lack of technological information as a barrier. *Systemic* industries report this barrier least often; in fact, we see that industry-groups reckognised by more frequent innovation cooperation report (*Systemic* and *Complex technology systems*) less often Lack of technological information as a barrier. *Research-oriented* industries report Regulations and standards as a barrier to inovation. However, for the latter barrier, we have few responses.

Company size and innovativity

What role does company size play for innovation? And what kind of company sizes marks our four industry groups? The following figure provides an overview of both innovativity and average company size. The x-axis shows average company size, while the y-axis shows share of innovative companies (of all companies, regardless of innovation activity). Industries belonging to different company groups are plotted with different markers.

Figure 12: Average company size (x-axis) and share of innovative companies in industry (y-axis), by company group.



The figure shows several interesting things. Firstly, it shows that *Craft-based*-industries are in average recognised by small companies and with a dominantly low innovation rate. Almost all industries have in average less than 50 employees, and about 45 or less percent innovative companies. The only exception is pulp and paper, with the highest innovation rate in its group (55 percent) and with high average company employment (120 employees).

For *systemic* companies, we find that there are indications of a relation between size and innovativity. Industries in this group range from low innovation rate and few employees per company (Trade, Mining) to many employees per company and higher innovation rates (Metals).

Thirdly, *complex technology systems* companies are in general more innovative than the two other large groups. In particular, Chemicals comes out as the most innovative industry. At the same time, the Recycling, el and water industry comes out as quite small and less innovative, with about 22 percent innovative companies and less than 50 employees. All other industries in this group have 40 percent or higher innovation rate. Oil companies distinguish themselves by having in average 230 employees per company. A second result from this figure is that average company size varies quite much between different industries in this group. Recalling that one of the determinants for this industry was engineer density, the figure above confirms that small companies is not a reason in itself for the high engineering density.

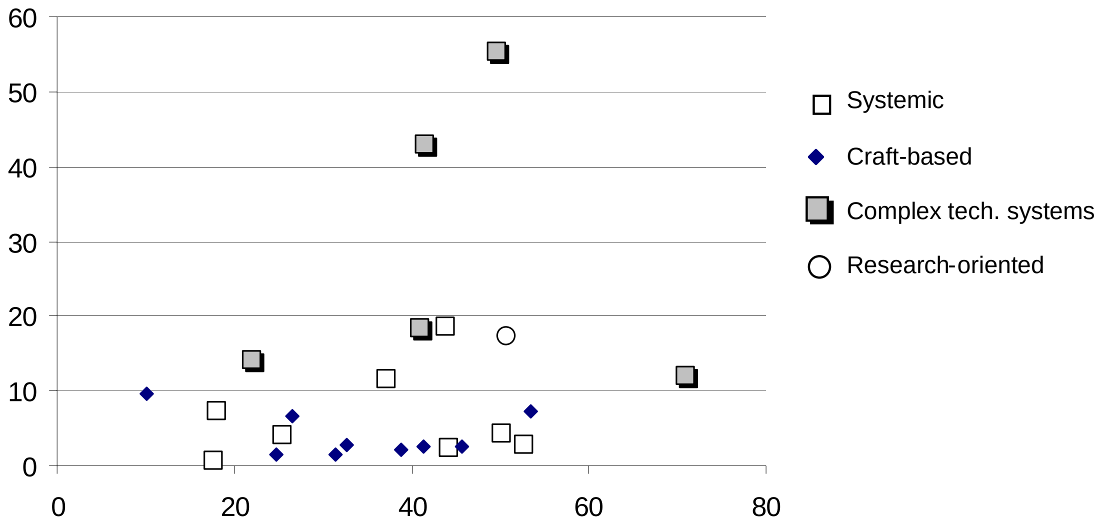
The *research-oriented* machinery industry comes out slightly higher than average on both axes, with about 50 employees per company and innovation rate on about 53 percent. This industry fits well into a more general point that this figures illustrates: A slight, but not overwhelmingly, log relation between industrial average company size and innovativity.

Innovativity and ICT

A central element in industrial innovation processes the last decaeds has been implementation and development of information and communication technologies. It is therefore at paradox that the most extensive questionnaire in Europe on innovation issues does not adress the role of ICT in the innovation processes.

One way to approach the role of ICT is to look at industrial variations in personell with higher ICT education. By looking at share of ICT-skilled employees, we get a pretty good picture of the role of ICT in various industries[28]. The following figure shows share of innovative companies (x-axis) and ICT intensity (y-axis)[29].

Figure 13: Share of innovative companies (x-axis) and ICT intensity 1999 (ICT-skilled per 1.000 employee, y-axis).



There are several interesting results from this figure. Firstly, it shows that there is ho correlation between ICT density and innovativity. In other words, it is quite possible

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[28] The method is described in full in Braadland and Ekeland (2001), *Distribution and diffusion of Norwegian ICT competencies*, STEP report R-06/01, STEP group, Oslo

[29] Note that some of the ICT skilled persons are also engineers, which were used to categorise the industries in the first place.

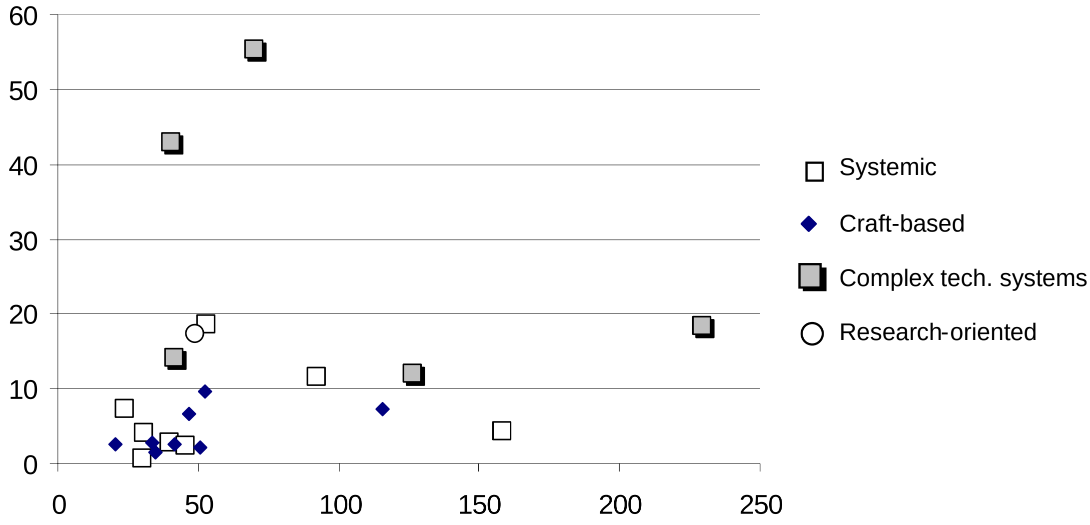
to be innovative without being ICT-orinteted. This applies to industries in all four groups, in particular; Rubber and plastics and Metals *(*both are *Systemic)*, Pulp and paper *(Craft-based)*, Chemicals (*Complex technology systems)*, and Machinery (*Research-oriented).*

Secondly, we find that *Complex technology systems* industries are in the higher end of the ICT intensity scale (regardless of innovativity). All these industries have more than 10 per 1.000 employees with higher education in ICT[30]. Also Machinery, our only R&D oriented industry, has a high intensity. The other two industries with high ICT skills are systemic industries. These are Financial services (43, 18), and Transport equipment (37, 11). The most ICT-intensive *Craft-based* industri is Transport services, including post and telecommunications.

ICT intensity and size

On the one hand, large companies should be better of in recruiting ICT-skilled persons, because they often can pay better or offer better jobs. On the other hand, small, ICT-intensive companies may be better in rapidly exploiting new possibilities in new technology, and attracting people that want to exploit their creativity to the full. On this background, a relevant question is to look for a relation between ICT intensity and size. The following figure shows a plot between average company size (x-axis) and ICT intensity (y-axis).

Figure 14: Average company size (x-axis) and ICT intensity (y-axis).



We find no relation between the two. Interesingly, we find two outliers; i.e. two industries with very high ICT intnsity and relatively low average company size. These are, not unexpectedly, Electrical and optical products (55, 50) and Business services, computing (43, 42). Even when we disregards these two, we get an R squared for linear relation on .2164.

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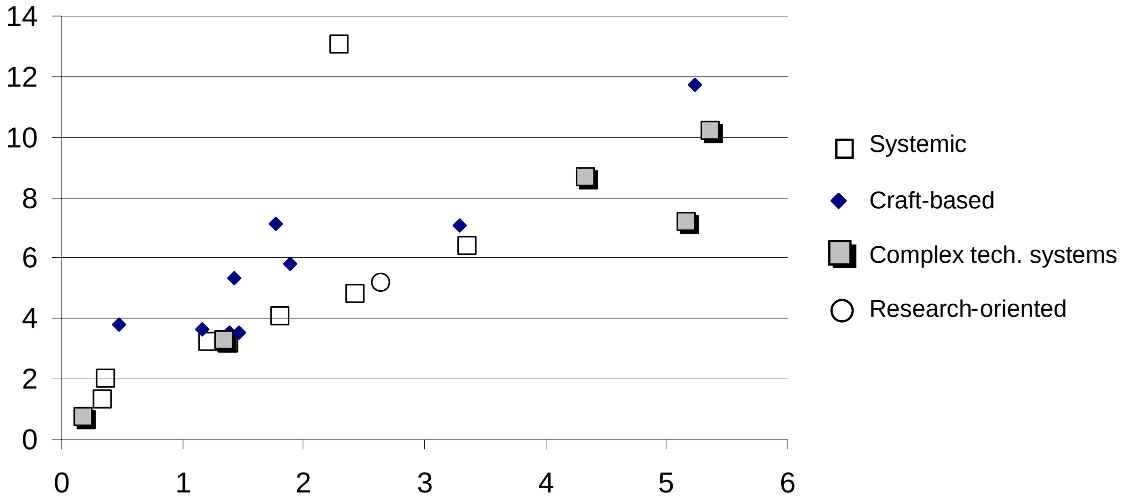
[30] Se Braadland and Ekeland (2001) for list of which educations are included.

Innovation expenditures

Is it possible to find some patterns with regards to innovation expenditures? Does *complex technology system* innovators in general have higher innovation costs than *research-oriented* companies. What about *craft-based* industries vs systemic industries? And how does this affect innovation outcome?

There are several ways to measure this. The following figure shows a plot of average industrial innovation expenditures[31] for all companies in industry (x-axis) and average innovation expenditure among those companies in industry with innovation (y-axis). The plots are distributed among our four groups.

Figure 15: Average industrial innovation expenditures for all companies in industry on, x-axis, average innovation expenditure among those companies in industry with innovation, y-axis.



With the exception of a couple of outliers (Mining and to some degree Chemicals) there is a clear linear relation between the two axes. It seems therefore of minor importance whether we chose the one or the other. In the following, we use average innovation cost among companies with innovation.

The following plot shows average innovation expenditures in industry (among companies with innovation) and share of innovative companies in industry.

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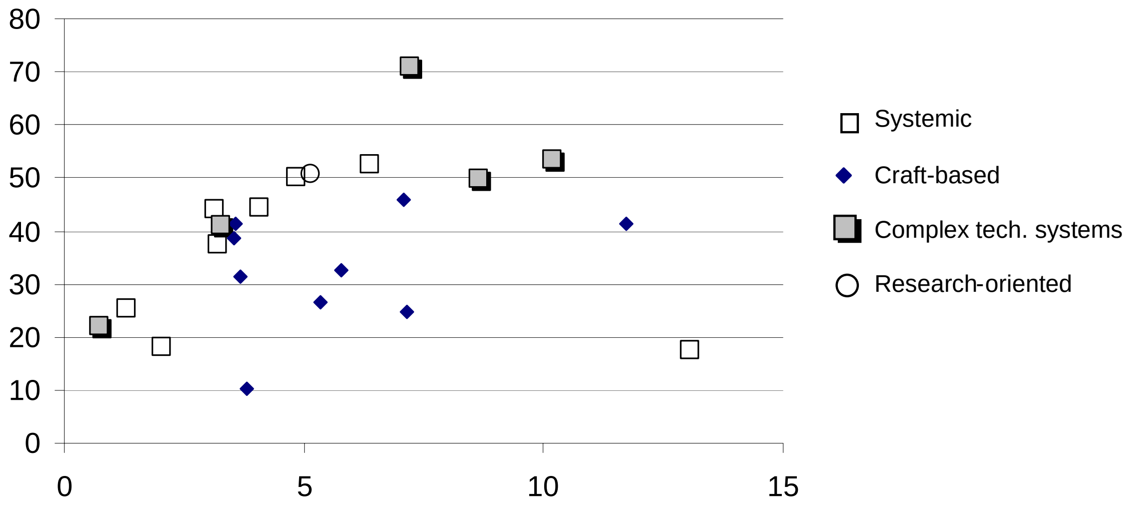
[31] By innovation expenditures we mean innovation expenditures as share of turnover.

Figure 16: Average innovation expenditures in industry (among companies with innovation), x-axis and share of innovative companies in industry, y-axis.



The figure shows a slight linear relation between the two axes. In general, therefore, we may argue there is a slight linear relation between average innovation expenditure intensity and share of innovative companies within an industry.

More interesting is it to find that a major difference within the groups in our taxonomy. First, we find that *craft-based* industries have less often innovation as output from the same share of innovation expenditures than other industry groups. Particularly seem *complex technology system* innovators to have innovation more often than other industry groups, when holding innovation expenditures constant. We also see that *systemic* innovators tend to have in general lower expenditure costs than for example *craft-based* industries, but not particularly lower innovation rates, rather the opposite. In general, therefore, it seems that the two groups of industries with innovation collaboration tend to have innovation more frequent than the two other industries, when innovation costs are constant.

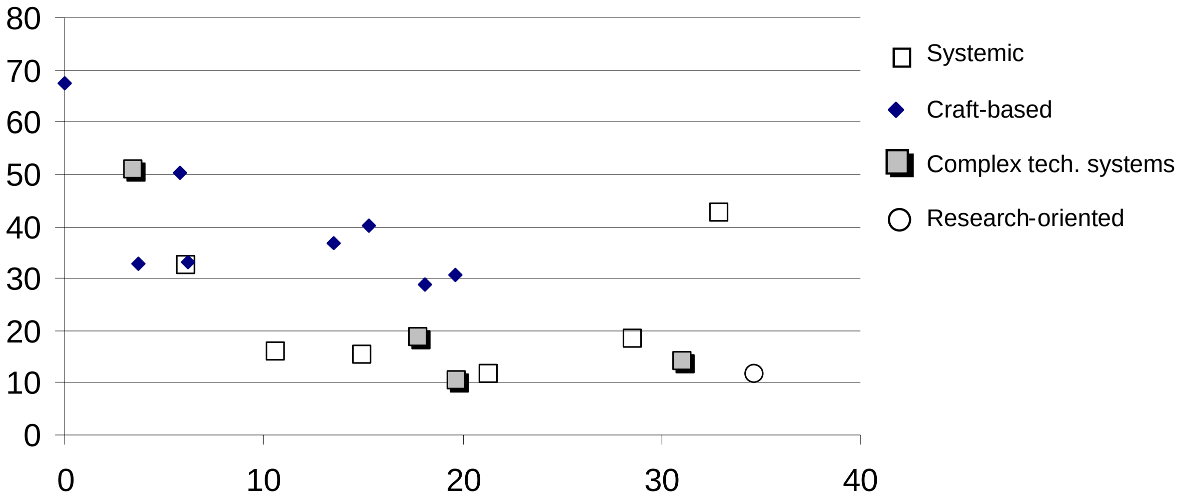
This figure may also be read another way: Industries with low innovation costs but with high innovation rates may indicate higher degree of informal innovation processes than those with high innovation rates and high innovation costs. This from-high-to-low innovation formality axis goes from upper left to upper right in the figure. We see that *systemic* industries are located towards the informal end of the scale, with the exception of one (Mining). Three of the five *Complex technology system* industries are located in the 'formal' part of the figure, with Recycling/water/electricity as the most dominant exception.

Interestingly, we find that our only *research-oriented* industry Machinery is slightly more towards the informal part of the scale, with modest average innovation costs and innovativity beyond average. This is at the same time an industry with relatively high engineer density.

Product vs process

Is it possible to find systematic variations in how different industry classes emphasise product versus process innovation? The following figure shows share of companies in industry with product innovation only (x-axis) and share of companies with process innovations only (y-axis). This figure does not include services, as they are not asked questions on process innovation in the innovation survey.

Figure 17: Share of companies in industry with product innovation only (x-axis) and share of companies with process innovations only (y-axis)



The figure shows a natural reverse correlation between the propensity of having either product innovation only or having process innovation only.

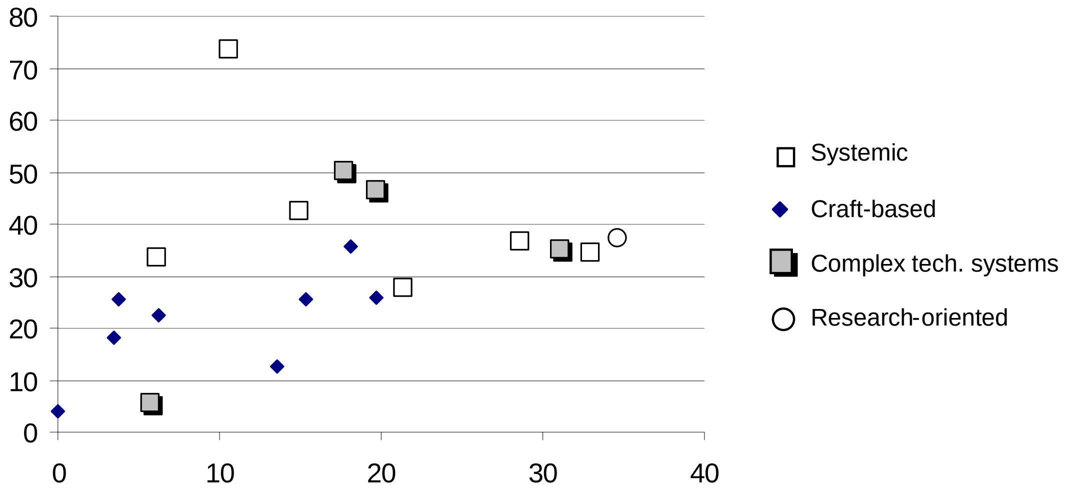
Concerning our industry groups, we find several interesting patterns. Firstly, *systemic* industries tend to be low on the process innovation axis, but quite spread on the product innovation axis. These industries seem in other words to a little degree emphasise process innovations, relative to other industries. Secondly, *Craft-based* industries are in general higher on process innovations than other industries, and they are also lower on product innovation. Further, the one *research-oriented* industry is quite high on product innovation and quite low on process innovation. For *complex technology systems* industries we find no dominant pattern.

New products to market

What do we know about different industry groups and their ability to develop and introduce brand new products? One would perhaps assume that engineering-intensive industries are more innovative, and that these industries would also come up as more frequent new-to-the-market product innovators. At the same time, we have shown that there is no 1:1 relation between engineer density and innovation (Figure 7).

One way to look at this is to look for variation in product innovation focus between industries. The following figure shows share of companies with product innovation only (x-axis) and share of innovative companies with new-to-market product innovations (y-axis).

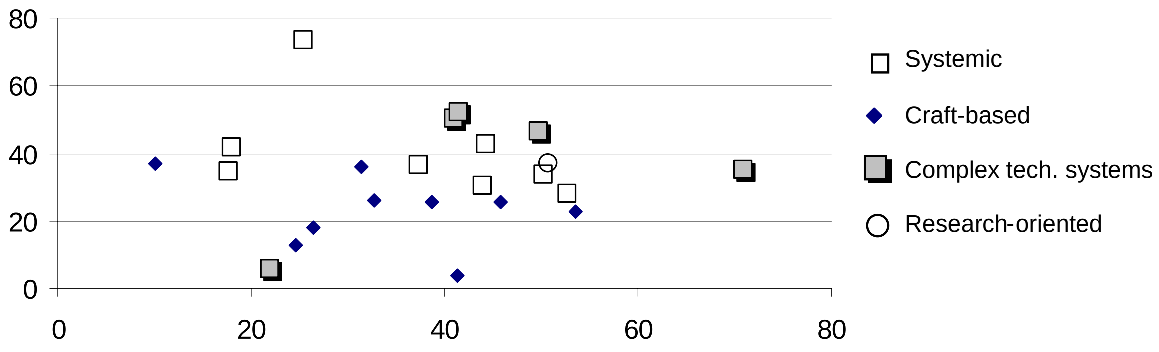
Figure 18: Share of companies with product innovation only *(x-axis) and share of innovative companies with new-to-market product innovations (y-axis)*



The figure shows that *craft-based* industries in general have lower focus on new product innovations than other industries. These industries scores low on both product-orientation axes. For *systemic* industries, we find that the ability to introduce new products is quite high; around 40 percent, and that this average holds even though industries vary with respect to whether they innovate through introducing new products only or not. We also see that the machinery industry has the highest proportion of companies with product innovations only.

Looking at ability to introduce new-to-market products in general, the following figure shows share of innovative companies in industry (x-axis) and share of innovative companies in industry with products new to market (y-axis).

Figure 19: Share of innovative companies in industry (x-axis) and share of innovative companies in industry with products new to market (y-axis).



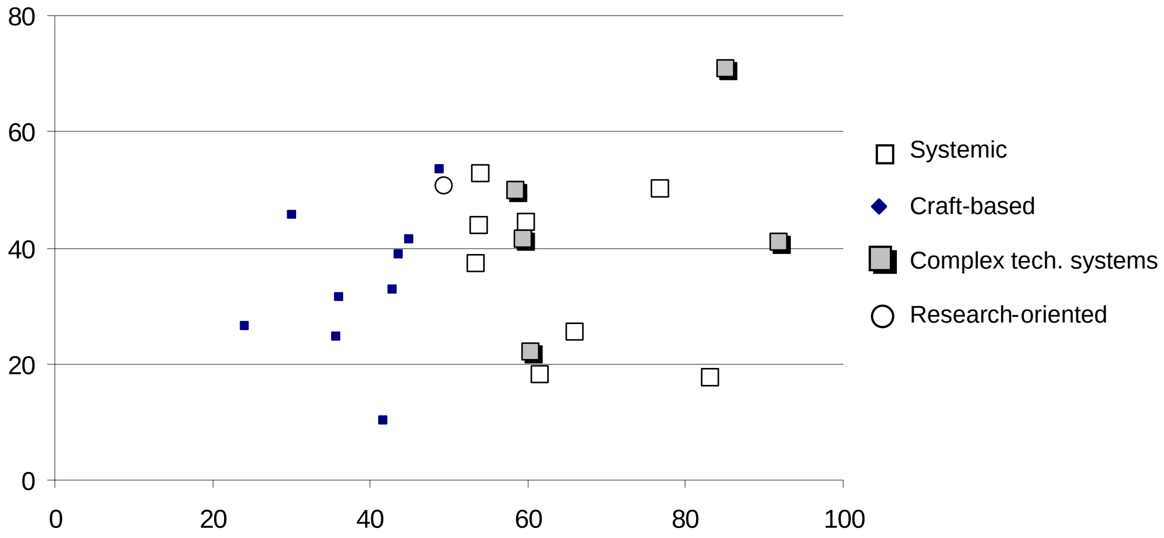
We find no strong indications of a relation between these two variables.

However, as above, we find that both two groups of engineering-intensive industries and *systemic* industries in average introduce new products to the market: For *complex technology system* industries, we find a general high share of innovative industries with new-to-market products, but with transport services as a clear exception. In sum, *craft-based* industries do in general have low share of new-to-market innovations, compared to for example *systemic* industries.

Innovation collaboration and innovativity

It is often claimed that innovation collaboration tends to increase innovativity. The following figure shows a plot of innovation collaboration (x-axis) and innovativity (y-axis).

Figure 20: Innovation collaboration (x-axis) and innovativity (y-axis).



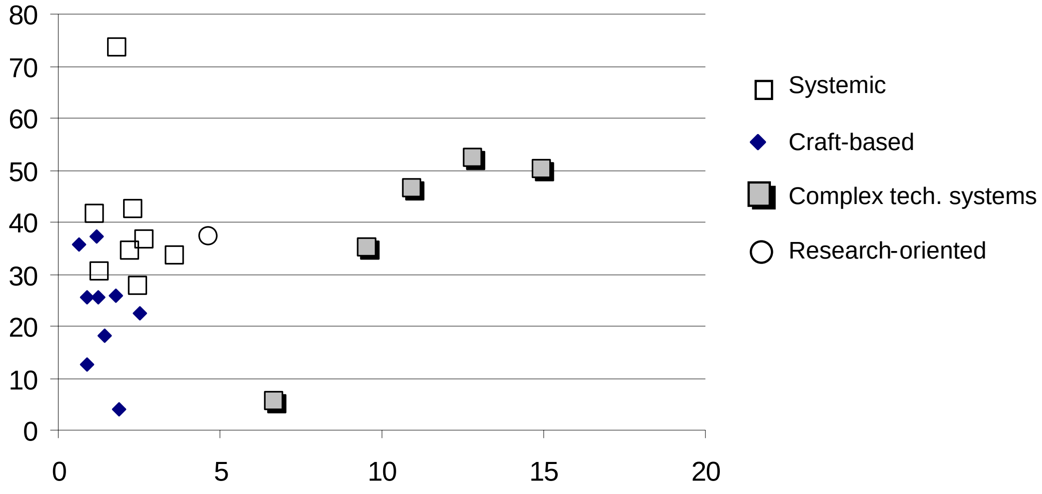
At industry level, we find no significant relation between the two (R squared for linear relation is 0.05). We see that all the three large industry groups are quite spread with regards to the innovativity.

Engineering intensity and new products

Following up our question from the previous section: Is there a relation between engineering-intensity and ability to introduce new products to the market? The answer is no.

The following plot shows how industries of different categories locate themselves with respect to engineering-intensity (x-axis) and share of innovative companies with new-to-market products.

Figure 21: Engineering intensity (x-axis) and share of innovative companies in industry with new-to-market products (y-axis)



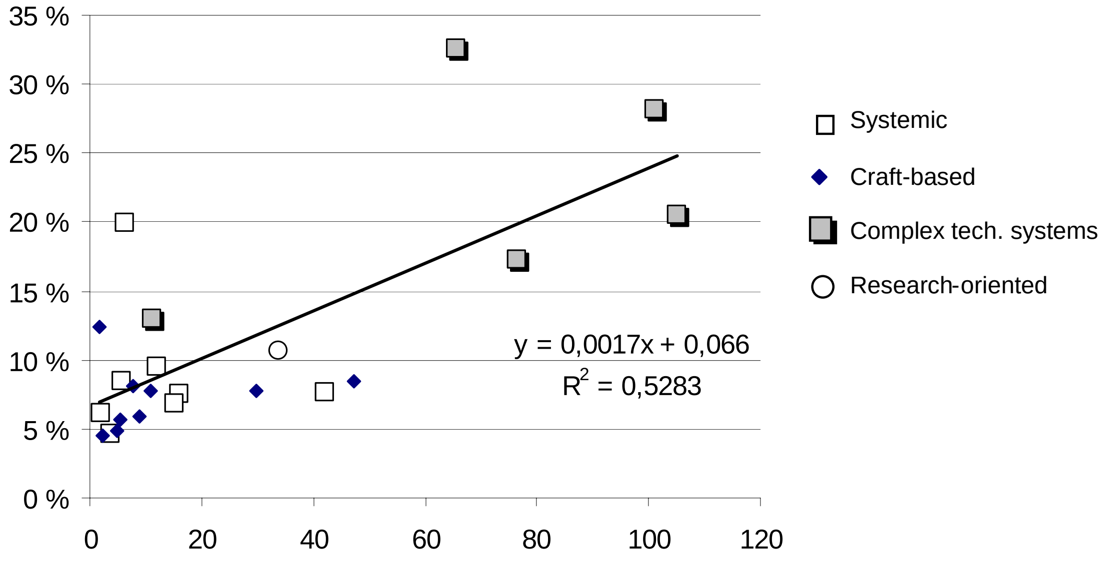
The figure shows that there is no systematic link between the two axes.

Higher education and R&D intensity

We have focused on technological knowledge. But if learning in general is important to novelty and innovation, it would be interesting to investigate the relation between higher education and R&D intensity, or higher education and innovativity.

The following figure present a picture of the relation between R&D intensity (x-axis) and share of employeed with 3 years or more at university level.

Figure 22: R&D intensity (x-axis) and higher educated as share of employment (y-axis).

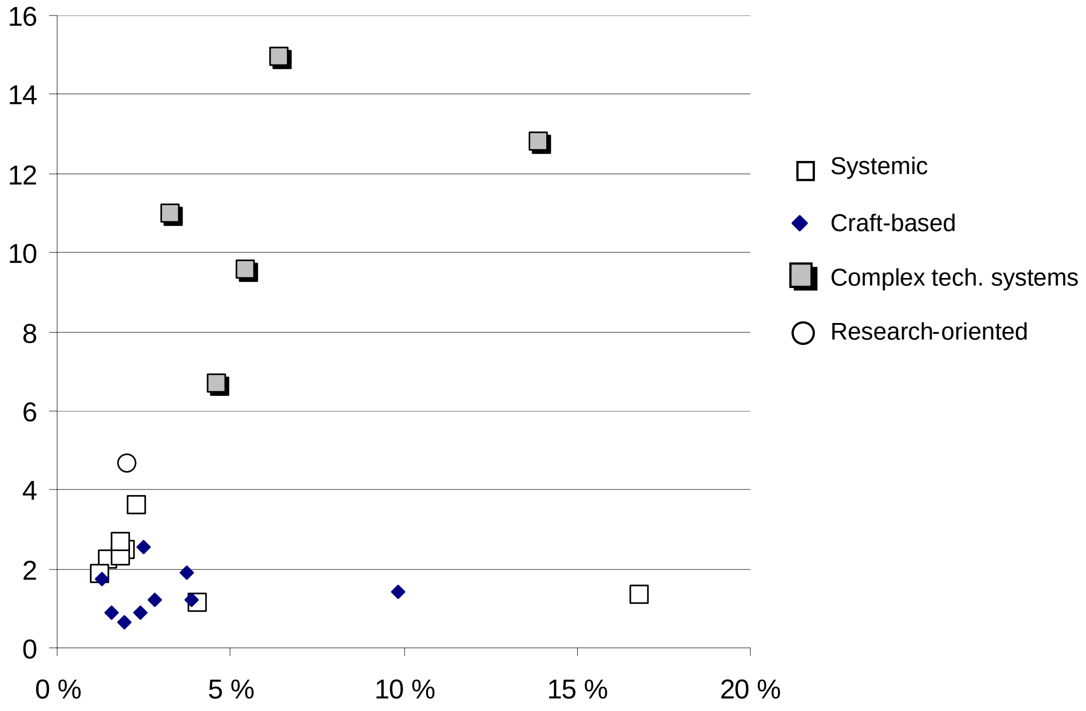


Looking at the general picture, we find that R squared for a linear relation is .5283, an interesting result. This is, however, not as strong relation as we found when looking at the relation betwee engineer density and R&D intensity (R was .78). In the figure, we find that five of the six higher educated-intensive industries are *Complex technological system* industries, like Business services, Oil companies, etc. (The exception is the *System* industry Financial services, with 20 percent of their employees with higher education). Four of the five most skill-intensive industries (again with the exception of Financial services) are also very R&D intensive, and they are all *Complex technology system* industries.

We also find that some industries (Financial services and Business services/Computing) represent outliers, with high degree of higher educated staff compared to R&D intensity. The Machinery industry is slightly below expected levels.

What then about the distribution of higher educated and engineers. The following figure looks at distribution of higher educated (minus engineers) and engineers.

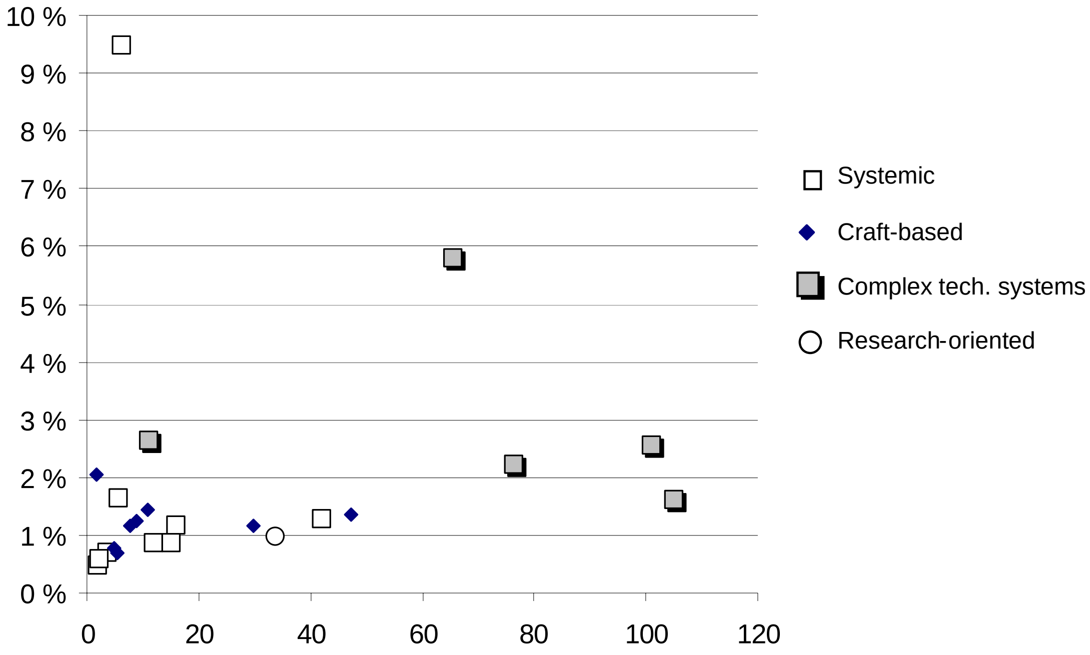
Figure 23: Share of employees with higher education (x-axis), percent, engineers not included, and engineer density (y-axis), per thousand



We find a slight correlation of the two axis, R squared = .1061. The relation is however less than what we found for example between higher educated and R&D. However, three outliers – all with higher share of educated staff than ‘expected’, influence the presentation; Business services, Financial services and Printing and publishing. If we take these three away, we get an R squared on about .5.

It is also to possible to look at other types of skill compositions. The following figure looks at R&D intensity and economist[32] density.

Figure 24: R&D density and economist density.



With the exception of Financial services on 9,5 percent and Business services on six percent, economists represent about 1-2 percent of industrial employment. There is no correlation between these axes, and even if we take away the two outliers we only get an R squared on .2658. The economist intensity is slightly higher in *Complex technology system* industries, but this may have to do with the fact that the intensity of higher educated staff in general is higher in these industries (see Figure 22).

We have earlier shown that there is a log relation between engieer density and innovation cooperation. Will we find the same when looking at higher education in general? The following figure provides us with an overview of higher educated employees and innovation collaboration.

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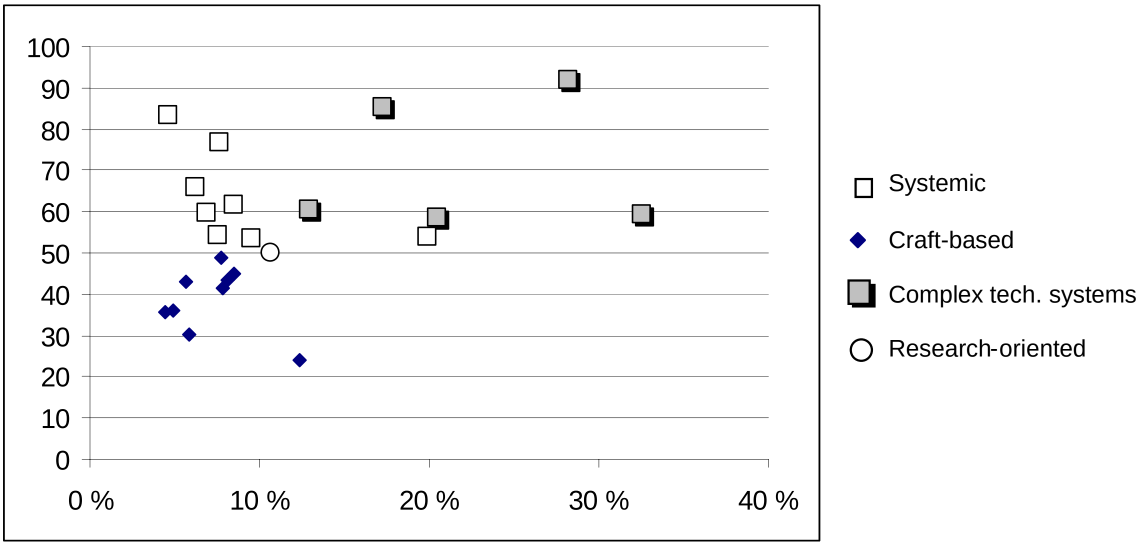
[32] Education class 641

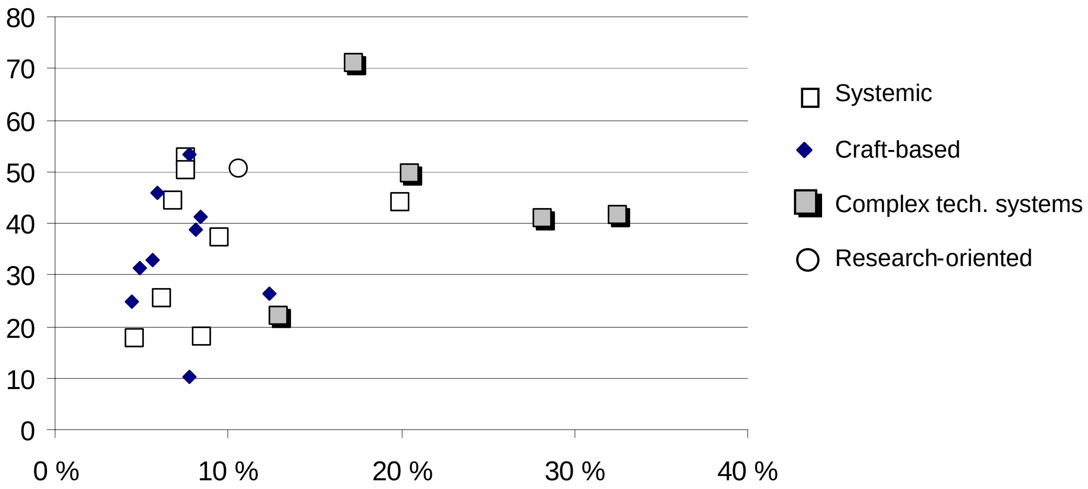
Figure 25: Higher educated as share of employees (x-axis) and share of companies with innovation collaboration (y-axis).



There log correlation between the two variables on .1312, in other words very weak. The figure tells us however, that – as with engineer density - there are no industries with high share of educated people and low share of innovation collaboration. However, within the collection of industries with less then 10 percent higher educated, innovation collaboration varies from 30 percent (Furniture, other man.) to 85 percent (Mining).

We also want to invcestigate the relation between higher education and innovation. The following figure shows a plot of Higher educated as share of employees (x-axis) and share of companies with innovation (y-axis).

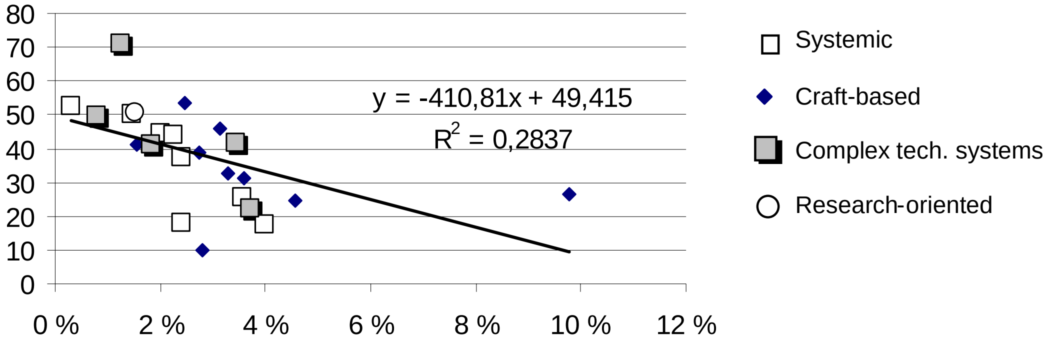
Figure 26: Higher educated as share of employees (x-axis) and share of companies with innovation (y-axis).



There is a very weak linear relation between the two axes, with a linear relation on only .0894. There are two outliers in the plot, both belonging to the *Complex* *technology system* industries: Oil production and Business services/Computing, with somewhat little innovation compared to education level; Chemical industry has for example an innovation rate on 70, with about 17 percent higher educated staff. If we take away the two outlieres, there is still a weak relation with R squared on .1618.

What then about relation between staff skilled in social sciences and innovation? In the following, we have looked at the share of staff with higher education (college/university 2-level, three years or more) in history, sociology, psychology and political science on the one hand, and share of innovative companies in industry on the other.

Figure 27: Share of educated in social science (x-axis) and share of innovative companies (y-axis)



We actually find that there is a negative correlation between propensity to hire social science staff and to innovate, on industry-level. This is quite an interesting result. Apart from the enterpretations that social science skilled staff are less innovative, we think that one reason may be that the effect is spurious; that social science staff more often goes to services, which come out as less innovative in such surveys. Another reason may be that we talk of a very low number of persons included; about 3.100.

Higher education and part-time working

It is also possible to use the data to investigate the relation between higher education, part-time and industry group. The following plot shows share of employees working full-time[33] and share of higher educated employees, by industry and industry group.

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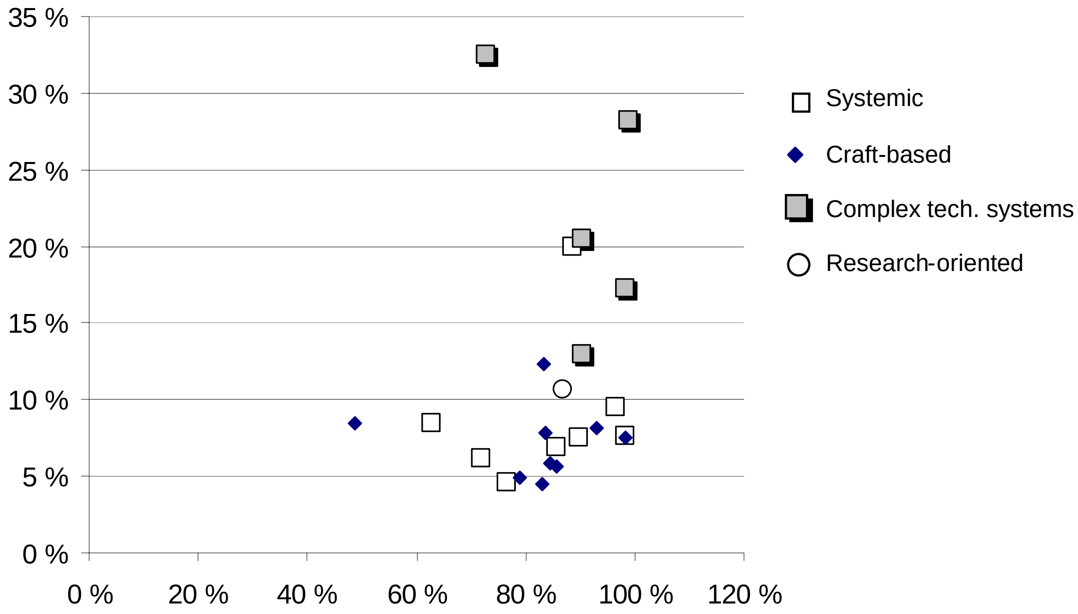
[33] Full-time is defined as those with income above 134.000 NOK in 1999.

Figure 28: Share of employees working full-time and share of higher educated employees.



We find that there is no relation, neither linear nor exponential, between higher education and probability of part-time working. Neither is there any visible difference in how the three large groups locate on the full-time axis, with industries from all groups spreading from 60 to 100 percent. If we should dare to describe any patterns, we could point out that three of the four industries with highest share of part-time are *Systemic*. Business services and computing is an outlier, with high share of higher educated staff and at the same time high share of part-time workers. Fishing and fish farming is the industry with most part-time workers; more than 50 percent of the employees earn less than 134.000 NOK per year. Even with fishing and fish farming and Business services/Computing held aside, we get an R squared for expontential relation on only .2185.

Summing up

We have used engineer density and innovation collaboration to categorize companies into four company groups; *systemic; complex technology systems; craft-based* and *research-oriented*. The *Systemic* industries group is the largest, covering about 50 percent of Norwegian private sector employment. 25 percent work in *complex technology systems* industries, while two percent work in research-oriented industry, according to our classification.

Craft-based industries are in average recognised by small companies and with a dominantly low innovation rate. These industries have less often innovation as output from the same share of innovation expenditures than other industry groups.

For *systemic* companies, we find that there are indications of a relation between size and innovativity. *Complex technology systems* companies are in general more innovative than the two other large groups. These industries have in general innovation more often than other industry groups, when holding innovation expenditures constant.

We found that *systemic* innovators tend to have in general lower expenditure costs than for example *craft-based* industries, but not particularly lower innovation rates, rather the opposite. *Systemic* industries have more often more informal innovation processes, with the exception of one industry (Mining). Our *research-oriented* industry is slightly more towards the informal part of the scale, with modest average innovation costs and innovativity beyond average. Interestingly, this is at the same time an industry with relatively high engineer density.

Systemic industries tend to be low on the process innovation axis, but quite spread on the product innovation axis. These industries seem in other words to a little degree emphasise process innovations, relative to other industries. Secondly, *Craft-based* industries are in general higher on process innovations than other industries, and they are also lower on product innovation. Further, our *research-oriented* industry is quite high on product innovation and quite low on process innovation. For *complex technology systems* industries we find no dominant pattern.

All but *craft-based* industries introduce more often completely new products to the market. For *complex technology system* industries, we find a general high share of innovative industries with new-to-market products, but with transport services as a clear exception.

We also found a general relation between engineer intensity and R&D intensity on industry-level. We have suggested this approach as a good alternative approach to normative R&D conclusions, compared to the often-used argument – but with little direction – that R&D levels need to be increased whatsoever. We claim that a good starting point to increase Norwegian R&D levels could be to find industries with low R&D compared to engineer density.

Policy conclusions

We have presented a taxonomy of industries based on what we regard as essential aspects of the innovation process. Our main reason for doing so was to challenge existing taxonomies, particularly the high-tech / low-tech taxonomy of the OECD. An embedded policy conclusion in the high-tech / low-tech taxonomy has been that some industries are more important than others, and that this variance in importance is rooted in how big share of turnover an industry spends on R&D.

However, we have argues that is not always obvious that increased R&D leads to more innovation. We have shown that there is a slight relation between the two variables on industrial level, but we also find that i) many industries with same innovation expenditures have quite differing outputs, and ii) many with high innovation rates have quite varying innovation expenditures. It is therefore not obvious that tax-arrangements to increase R&D are sufficient means to increase innovation. Firstly, as mentioned, we have shown that R&D intensity is associated with engineer density. This means that increased R&D requires more engineers. This means again that tax-incentives to increase R&D must be followed by a similar investment in education.

R&D levels can be compared between industries and within industries. OECD's division between R&D-intensive (high-tech) industries and low-tech industries is an example of the first. We argue that the second method is better, as it takes into consideration that every industry have a unique needs or degree of appropriability for R&D in their innovation process. With this as a starting point we have suggested to use the linear relation between engineer intensity and R&D intensity on industry-level to find industries with highest potentials for increased R&D. Service-industries like Business services/Computing and Recycling/electricity and water suppliers come out as such industries in our study.

Methodological comments

Our taxonomy is based on what we believe are central aspects to how industries organize their innovation process. Our taxonomy has therefore parallels to Pavitt's taxonomy. Both taxonomies focus on linkages between industries and collective innovation patterns rather than isolated industries. Much of the critique of Pavitt's taxonomy therefore also applies to ours.

What separates our study from Pavitt's mid-eighty study is that Pavitt presents – like for the high-tech / low-tech taxonomy of the OECD - a canonical taxonomy of industries[34], while ours is more flexible. Where Pavitt suggest where different industries by definition belong – according to a British survey – we have used a standardized innovation survey (CIS) linked to data for engineer density on industry level, making it easy for other countries to copy the method and find how their industries vary from the Norwegian configuration. Surely, other countries would find that their industries would locate differently along innovation cooperation and engineer density axis.

Our study has used industries, and not companies, as unit. This has several drawbacks. This means we ignore the often large differences between companies within the same industries: Some companies we found to belong to the *systemic* group may be research-oriented according to innovativity and engineer density *in this company*[35]. Using company as unit would perhaps have provided other results. We have not had the time to check this.

This is related to a second point: Another critique towards this study is that some industries differ rather little in terms of innovation collaboration and/or engineer density, but still come in different industry groups. For example, the Machinery industry was just above average on both axes, and therefore classified as a *research-oriented* industry. With only a few hundred less engineers, the industry would have been classified as belonging to the *craft-based* group.

This point is again related to a third critique: We used arithmetic average in distinguishing our industries (either above average or average or below). If we had used median average, we would have gotten a slightly different result. This is shown in the figure below. The median lowers the treshold to both enter engineer intensive

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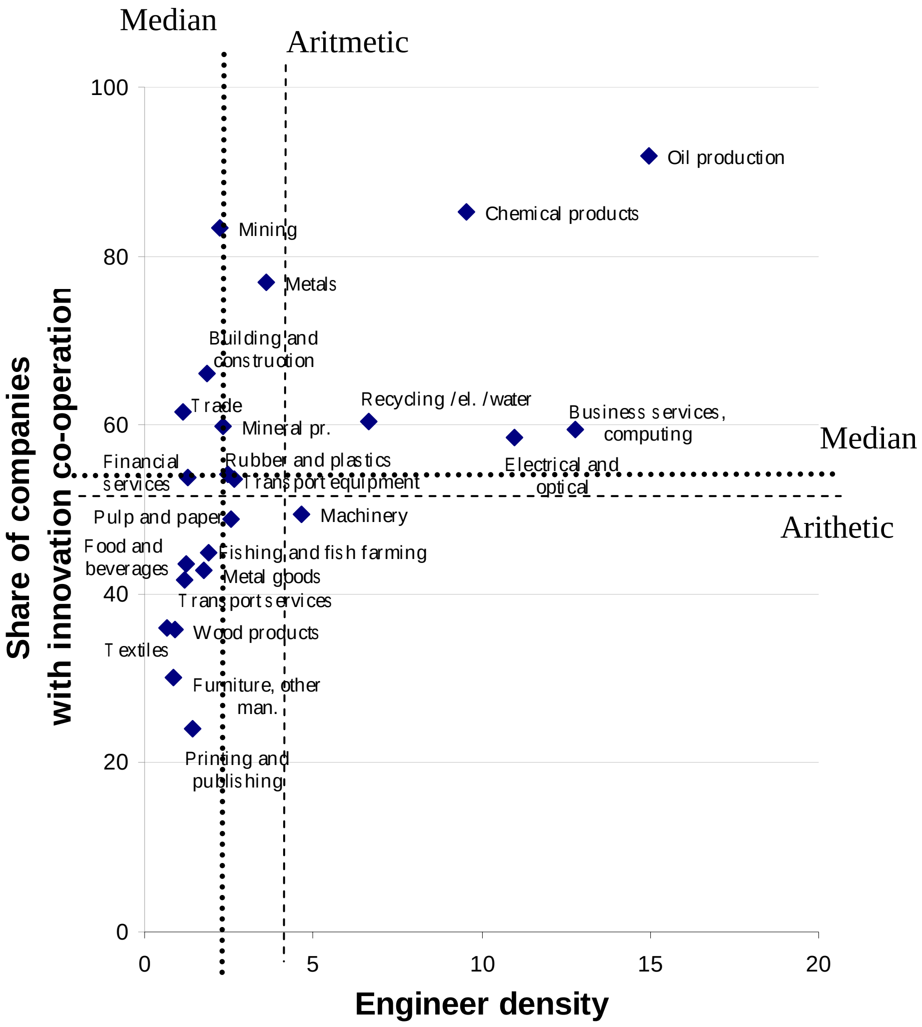
[34] D. Archibugi (2001), op. cit.

[35] D. Archibugi (2001), op. cit.

groups and groups with often innovation cooperation. We see for example that Metals enter the *Complex technology systems* group, while Mining and Mineral products are very close to average. Pulp and paper enters the research-oriented classification together with transport equipment (ship yards). Rubber and plastics is very close to median on both axes.

Figure 29: Company classification using median instead of aritmetic average



Another critique is that we have not looked at how industries change over time with respect to how they locate in our matrix. We could have used the CIS 1993 survey results to look this up, combined with employment register data for the same year. However, the survey had a rather small sample, and we regard it as more relevant to perform such a study on data from the forthcoming CIS 2001.

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Appendix

Hi-tech industries:

- Aerospace
- Computers and office machinery
- Radio, TV and communications equipmen
- Pharmaceuticals
- Electrical machinery
- Scientific instruments

Medium-technology industries:

- Motor vehicles
- Chemicals

Low-tech industries:

- Food, Beverages & Tobacco
- Textiles, Apparel & Leather
- Wood Products & Furniture
- Paper, Paper Products & Printing
- Petroleum Refineries & Products
- Chemicals excl. Pharmaceutical
- Rubber & Plastic Products
- Non-Metallic Mineral Products
- Iron & Steel
- Non-Ferrous Metals
- Metal Products
- Shipbuilding & Repairing
- Other Transport Equipment
- Other Manufacturing, nec

Table 2: Overview of industry classes

NACE 2	Industry	Name	Share inno-cooperation	Engineer density	Group	All innovative, weighted	Total R&D/empl.
10, 12-14	2	Mining	83,29	2,24	Syst	12,25	3,59
25	10	Rubber and plastics	54,11	2,45	Syst	75,84	15,98
26	11	Mineral products	59,87	2,32	Syst	63,36	15,09
27	12	Metals	76,91	3,60	Syst	36,13	42,09
34-35	16	Transport equipment	53,56	2,67	Syst	127,89	12,03
45	19	Building and c.	66,01	1,85	Syst	20,91	1,93
50-55	20	Trade	61,59	1,14	Syst	378,37	5,77
65-67	22	Financial services	53,86	1,28	Syst	126,76	6,39
500	1	Fishing, f. farming	44,95	1,89	Cb	35,12	47,15
15-16	4	Food and beverages	43,55	1,23	Cb	311,12	7,74
17-19	5	Textiles	36,01	0,67	Cb	58,67	4,94
20	6	Wood products	35,76	0,90	Cb	82,77	2,43
21	7	Pulp and paper	48,94	2,55	Cb	32,08	29,76
22	8	Printing and publ.	24,06	1,42	Cb	142,70	1,73
28	13	Metal goods	42,90	1,76	Cb	151,51	5,49
36-37	17	Furniture, other man.	30,06	0,88	Cb	135,92	8,94
60-64	21	Transport services	41,63	1,21	Cb	130,64	10,93
11	3	Oil production	91,84	14,96	CtS	22,52	101,20
23-24	9	Chemical products	85,18	9,54	CtS	55,31	76,55
30-33	15	Electrical and optical	58,46	10,96	CtS	118,34	105,23
40-41	18	Recycl., water, power	60,38	6,67	CtS	56,02	11,23
70-74	23	Bus. services, comp.	59,46	12,80	CtS	319,76	65,59
29	14	Machinery	49,46	4,65	R-o	184,92	33,80

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STEP-gruppen ble etablert i 1991 for å forsyne beslutningstakere med forskning knyttet til alle sider ved innovasjon og teknologisk endring, med særlig vekt på forholdet mellom innovasjon, økonomisk vekst og de samfunnsmessige omgivelser. Basis for gruppens arbeid er erkjennelsen av at utviklingen innen vitenskap og teknologi er fundamental for økonomisk vekst. Det gjenstår likevel mange uløste problemer omkring hvordan prosessen med vitenskapelig og teknologisk endring forløper, og hvordan denne prosessen får samfunnsmessige og økonomiske konsekvenser. Forståelse av denne prosessen er av stor betydning for utformingen og iverksettelsen av forsknings-, teknologi- og innovasjonspolitikken. Forskningen i STEP-gruppen er derfor sentrert omkring historiske, økonomiske, sosiologiske og organisatoriske spørsmål som er relevante for de brede feltene innovasjonspolitikk og økonomisk vekst.

The STEP-group was established in 1991 to support policy-makers with research on all aspects of innovation and technological change, with particular emphasis on the relationships between innovation, economic growth and the social context. The basis of the group's work is the recognition that science, technology and innovation are fundamental to economic growth; yet there remain many unresolved problems about how the processes of scientific and technological change actually occur, and about how they have social and economic impacts. Resolving such problems is central to the formation and implementation of science, technology and innovation policy. The research of the STEP group centres on historical, economic, social and organisational issues relevant for broad fields of innovation policy and economic growth.