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**Johan Hauknes**

# Norwegian Input-Output Clusters and Innovation Patterns

**Johan Hauknes**
**STEP**
**Storgaten 1**
**N-0155 Oslo**
**Norway**

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STEP group
Studies in technology, innovation and economic policy
Studier i teknologi, innovasjon og økonomisk politikk

Storgaten 1, N-0155 Oslo, Norway
Telephone +47 2247 7310
Fax: +47 2242 9533
Web: http://www.sol.no/step/

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# Preface

This work is part of the Norwegian contribution to the focus group on clusters in innovation policy under the OECD/CSTP project on National Innovation Systems. Comments and coercions of the editors of this volume, as well as comments on a preliminary version of this paper by participants at the focus group work shop in May 1998, is gratefully acknowledged. Support from Norges Forskningsråd is similarly acknowledged.

# Abstract

Current understanding of innovation and technical change emphasises the importance of the systemic dimensions to innovation performance. Being a basis for the innovation system approach for analysing innovation activities, this emphasises the need for understanding economic and technological interaction beyond the level of firm to firm relations. Aggregate structural characteristics of user-producer links in the Norwegian economy are analysed in this paper through the use of input-output tables. The resulting clusters are described. The main question addressed in this paper is of the existence of cluster-wide innovation patterns; can we discern cluster specific modes of technical change and innovation at the cluster level, and if so, what are their main dimensions? We conclude that there is indeed cluster-specific signatures, or modes, of technical change, reflecting underlying innovation and technical specificities of industries and the complementary interaction between these that is highlighted by the cluster approach.

*Keywords: Clusters; Innovation systems; Technical change; Innovation*

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# Norwegian input-output clusters and innovation patterns

## 1. Introduction

Modern approaches to innovation and technical change place increasing emphasis on the systemic analysis of innovation processes and the determinants of innovation performance. Questions about the relationship between firm growth and evolution, industry development and differentiation and its structural macro-economic effects are at the core of modern innovation analysis and theorising. Resource-based theorising of the firm, finding many of its core ideas and assumptions in Edith Penrose's seminal work, Penrose [1959] (1995), is central to learning based approaches to innovation systems: learning processes are seen as instrumental for the ability of the firm to shape its own development and environment so as to foster firm growth and industrial development.

This suggests that clustering of firms and industries are (increasingly) important aspects of firm and industrial development. With learning and capability formation as a main basis for innovation performance, and innovation as the main driver of industrial development and structural change, a resource-based approach must be fundamental to the understanding of innovation processes. The importance of local learning environments, or innovation systems, suggests that a natural unit of analysis in aggregate approaches to industrial development may not be the single industry or product market; these learning processes bridge industrial divisions and product groups. Learning is structured through an extended network, any analysis of industrial development must of necessity consider inter-industrial and inter-organisational interaction.

Mapping such relations, which entails mapping the topology of the innovation system (cf. f.i. Hauknes (1998a)), yields an appreciation of the connectivity and separability of systems of innovation. The innovation clusters that emerge from such an analysis form a natural focus unit for studies of innovation dynamics, just as they comprise the essentially behavioural related variables for such an analysis. Evidently a mapping like this would have to include diverse sets of interrelations between firms and their environment to cover essential modes for the development of capabilities and innovative performance. It follows from this that such a mapping would quickly bring us beyond relations mediated through market relations.

Lundvall's learning-based approach to innovation systems stresses the important role of user-producer relations, and more generally, the relations that are constituted in or through the market place (see for instance Lundvall (1992) and Edquist (1997)). At the firm level, it should be evident that for most firms, their relations to customers, competitors and suppliers are the most significant links to their environment, to the extent that these agents constitute the major dimensions of this environment. It is not unlikely that these immediate relations shape the major learning modes for a majority of firms. This supposition finds strong support in the many innovation surveys based on the OECD Oslo manual of innovation indicators OECD (1997), where one very consistent result is the importance stated by the respondents of customers and suppliers as sources of information for innovation.

In this paper we will focus economic transactions at a sector level to identify bounded cluster structures in the Norwegian economy. Though an approximation, these structures will form part of a more general mapping exercise. From the importance of customer and supplier relations as channels for acquiring informational inputs to innovation processes, it is also a reasonable assumption that these commercially based relations will form a significant part of a more completely mapped innovation landscape.

Hence, we suggest that we may approach a general mapping by identifying dominant characteristics of such innovation systems or clusters, starting from the centrality of user-producer links. With transaction data we internalise user-producer links by distinguishing clusters of strongly interacting industries or firms. With the argument outlined above, the internal structure of these clusters describes dominant channels of learning. In addition the composition of clusters may be interpreted as a signature of overall degree of functional diversity of learning by user-producer interactions. Internalising user-producer linkages we may look for residual modes or fingerprints of innovation at cluster level. To the extent that specific characteristics of use of innovation inputs and composition of innovation performance survive at cluster level, they are indicators of specific innovation patterns at cluster level, with rather obvious implications for policy formulation. In this paper we will consider the sectoral use of three supplementary input factors to innovation; R&D, outsourcing of knowledge intensive business services (KIBS) such as management consultancy, various IT services, technical design and engineering services, and use of professional personnel as proxied by personnel with tertiary education.

On this basis we will first discuss how clusters may be identified in economic transaction data. The second part of the paper will briefly outline relevant aspects of the six clusters we have identified. Lastly we will distinguish innovation patterns of these clusters by the use of such supplementary data.

## 2. Identification of clusters

### 2.1. The data

National accounts data give a structural decomposition of the Norwegian economy at sectoral level that is useful for such structural mappings. Input-output tables, an integrated part of the national system of national accounts, are the only data that describe economy-wide structural relations. In this exercise we use Norwegian input-output data for 1993.

The input-output data used is a modified sector-sector table, based on make and use tables at the most disaggregated level available. Norwegian national accounts, based on ESA 1995, has nearly 150 industrial production sectors, convertible to NACE classification, distributed over five institutional sectors, cf. appendix 1. At the most disaggregated sectoral level, this gives a resolution into 179 industrial-institutional sectors altogether. For the sake of this analysis, we have aggregated into 161 industrial sectors, with 18 ‘public’ SNA production sectors and 143 ‘private’ production sectors. The resulting input-output table of the Norwegian economy describes flows of intermediate manufactured and service goods between these sectors.

The resulting input-output table has nearly 21 000 sector-sector links[1], with 151 of the 161 sectors having intermediate deliveries to other sectors[2]. Sectors that do not participate in intermediation networks are all sectors with no or negligible output. Given this denseness of linkages, even just a one-step identification of interacting sectors would link almost all sectors, producing one giant, economy-wide cluster. Obviously there is no true way of identifying clusters. Any algorithm must be developed to balance several factors, the resulting clusters in an ideal sense being structurally stable. We will identify clusters by mapping paths described by sector-sector intermediate flows, looking for weakly interacting substructures of the complete input-output matrix[3]. Thus the essence of the approach is to look for block-diagonal structures in the input-output table (see Leontieff (1986)), where blocks of interdependent sectors form input-output clusters with inter-cluster trade flows being small compared to intra-cluster flows.

The analysis of innovation patterns is supplemented with two further data sources. R&D based variables are taken from the 1995 national survey of R&D in the business sector, performed by Statistics Norway in 1996. This survey includes questions on innovative performance of firm units[4], asking firms at unit level about the introduction of new or significantly improved processes or products over the period 1993-1995, as well as on the unit's participation in technological co-operation in the survey year. There are thus two main reasons for using 1995 data, rather than 1993 data

1 Of the resulting 161 sectors, 3 had no economic activity in 1993. With 158 sectors the maximal possible number of links is nearly 25 000. According to table 1 below the number of actual links covers 85% of this set of potential links; the actual sectoral network almost completely exhausts the potential set of links.

2 In constructing subsequent tables, figures and clusters we have subtracted intra-sector intermediate deliveries. In line with the approximation discussed below, of treating the sectors as (technologically) homogenous, we interpret intra-sector deliveries as expressing the effects of a functional differentiation within a homogenous technical production activity.

3 The data describe domestic flows, a full analysis of 'technological' links would involve a sectoral decomposition of the sources of import flows, as well as a two-way sectoral decomposition of the flows of investments. Similarly, with the 'innovation cluster' emphasis of this approach, a sectoral decomposition of exports would be necessary for a full analysis of such 'technological' links. With our data we are implicitly making an assumption that the domestic intermediate flows are representative of the full technological flows. As an assumption for the foreign trade dimensions, in line with the often-made assumption of input-output analysis about sectoral 'import market shares', see e.g., Miller and Blair (1985), is clearly less reasonable for smaller economies than for large ones, see Archibughi and Pianta (1992).

4 The survey unit in the Norwegian R&D surveys is a 'firm' or 'industry' unit, defined as all plants within one single enterprise that are classified in the same industry category at a detailed level.

corresponding to the vintage of input-output data. In contrast to the 1993 survey, the 1995 survey sample was a statistical sample allowing data scaling and cross-sectoral comparisons. Secondly only the 1995 survey included the questions of innovation performance. A further data set prepared by Statistics Norway on the basis of administrative registers links all employees in Norway with their main employers for the period 1986-1996. Here we use these data for information on sectoral shares of higher educated personnel in 1993.

## 2.2. Cluster definition

A variational principle of defining clusters has no well-defined optimum, apart from the trivial ones. However, we may suspect that most of the inter-sectorial links are weak in the sense that:

- links may involve sectors with negligible economic activity,
- the flow along a single emitting link from a given sector is small compared to the other emitters from the same sector, or
- a receiving link is weak in the same sense from the perspective of the receiving sector.

*Table 1* *Input-output networks*

| | *Links* | *Sectors* | *Delivering sectors* | *Receiving sectors* |
|---|---|---|---|---|
| *Off-diagonal flows* | 20985 | 156 | 151 | 156 |

| *Cut-off schemes* | *Cut-off 1* | *Cut-off 2* | *Links* | *Sectors* | *Delivering sectors* | *Receiving sectors* |
|---|---|---|---|---|---|---|
| *Prime links* | *0%* | - | 151 | 151 | 151 | 54 |
| | *15%* | - | 107 | 119 | 107 | 45 |
| *All links* | *15%* | - | 163 | 125 | 107 | 60 |
| | *10%* | - | 249 | 137 | 127 | 73 |
| | | *1 ‰* | 185 | 108 | 92 | 65 |

For the Norwegian 1993 input-output table this conjecture is indeed confirmed, cf. table 1 for the case of forward linkages. The table describes some reduced input-output networks and compares them to the full network, given in the first row. As suggested by the conjecture, the table describes the reduction in terms of two cut-offs. The first cut-off restricts *link strength* between sectors, restricting attention to links carrying flows above a certain fraction of total intermediate deliveries from each sector. The second cut-off restricts the network to *significant sectors*, sectors representing at least a minimum fraction of total intermediate deliveries.

The table identifies variant cut-off schemes to illustrate both the reduction effect of cut-offs and the sensitivity of network structure on variations in the suggested cluster-identifying algorithm. The first scheme identifies the maximal forward linkage from any sector, measured in value-terms, irrespective of both the relative link strength and sector weight in the total inter-sectoral flows. By definition this scheme identifies 151 sectors as delivering sectors, and hence 151 links. Restricting to maximal links that represent at least 15% of intermediate deliveries from any sector reduces the number of sectors to 119, with 107 as delivering sectors, and hence 107 links. Retaining this cut-off of link strength while including all links adds just a few new sectors, while considerably expanding the number of links. A further reduction of the cut-off to 10% increases the number of links by another 50%. Thus most links are indeed weak, and with a fairly strong dependence of the density of resulting links on the cut-off. With this cut-off going down, clusters tend to merge. To exclude merging through inclusion of negligible sectors as bridges, the effect of the second cut-off is illustrated in the last row. A combined cut-off on link strengths of 10% and sector size of 0,5 - 1‰ produces a network of comparable sectoral coverage to the two 15% schemes, but with a richer network structure[5]. Interpreting significant links as major channels for interactive learning thus requires a consideration of both types of cut-offs.

This suggests a process of identification of clusters in a reduced input-output network, the full input-output table is reduced by neglecting weak links and small sectors. Identification of structural input-output clusters is suggested as a variational principle on reduced networks. We attempt to decompose the input-output matrix of transaction

5 The second cut-off is, opposite to the link strength cut-off, inversely related to the resolution of the sectoral classification. As the resolution power of the classification goes up, i.e. as the classification gets more detailed, sectors are increasingly likely to be smaller than a given cut-off on sector size. In the same limit the specialisation of intermediate outputs would increase, more links would be stronger than a given cut-off on link strength. Similarly, as sectoral resolution gets low, specificities in sectoral trade flows are ’washed out’, while sectors grow larger. In this sense the link strength cut-off is a low-end cut-off, while the sector size cut-off may be considered a high-end cut-off.

flows to minimize inter-cluster flows, with clusters that are robust towards variations in the cut-offs. Robust clusters remain unchanged in their main structural features over ranges of cut-off parameter values. In addition we require that the resulting clusters should make economic sense, calling for a qualitative assessment of the sectoral content of the clusters and the inter-sectorial relations. Hence, we should not expect to be able to make a complete decomposition but allow for residual sectors without any clear cluster formation.

Attempts to identify input-output clusters face the problem of overlap between clusters and inhomogeneities within sectors. Overlap, inter-cluster trade flows, is minimized by the cluster identifying schemes. Inhomogeneities of sectors are closely related to the detail of sectoral classification.[6] The degree of homogeneity of any classification is broadly measured by the number of sectors and the size distribution of sectors within the chosen classification scheme. A high aggregation of any sectoral area may lead to the possible misidentification of clusters that would be resolved into separate parts ‘belonging’ to other clusters in a more disaggregated analysis. This calls, at any level, for a judicious assessment of the cluster structures that emerge from a given classification scheme.

[6] Among the largest sectors measured in intermediate trade flows, we expect to find sectors that serve as important nodes in clusters. But among large sectors we expect higher probability of finding heterogeneous sectors, especially if the industrial classification is coarse. Most prominently of such sectors is wholesale trade, which is partaking in nearly 12% of total intermediate trade flows, either as a delivering or receiving sector, it links up with a large cross-section of the economy. Following Roelandt et al, we could identify trade as part of an economy-wide service cluster. Significant inter-sectoral trading between the underlying components of the aggregate wholesale trade is required to support this interpretation. If this is not the case, we must conclude that the genericity of wholesale trade is an artefact of the statistical classification; it is an agglomeration of separated sub-sectors, each interacting with bounded sets of clusters. The data we have does not allow us to resolve this question. However, observation of the actual organisation of wholesale trade sectors suggests that the position of trade sectors in these networks is an artefact of the industrial classification. Hence we will not include trade sectors as part of any cluster here.

# 3. Clusters in the Norwegian economy

## 3.1. Decomposing the Norwegian economy

On the basis of the Norwegian 1993 input-output data we have identified five reasonably well-defined clusters in the Norwegian economy, as well as a network of information intensive activities. The clusters are:

- *agrofood* industries,
- a cluster representing the main supply-network and refining activities related to *oil and gas extraction*,
- a cluster of activities related to *construction*,
- a *paper and graphical* cluster,
- and an inter-related set of *transport* activities.

The sectoral content of the six cluster networks is described in appendix 2. Including four trade sectors, we have been unable to relate the remaining 55 sectors with any specific cluster, mainly due to their small size. A few large sectors remain outside the identified clusters and networks, the main part is accounted for by public administration, education and health and social services, representing two thirds of sectoral product outside the clusters and networks.

*Table 2 A 'clustural' decomposition of the Norwegian economy*

| | *No of sectors* | *Share of GDP* | *Labour costs* | *Consumption* | *Exports* |
|---|---|---|---|---|---|
| *Six clusters* | 104 | 62,3% | 46,1% | 43,9% | 76,8% |
| *Public and social services* | 15 | 19,2% | 32,0% | 38,7% | 0,4% |
| *Trade* | 4 | 10,1% | 12,5% | 10,1% | 6,4% |
| *Other, exc. trade* | 35 | 8,4% | 9,4% | 7,4% | 16,4% |
| *Total* | 158 | 100,0% | 100,0% | 100,0% | 100,0% |

These six networks accounted for 62% of GDP in 1993, with more than 50% residing in the five clusters, cf. tables 2 and 3. The share of labour costs is substantially lower, reflecting the dominance of various labour intensive public services in the residual outside the clusters. The 104 sectors account for nearly 45% of domestic consumption, while their share of exports is more than 75%. Through these six clusters we have covered a major share of the Norwegian economy along several economic dimensions.

The clusters vary from highly capital-intensive to relatively labour-intensive. The oil and gas cluster is the most capital-intensive of the clusters, accounting for nearly 1/4 of the national capital stock. Table 3 gives the average capital-labour ratios of the clusters, relative to the national average. The agrofood and construction clusters are medium to high labour intensive, while the transport cluster on the higher end of capital intensity. The oil and gas cluster has a capital-labour ratio nearly six times larger than the national total, while the capital-labour ratio of the paper and graphics cluster and the information network is just about half the all-economy average, also lower than the capital-labour ratio of public and social services.

*Table 3* *Clusters in the Norwegian economy*

| | *GDP** | *Employment* | *Capital stock** | *Relative capital-labour ratio* |
|---|---|---|---|---|
| *Agrofood* | 8,9% | 11,0% | 9,6% | 0,870 |
| *Oil and gas* | 17,7% | 4,2% | 23,4% | 5,609 |
| *Construction* | 7,7% | 7,9% | 5,7% | 0,719 |
| *Transport* | 9,2% | 7,9% | 11,5% | 1,456 |
| *Paper and graphics* | 2,9% | 2,9% | 1,6% | 0,569 |
| *Information intensive* | 11,8% | 8,8% | 4,5% | 0,516 |
| *Sum* | 58,2% | 42,6% | 56,3% | 1,321 |

* Relative to national capital stock exc. household owned dwellings.

Following identification of clusters, the full input-output table may be decomposed, an aggregated table describing intermediate flows at cluster level[7] and a series of cluster maps outlining the trade flows within the individual cluster networks. While the latter are considered as maps of internalised user-producer links in the next section, table 4 outlines some structures of the resultant input-output table at cluster level. The four penultimate columns distinguish resp. intermediate trade flows within each cluster network, between or into clusters, into public administration and social services and into industrial sectors that are not linked to clusters, as shares of total intermediate deliveries from the resp. category. The last column gives the share of total intermediate deliveries in total production for each category.

*Table 4 Production structure in the Norwegian economy*

| | *Intra-cluster*[*] | *Inter-cluster*[*] | *Public and social serv.*[*] | *Extra-cluster*[*] | *Interm. deliv.*[**] |
|---|---|---|---|---|---|
| *Agrofood* | 79,9% | 12,2% | 3,8% | 4,1% | 45,1% |
| *Oil and gas* | 55,1% | 28,4% | 3,6% | 12,9% | 27,5% |
| *Construction* | 50,3% | 20,4% | 17,4% | 11,8% | 33,6% |
| *Transport* | 50,2% | 24,8% | 8,3% | 16,8% | 37,8% |
| *Paper and graphics* | 32,2% | 25,5% | 13,3% | 29,0% | 64,5% |
| *Information intensive* | 27,8% | 32,9% | 13,4% | 25,8% | 51,1% |
| *Six clusters* | 51,3% | 23,5% | 9,9% | 15,3% | 39,0% |
| *Public and social serv.* | -- | 62,7% | 14,4% | 22,9% | 6,3% |
| *Private* | 40,0% | 31,4% | 10,3% | 18,3% | 38,3% |
| *Total* | 38,8% | 32,3% | 10,4% | 18,5% | 33,4% |

[*] As share of intermediate deliveries from category
[**] As share of total production

For the six clusters 39% of total production is allotted to domestic intermediate use. The high export share of some clusters indicate that the ‘real’ technological intermediation rate of these clusters is higher. The cluster with the largest share of intermediate demand is paper and graphics, nearly 2/3 of its output is fed into domestic intermediate inputs. Trade with clusters account for 75% of intermediate trade flows from the clusters, most of which is within each cluster. About 10% of intermediate deliveries from clusters are to public and social services, with another 15% to other industrial sectors. For all clusters intermediate deliveries are dominated by intra- and inter-cluster trade flows, with intra-cluster flows greater than inter-cluster trade for all except the network of information intensive activities. The lower intra- and inter-cluster shares of the paper and graphics and information networks is to a large extent explained by trade with wholesale trade. Note that the agrofood cluster appears to be almost completely isolated from the other clusters in this table. The two general ‘networks’ of trade and information intensive activities are more heavily disposed towards inter-cluster trade, a fact which reflects their wider ranging links to many sectors.

We conclude that we have been able to define delimited clusters that cover a major part of the Norwegian economy, with aggregate features that in most measures reflect

[7] Full tables are available on request from the author, at johan.hauknes@step.no

the overall structure of the Norwegian business sector. On the other hand there is considerable inter-cluster variety in several economic characteristics, suggesting that the structure of economic change may vary significantly between clusters, hence supporting the assumption that we should be able to identify cluster-specific modes of innovation.

## 3.2. The individual clusters

### 3.2.1. Economic dimensions and inputs to cluster

This section describes intra-cluster structure and functional content of the individual clusters. Table 5 outlines some relevant economic dimensions of the six cluster networks. The table identifies gross product of each cluster (measured at factor cost) in bill. NOK, total employment and employment of higher educated personnel (in 1000), total capital stock. The three last variables indicate forms of intangible investments in the cluster, R&D expenditures, intermediate use of knowledge intensive business services and frequency of use of public innovation policy initiatives by firms in the cluster.

*Table 5 Economic dimensions and inputs to clusters*

| | *Agrofood* | *Oil and gas* | *Construction* | *Transport* | *Paper and graphics* | *Information intensive* |
|---|---|---|---|---|---|---|
| *Gross product (GNOK)* | 62,0 | 123,7 | 53,6 | 64,0 | 20,2 | 84,7 |
| *Total employment ('000)* | 223,7 | 84,9 | 161,5 | 160,6 | 58,6 | 193,0 |
| *Higher educated personnel (HEP)*[c] | 4,3 | 14,6 | 7,1 | 4,3 | 4,8 | 25,6 |
| *Capital stock (GNOK)* | 171,8 | 420,4 | 101,8 | 206,4 | 29,4 | 82,1 |
| *R&D*[††] *(MNOK)* | 519 | 2 326 | 698 | 251 | 304 | 2 864 |
| *KIBS inputs*[cc] *(MNOK)* | 3 571 | 11 167 | 4 527 | 3 468 | 1 835 | 12 974 |
| *Public assistance*[†] | 22,5% | 29,7% | 25,1% | 17,1% | 19,8% | 16,1% |

[c]Higher educated personnel is defined as personnel with formal education at levels comparable to ISCED 6 or higher.
[cc]KIBS is defined in the table as the sum of intermediate inputs from sectors 720, 730, 74X, 642, 112, P74X, exc. 747, 800, P800.
[†]Share of firms having used public innovation policy initiatives 1993-1995.
[††]R&D expenditures in 1995

The cluster maps in figures C1 – C6 outline the main internal trade flows of the clusters, here interpreted as main channels for interactive user-producer learning. We will use this information and the six cluster maps to describe economic characteristics and internal structure of these clusters, as a way of identifying aspects of processes of economic and technical change. In the next section this will be the basis for an attempt to describe cluster-wide innovation modes.

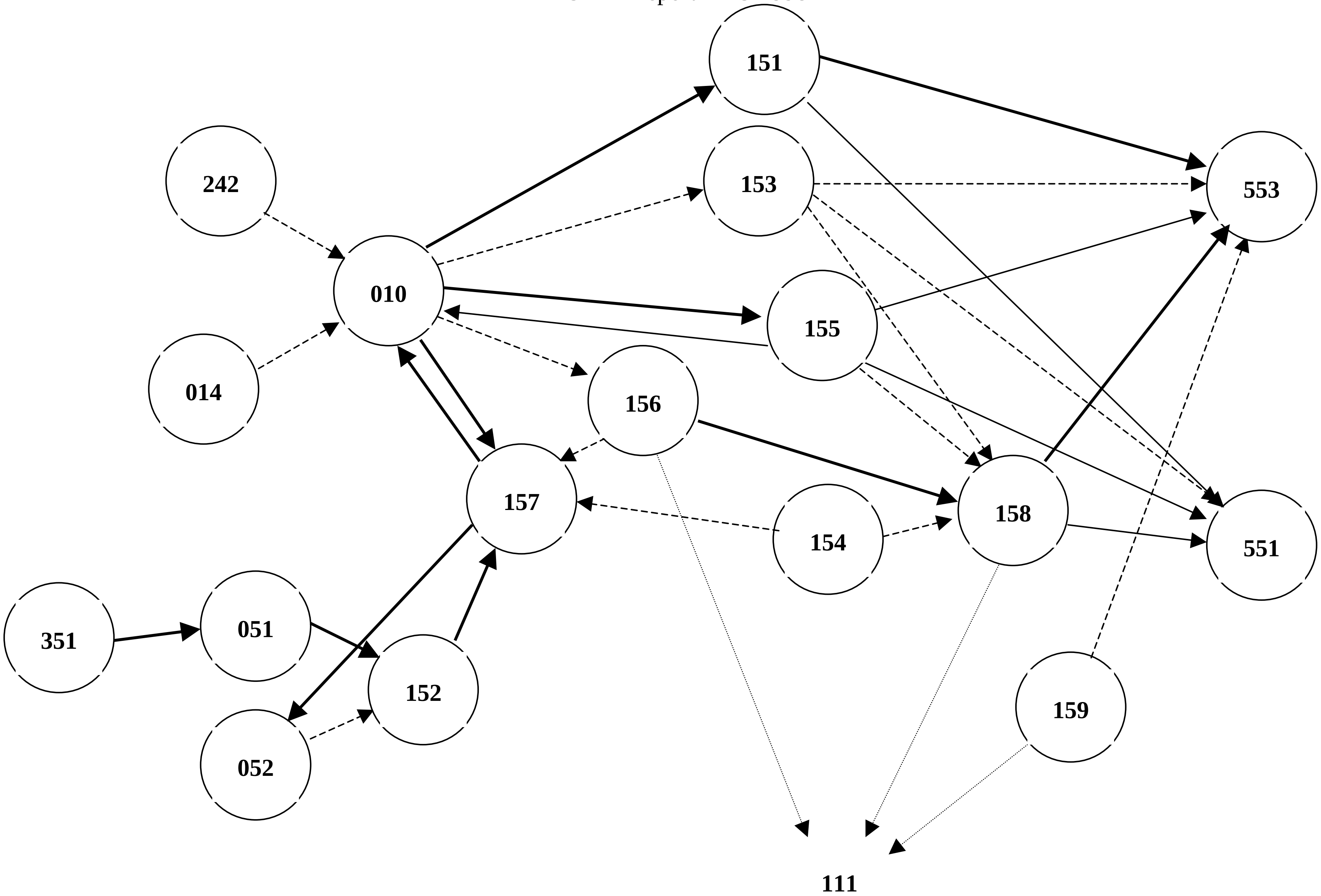


*Figure C1 The agrofood cluster*

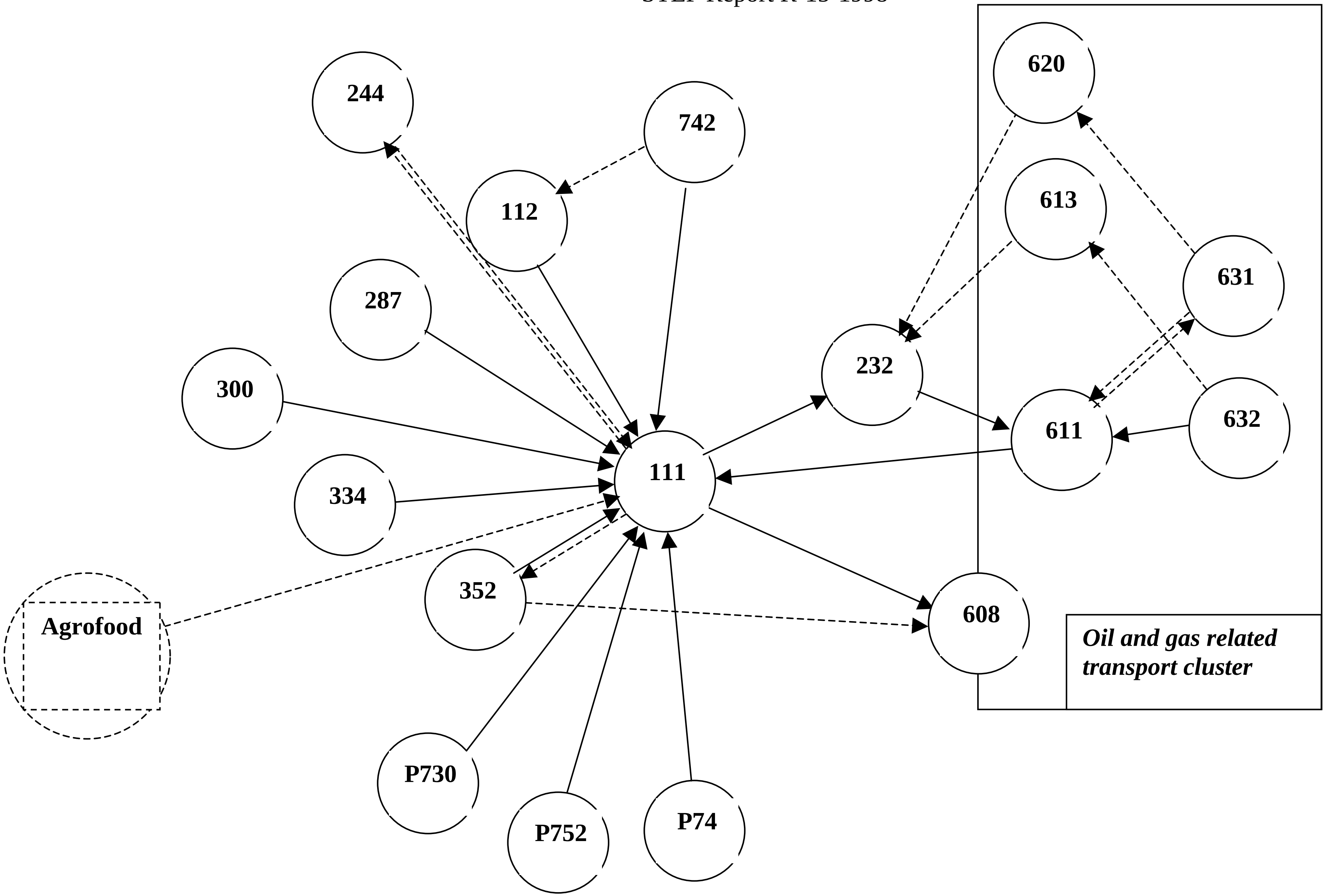


*Figure C2 The oil and gas cluster*

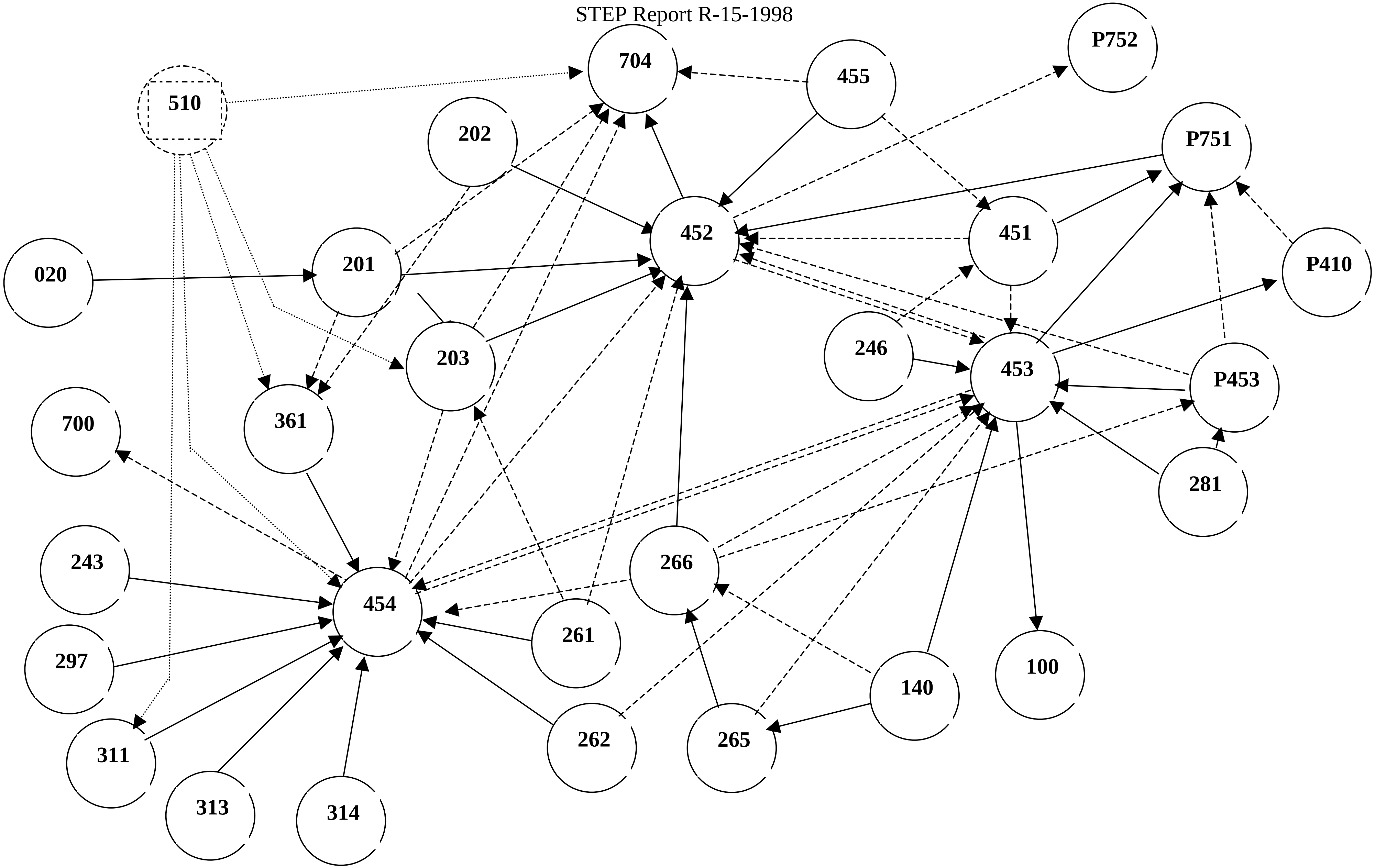


*Figure C3 The construction cluster*

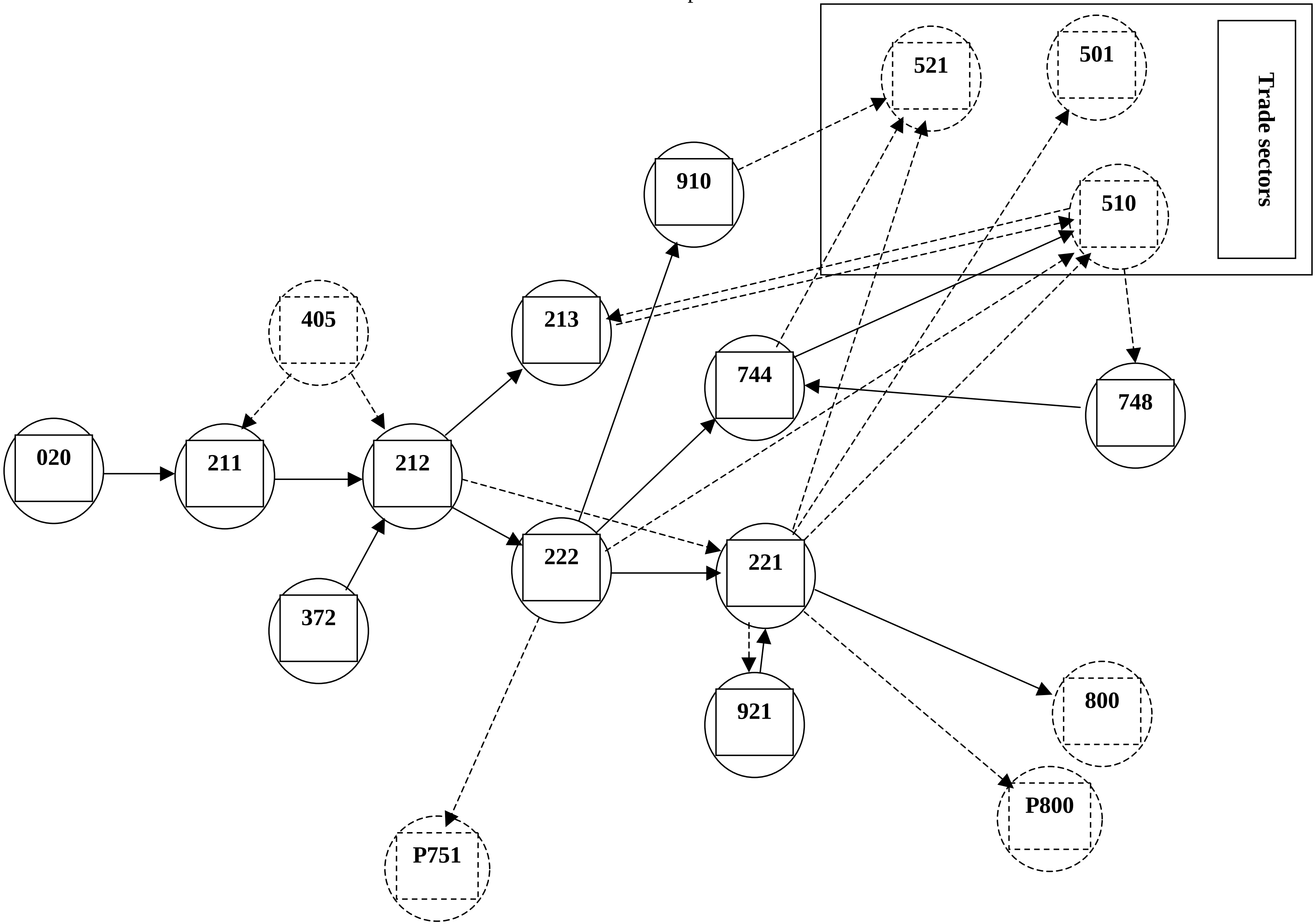


*Figure C4 The paper and graphics cluster*

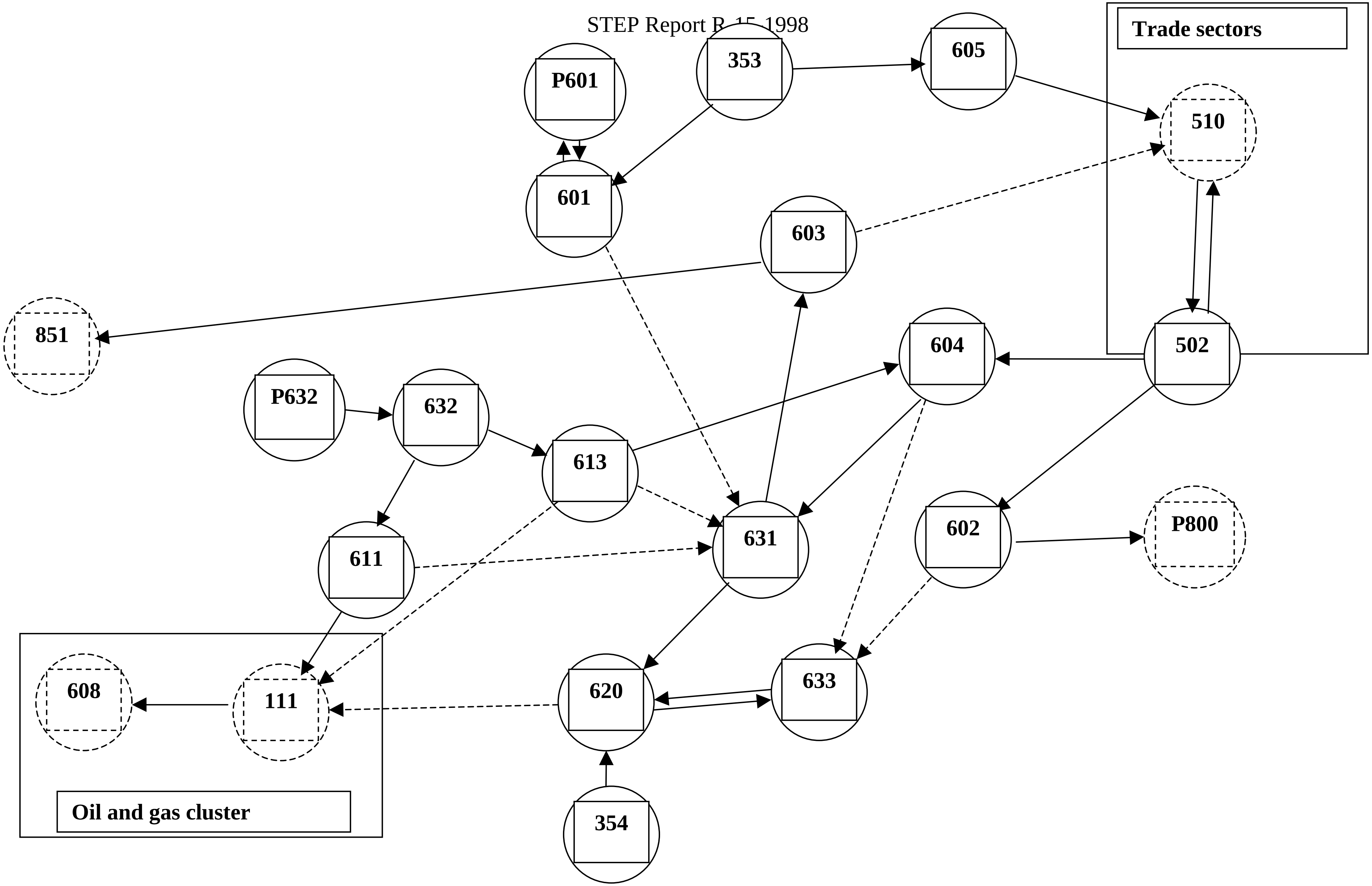


*Figure C5 The transport cluster*

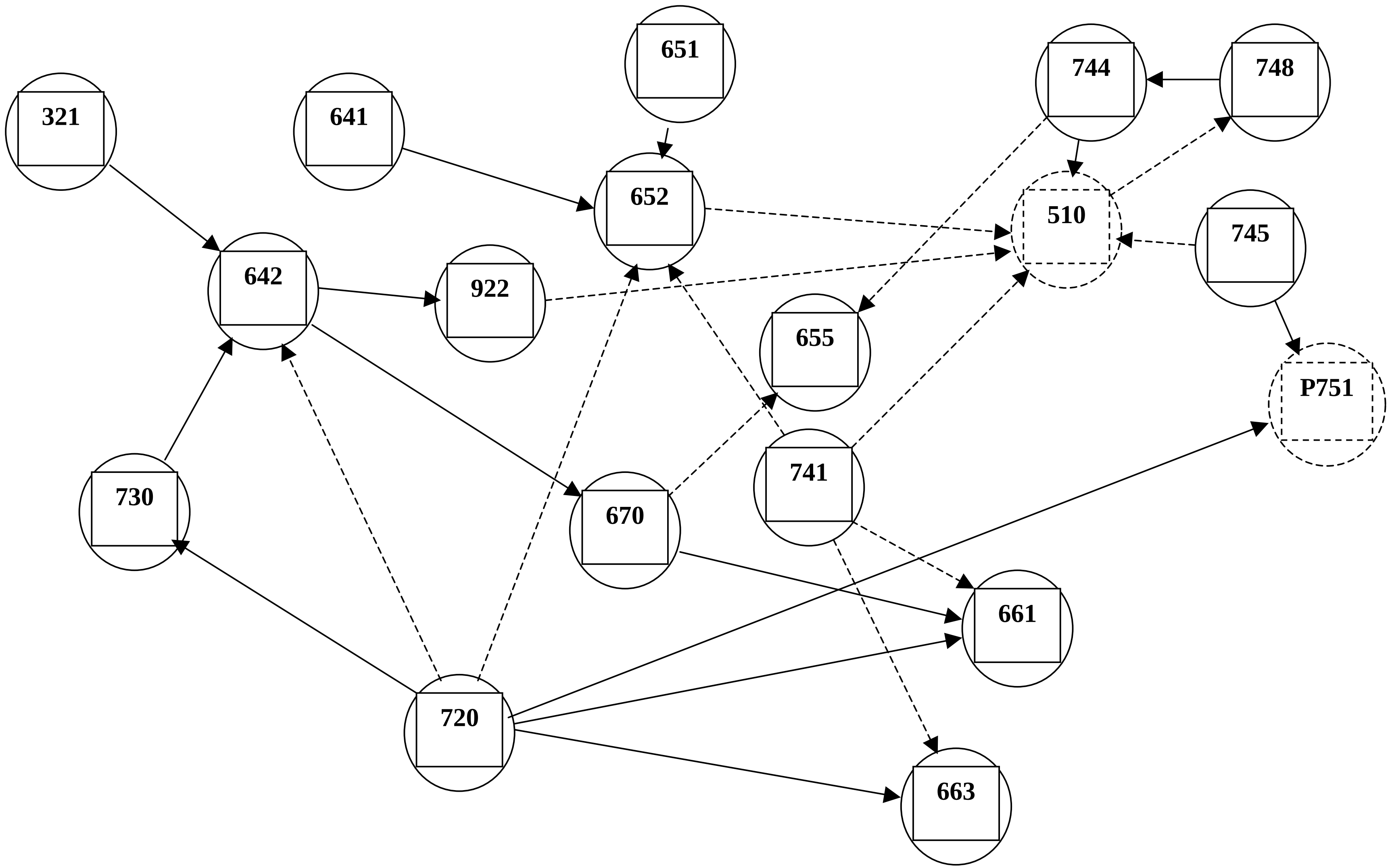


*Figure C6 Information intensive activities*

### 3.2.2. The agrofood cluster

Gross product of the agrofood cluster was 62 bill NOK in 1993. The capital share of gross product is about 0,55, with a capital labour ratio of 750 kNOK, about 100 kECU, per employed person. This capital share is fairly high. About 5% of total business sector R&D expenditures is however on the low end of the scale. 1 in 6 firm units in the agrofood cluster performed R&D in 1995, each unit on average spending about 4,5 MNOK, compared to 1 in 3 being innovators. With less than 3% of employment, the cluster is the least intensive user of HEP of the clusters and networks, reflecting the food industry's traditional high reliance on low- and unskilled labour.

Overall, we may characterise the agrofood cluster as a medium-to-low intensive user of KIBS inputs. However, inputs from public technology infrastructures – intermediate inputs from contract R&D institutes (NACE 73), and educational institutions (NACE 80[8]), the corresponding share of PTI inputs – is about 6%. This may be compared to the share for the total private sector of 4,3%. A reason for this relatively high share of PTI inputs may be the presence of the agriculture sector in the cluster, the agrofood cluster has a substantially higher relative rate of interaction with PTIs.

The agrofood cluster has its main emphasis in the agriculture sector. In addition, we have included production of fertilisers a.o. from the chemical industry, a major input factor to the agricultural sectors. Similarly, fisheries appear as a major user of the output of sector 351 - shipbuilding. The agricultural sector plays a key role in the cluster, generating key inputs into the major parts of the food industry, meat products, dairy products and milled products, as well as the residual sector 158, dominated by baked products. The indicated interaction with oil and gas extraction reflects the catering activity at oil and gas installations in the North Sea.

With inclusion of recipient sector specification of investment data, we would expect some interaction with investment goods producing sectors to show up in such data, reflecting an expected significant role for capital embodied technological change in

[8] The input-output table does not allow us to differentiate between different parts of the education system.

these industries, cf. the relatively high remuneration of capital inputs indicated by the capital share.

Besides it agricultural focus, the cluster is weakly coupled to fishing, fish farming and related manufacturing. The only input to fish farming that survives the various cut-offs is fish feed, which again is fed with manufactured fish products as the basis for feed production. The ‘fishy’ sub-cluster is unrelated to the more general agrofood cluster other than through this indirect route. The dominant mode of trade flows from these sectors is directly to final demand sectors, either through domestic consumption, or through the substantial exports of fish and fish products. This seems to be a basic characteristic of the agrofood cluster; with few exceptions, it consists of industries that might best be characterised as vertically integrated industries fed by the agricultural sector.

### 3.2.3. The oil and gas cluster

The oil and gas cluster is dominated by its prime functionality, the extraction, refinement and distribution of petroleum products. It had a total product in 1993 of 124 bill. NOK, or about 16% of total GDP. The dominating feature of this cluster is its capital intensity. Total employment in the cluster, about 85 000, amounted to just 4% of total employment in Norway in the same year, while the capital share in gross product was more than 75%. The capital labour ratio is by far the largest in the Norwegian. The forward linkages are mainly restricted to its production chain, with few signals of significant multiplier effects. The input structure is more diverse, but its structure and possible backward multiplier effects are closely related to its capital intensity. The wider technology intensity, through KIBS inputs, higher educated personnel and R&D expenditures, is similarly related to its intensity in physical capital. These tangible and intangible aspects of the cluster’s capital intensity, together with its size and network structure, suggest that the main impacts of the cluster on the overall technological performance of the Norwegian economy are at an macroeconomic level; on development of total investments, effects related to changes in the offshore sectors investment activity on supplying industries and factor markets, and the effects on specialised labour markets.

The oil and gas cluster is a prominent feature in the Norwegian economy along almost all dimensions. Considering that about 50% of the total labour stock with education at

ISCED level 6 or above is employed in education and social welfare systems, the cluster's share of the higher educated labour stock outside these sectors is more than 13%; a share comparable to the share of business sector R&D expenditures and KIBS inputs. In total, this cluster plays a decisive role in Norwegian technological performance, and hence gives a considerable impetus to the development of 'intangible capital' providing sectors.

From the cluster map, it might reasonably be asked whether these sectors should be identified as a cluster. The cluster structure describes oil and gas extraction, its supplying industries and two major 'user' industries; the petrochemical industry and the sector of pipeline transportation of oil and gas. The main interactions with other clusters are with the transport cluster on the right, concentrated on marine transport and shipping (sectors 611 and 613).

We note three features. First the 'supply chain' structure of the cluster suggests that it is open-ended: the network may be expanded in particular through the supply industries of the oil and gas sector, an expansion that would quickly cover a diffuse and functionally diverse cross-section of major parts of the Norwegian economy. In this sense, this cluster, in contrast to those described, is not insensitive to the application of cut-offs. Through a qualitative assessment of the linkages, their strengths and the functionalities of the sectors involved, we have limited the cluster to the core structure.

Secondly, we note the inclusion of pipeline transport in the oil and gas cluster, rather than in the transport cluster. Further, the sector 608 is economically separated from the sectors included in the transport cluster.

Thirdly, the sector of engineering and technical consultancy and related activities has been included in the cluster. The size of the petroleum extracting sector and the technologically complex nature of offshore petroleum extraction and processing, makes it no surprise that the sector is the major user sector of engineering and technical consultancy. In fact sector 742 (NACE 74.2 and 74.3) represents more than 70% of the KIBS inputs into oil and gas extraction, or 16% of its total domestic intermediate inputs. The oil and gas cluster is the recipient of nearly 50% of the intermediate output of sector 742. The total KIBS inputs have three equally-sized components,

- trade flows within sector 742,
- services from sector 742 to oil and gas companies,
- KIBS inputs from other KIBS sectors.

As discussed above, an extension from the intermediate flows to include investment flows will probably increase the strength of the interaction between the two sectors of technical and engineering consultancy and oil and gas extraction further. Hence we have included sector 742 in this cluster.

### 3.2.4. The construction cluster

The total gross product of the construction cluster is about 8% of national GDP. The cluster's share of the total capital stock of about 4% indicates a fairly low capital intensity, it also has the lowest capital share of these clusters. The capital labour ratio of the cluster is estimated to 0,63 mill. NOK. This figure is comparable to similar ratios for the agriculture and paper and graphics clusters. The lower capital share in GDP suggests, however, that the remuneration of capital is lower in the construction cluster. R&D measures suggest that the overall R&D expenditures in the cluster was about 700 mill NOK in 1995, corresponding to about 1,3% of value added, comparable to the oil and gas cluster. There is, however, a considerably skewed distribution across sectors in R&D performance. Inclusion of the sectors 243 (chemicals, paints and varnishes), sector 246 (other chemicals) and 311-314 (electrical machinery) in the cluster, accounts for about 2/3 of total R&D expenditures are covered.

The structure of KIBS inputs shows a different pattern; the same industries represent less than 9% of the cluster's KIBS inputs, while the construction sector NACE 45 accounts for more than half the KIBS inputs. The largest contribution to KIBS inputs into these core sectors is from technical and engineering consultancy, sector 742. The cluster's share of HEP in employment tends towards the lower end of the scale.

The construction cluster is a network with a constituent part located in the inter-relationships between the construction sectors 452, 453 and 454, corresponding to NACE 45.2 and 45.3. The core role played by these three sectors is evident in the cluster map, the triangle of these sectors forms the backbone of the cluster. The left hand side of the map, concentrated around the sectors 452 and 454 concerns erection and completion of buildings. The three industries of wood products (sectors 201, 202 and 203) are linked to this sub-network, highlighting the position of wood as construction material. Electric and plumbing installation, painting and similar activities are located in sector 454, reflected in this sector's input structure towards the lower left. The map suggests that production of furniture, sector 361, is included in the cluster. Rather than reflecting the general structure of the Norwegian furniture industry, this relates primarily to one specific part of this sector, production of complete kitchen installations. As the kitchen furniture industry (corresponding to NACE 36.13) is only a minor part (about 15% in value-added terms) of the 2 bill NOK Norwegian furniture industry, we have chosen to exclude this sector from the cluster.

The map includes a group of industries producing mineral products, such as glass products, ceramics, bricks and tiles and cement and plaster. This group of industries serves all three construction industries, including the civil engineering dominated activities of sector 453. While the building-related sectors are suggested in the map as being more closely related to building property through 'user' sectors 700 and 704, the engineering based activities of 453 are closer to public administration and utilities as major user sectors, probably to a large extent reflecting major infrastructure projects, such as roads, or the construction of the new Gardermoen airport, etc. Road construction is a significant part of the explanation of the presence of the public sector P453, including the construction activities of the National Road Authority (Statens Vegvesen). The three core sectors are characterised by a share of intermediate deliveries in total production of 25 – 50%, and by final demand almost exclusively being oriented towards investment. A sectoral resolution of these investment flows will probably further increase the linkage between these sectors and their major 'user' sectors.

### 3.2.5. The transport cluster

The 9% 1993-share of the transport cluster in national GDP is similar to its employment share. The capital labour ratio is significantly larger than the ratios for all the other clusters, apart from the oil and gas cluster. The cluster scores low on all intangible dimensions compared to other clusters. R&D expenditures in 1995 of 250 mill. NOK implies an R&D intensity of 0,4%, relative to GDP, the lowest intensity of the six clusters and networks we have described here. Furthermore, about ¾ of these

R&D expenditures are accounted for by the sector's manufacturing transport equipment, NACE 34 and 35. However, with HEP personnel, the two manufacturing industries represented less than 6% of the cluster's employment of HEP personnel; while nearly 60% is accounted for by land and marine transport. The most intensive user category of HEP is air transport, with a HEP share of nearly 7%. All in all, this suggests a differentiated pattern of innovation and technological change in the various segments of the transport cluster.[9]

The transport cluster is an inter-related network of transport functions and associated services. We may broadly identify three substructures in the cluster map, with land transportation located in the upper right of the diagram, marine transportation in the middle left with related support services, air transportation towards the bottom, while other support and auxiliary services are located in the middle. In contrast to the paper and graphics and oil and gas clusters, there is no immediate suggestion of an overall 'filière' structure. Rather the transport cluster as identified here is a loose network of interrelated activities.

### 3.2.6. The paper and graphics cluster

The paper and graphics cluster is the smallest cluster. Its 1993 capital share is the lowest of the clusters considered here, of the same order as the capital share of the construction cluster. The intensities of intangible investments are somewhat larger than the average. This is to a large extent due to the presence of the pulp and paper industry; this industry dominated R&D expenditures in 1995. The cluster's relative size in the context of the Norwegian economy is given in table 18.

It is a cluster of production activities mainly concentrated on pulp, paper and graphical production. As shown in the cluster map the cluster has an open structure that is readily understandable in terms of flows of pulp and paper based production activities. The sectors included in this cluster are listed in table 16. The central chain of this cluster consists of the pulp and paper industries, NACE 21, and the graphical, printing and publishing industries, NACE 22. When we note that the publishing industry includes both book and newspaper publishing, the linkages to sectors surrounding the cluster are almost intuitive.

9 For a study of freight land transport, in this cluster related to sectors 604 and 631, see Ørstavik (1998).

One noteworthy feature of the cluster map is the presence of the advertising sector as a major user of graphical products. It is part of a rather strong link between the printing and publishing industry and KIBS, around technical, accounting and administrative services, as well as advertising services.[10] Note that this cluster is also a relatively intense user of KIBS inputs; the ratio of KIBS inputs to GDP is the highest of the five cluster, and also higher than the relevant ratio for the oil and gas cluster.

**3.2.7. Information intensive activities**

The information intensive network represents a gross product of about 84 bill. NOK, or about 12% of GDP, with an employment of 193 000. The overall capital output ratio is below unity with a capital labour ratio, or average (tangible) capital behind each employed person, of just 425 000 NOK. This is in striking contrast to a capital share of 48%. The misbalance between these measures contrasts with the role of intangible investments and assets in these industries, almost 30% of business sector R&D expenditures are linked to the industries in this network. It follows from this that the R&D/GDP ratio is high compared to most other industries, and significantly higher than the similar ratios for the clusters described above.

Compared to the other clusters, the average R&D expenditures of R&D performing firm units is high. The average R&D performer spent nearly 23 mill. NOK in 1995 on R&D, considerably higher even than the oil and gas cluster. There is however, a lower propensity for firms to perform R&D, while 40% of firm units in the oil and gas cluster were R&D performers, just 22% of firm units in information intensive activities were R&D performers in 1995.[11] The share of firm units involved in technological co-operation is second only to the oil and gas cluster. In both cases units belonging to KIBS sectors represent major shares of co-operating firm units.

R&D is dominantly performed in-house, about 27% of total R&D expenditures were contracted out. This share is somewhat lower than the shares for other parts of the economy, and considerably lower than for the relatively R&D intensive oil and gas cluster. A more substantial difference emerges, however, when comparing this share with the share of contract R&D that is contracted to national R&D institute and HEIs.

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10 So much for the paperless office!

11 572 of the 4 394 firm units that were surveyed in the 1995 R&D survey belong to the network of information intensive activities. Of these 126 were R&D performing.

Less than 8% of externally contracted R&D is contracted to such institutions, suggesting a considerably weaker overall linkage between these sectors and PTIs.

The KIBS inputs into this sector is high, corresponding to 16% of value added. Even though this reflects the inclusion in the network itself of several KIBS sectors, intra-sectorial flows among KIBS sectors covers less than 20% of the total KIBS inputs. Even after adjusting for this the network still remains an intense KIBS user. Similarly, it may be noted that the network is a heavy user of personnel with higher education. Nearly 15% of employees have an educational background at a level corresponding to ISCED 6 or higher. Almost 1 in 4 of employees with tertiary education outside the social service systems is employed in these sectors.

The network is concentrated on financial, business and communication services, with a broad set of linkages to other sectors and clusters across the economy. As shown in the appendix tables, this network is, apart from the construction cluster, the largest or second largest originator of inter-cluster intermediate inputs of all those we have looked at. Note that in addition, public and social services are large recipient sectors of the output from this cluster. The sectors in the upper left corner of the cluster map are only weakly connected to the rest of the network; advertising, miscellaneous business services and labour recruitment are clearly more closely related to major users of the network than to the network itself. There are two sectors in particular that tie the network together, computer services (sector 720) and the variegated category of business services 741.

## 4. Innovation patterns and intangible investments

We have identified six clusters and networks through transaction flows of goods and services, representing more than 60% of Norwegian GDP. Though there is considerable ambiguity in this approach, the fact that we have managed to identify clusters with relatively clear economic and functional characteristics lends support to our approach. The rationale for this approach was an attempt to identify some main features of systemic innovation, on the hypothesis that user-producer links, viz. traded flows, form a substantial basis for the topology of systems of innovation. In this last section we will outline features of investments in innovative activities at cluster level, concentrating on four gross dimensions, capital intensity, R&D measures, employment and inputs from knowledge intensive business services.[12] Without time series presentation of variables, we will treat level variables as equilibrium values or nearly so; i.e. we assume that the documented levels reflects underlying technological and economic characteristics without significant expectation gaps. Table 6 outlines these features of innovation activities at cluster level.

[12] For KIBS inputs as inputs to innovation, see Bilderbeek et al. (1998) and Hauknes (1998b)

*Table 6 Patterns of tangible and intangible investment*

| | *Agrofood* | *Oil and gas* | *Construction* | *Paper and graphics* | *Transport* | *Information intensive* |
|---|---|---|---|---|---|---|
| *Innovators* | 35,6% | 42,8% | 34,4% | 42,2% | 27,8% | 35,8% |
| *Capital share* | 0,55 | 0,76 | 0,37 | 0,38 | 0,48 | 0,48 |
| *Capital labour ratio (kNOK pr emp.)* | 768 | 4 952 | 630 | 502 | 1 285 | 425 |
| *R&D performers* | 16,4% | 39,2% | 23,8% | 11,5% | 12,6% | 22,0% |
| *Technological co-operation* | 12,4% | 34,6% | 18,4% | 19,2% | 16,6% | 22,0% |
| *R&D expenditures (mill NOK)* | 519 | 2 326 | 698 | 304 | 251 | 2 864 |
| *KIBS inputs (mill NOK)* | 3 571 | 11 167 | 4 527 | 1 835 | 3 468 | 12 974 |
| *R&D/GDP* | 0,8% | 1,9% | 1,3% | 1,5% | 0,4% | 3,4% |
| *KIBS*/GDP* | 5,8% | 9,0% | 8,3% | 9,1% | 5,4% | 15,7% |
| *Share HEP in employment* | 2,9% | 19,1% | 4,7% | 8,8% | 3,7% | 14,6% |
| *R&D/firm unit (kNOK)* | 4 513 | 16 151 | 4 282 | 8 440 | 5 576 | 22 731 |
| *External R&D/Total R&D* | 32,1% | 41,5% | 21,5% | 34,7% | 37,6% | 26,8% |
| *PTI/External contract R&D* | 34,9% | 44,3% | 21,1% | 8,4% | 19,4% | 7,7% |

The share of innovators, firms that have introduced product or process innovations over the three-year period 1993-1995, is used as an output measure. While 43% of firms in the oil and gas cluster are innovators, the share is 28% in the transport cluster. Though variable, the variation in inputs is generally more pronounced than variation in this innovation output measure.

Capital variables, capital share, measuring the gross return to capital inputs, and capital-labour ratio as a measure of capital intensity, points to the outlier character of the oil and gas cluster. A capital labour ratio of 5 mill NOK and capital share of 76% , technology intensity is a profound characteristic of this cluster. In the agrofood cluster the capital share of income is more than 50%, indicating the a considerable role is played by capital in this cluster. Its capital-labour ratio is slightly higher than the all-economy ratio, excluding the oil and gas sector and household owned property. The small capital base of information intensive activities and comparatively high capital share of income, suggests that considerable returns on intangible assets are included. This situation is reversed for the transport cluster, suggesting a more dominant role for capital embodied investments. This applies also to the construction cluster, considering its capital intensity, while the paper and graphics cluster is suggested to either have a higher gross return on capital investments, or a stronger reliance on intangible investments.

The intangible variables in table 6 expands on these suggestions. In contrast to the oil and gas cluster the share of R&D performers and R&D intensity implies a more substantial role for non-R&D innovation patterns in the other clusters, while the information network, though skewed in terms of R&D performers, is highly R&D intensive. KIBS intensities show a similar pattern, but also strengthens impression of the paper and graphics and construction clusters as dependent on ‘softer’ modes of innovation. Somewhat surprising is the weak role of technological cooperation in all clusters except oil and gas. The share of higher educated personnel in employment varies considerably, from a low 3% in the agrofood cluster to a high 19% in oil and gas. Again paper and graphics shows up as medium-to-high intensive.

The last two indicators in table 6 describes interactive aspects of R&D investments. The first measures the share of total R&D expenditures performed outside the R&D investing firm, in other companies and in R&D institutions. The second variable gives the share of external R&D contracted to public technology, or knowledge, infrastructures. The most prominent feature is the weak integration of the ‘soft’ mode innovators of information activities and paper and graphics with such PTIs. The specialisation of PTIs towards the oil and gas cluster is also pronounced.

Figures 1 compare five measures of input requirements of the clusters. The plots measure five different kinds of inputs into production: labour inputs measured in terms of total employment, (physical) capital stock, as given in the national accounts data used in the description above, KIBS inputs from input output data, the number of employees with tertiary education, and R&D expenditures in the cluster or network. In each case it gives the ratio of the share of the cluster in the relevant variable and the share of the cluster in total GDP, or what is identical, the input to gross product ratio in the cluster relative to the input to GDP ratio for the whole economy. A cluster with a ratio larger than unity thus requires more of the relevant input per unit output valued in terms of value-added. The HEP variable has been modified somewhat. Due to the large share of HEP employees in education and health services, we have formed the ratio for the HEP variable from the parallel data restricted to the economy outside these services. The only effect of this modification for the clusters and networks we consider here is to scale the axis: it does not affect the relative values of the different clusters.

The axes of total employment and capital stock are measures of the traditional physical inputs into production. An industry or group of industries with a value along the labour axis above unity thus requires more labour inputs into production than its share of GDP and the average share of labour in GDP would suggest. There are similar considerations for the other axes. A sector with a high (low) capital labour ratio, being relatively capital (labour) intensive, would score high (low) on the capital axis and low (high) on the labour axis. The HEP axis, measuring the relative intensity of employment of personnel with tertiary education above ISCED 6 level, is suggested to be a combined measure of (1) the structural composition of the labour force within the industry, and hence of the limitations of the homogeneity assumptions of labour inputs, and (2) a measure of the requirements for intangible inputs that are present in these labour inputs as a consequence of their educational background and the specific experiences that this allows.

Figure 1a identifies the three networks of oil and gas, paper and graphics and information intensive sectors. Comparing across the plots, the latter two networks are extensively dominated by intangible inputs, scoring high on these axes, and with low values on capital inputs. The oil and gas cluster appears as only weakly more KIBS and R&D intensive than the rest of the Norwegian economy. Its labour input requirements are substantially lower, reflected also in the fact that its input ratio for HEP is less than unity. However, the differences in the labour and HEP input ratios emphasise the structurally stronger dependence on HEP labour inputs in this cluster. The capital intensity is just slightly larger than unity. We will nevertheless interpret this cluster as relatively capital intensive. The oil and gas cluster's share in the aggregate capital stock that we use as the benchmark, is nearly 40%. Hence the cluster is less inclined to variation in this ratio than other clusters. In total, this implies a profile of the oil and gas cluster that is elongated along the capital and R&D axes, and somewhat weaker towards the KIBS axis. This is a reflection of a strong reliance on explicit modes of acquiring assets, rather than implicit ones such as through KIBS inputs.

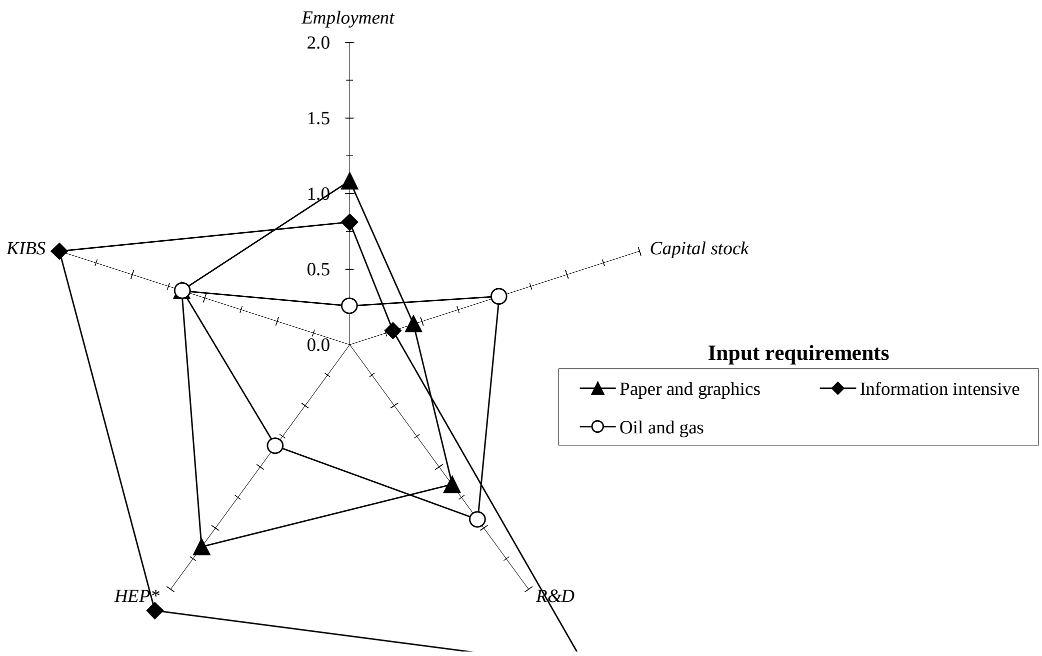


**Figure 1a Input requirements in the oil and gas, paper and graphics and information intensive activities clusters**

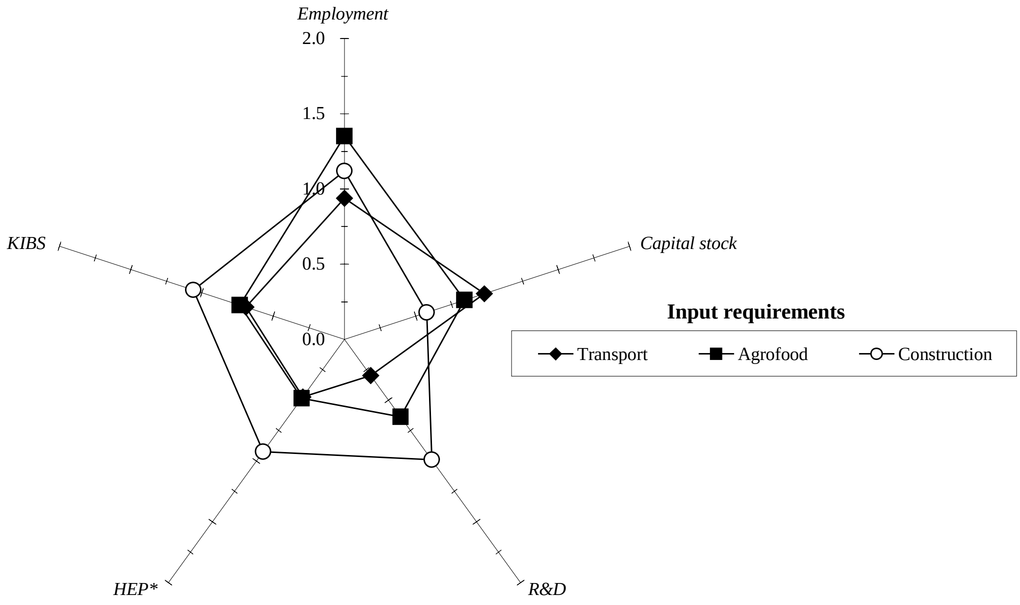


*Figure 1b Input requirements in the agrofood, construction and transport clusters*

The agrofood cluster has characteristic factor requirements less than unity for all dimensions except total labour inputs, emphasising the labour intensity of the cluster. The same applies to the transport cluster, with a somewhat higher capital index. The construction cluster, which was the birth place of offshore (oil and gas) engineering, is relatively more inclined towards KIBS inputs.

The argument of the introduction that learning-by-interacting is related to challenges in the interaction between producers and users, suggests attempts to grade trade flows according to some measure of content of new or innovative technology. This suggests a redefinition of link strengths, to a combined measure of trade volume and a measure of 'technology' or knowledge intensity. A simple way to approximate such a method is to use R&D adjusted input output coefficients[13]. Figure 2 describes the composition of technological intensity of clusters, distinguishing between R&D performed in each sector, i.e. direct, and indirect (domestic) inter-sectoral embodied technology flows.[14] For the three clusters transport, agrofood and construction

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13 The methodology is outlined in Hauknes (1997) and (1998c)

14 The computation is based on sector-sector coefficients, rather than sector to final output coefficients. The embodied technology flows are distributed over the whole output of the recipient sector, giving a modified technology intensity of the sector, rather than of its final output.

imported embodied technology is larger than the aggregate intra-sectorial technology generation within each sector in the clusters. In contrast the information network and the oil and gas and paper and graphics clusters have a higher self-sufficiency in terms of technology generation.

*Figure 2: Technology content of clusters*

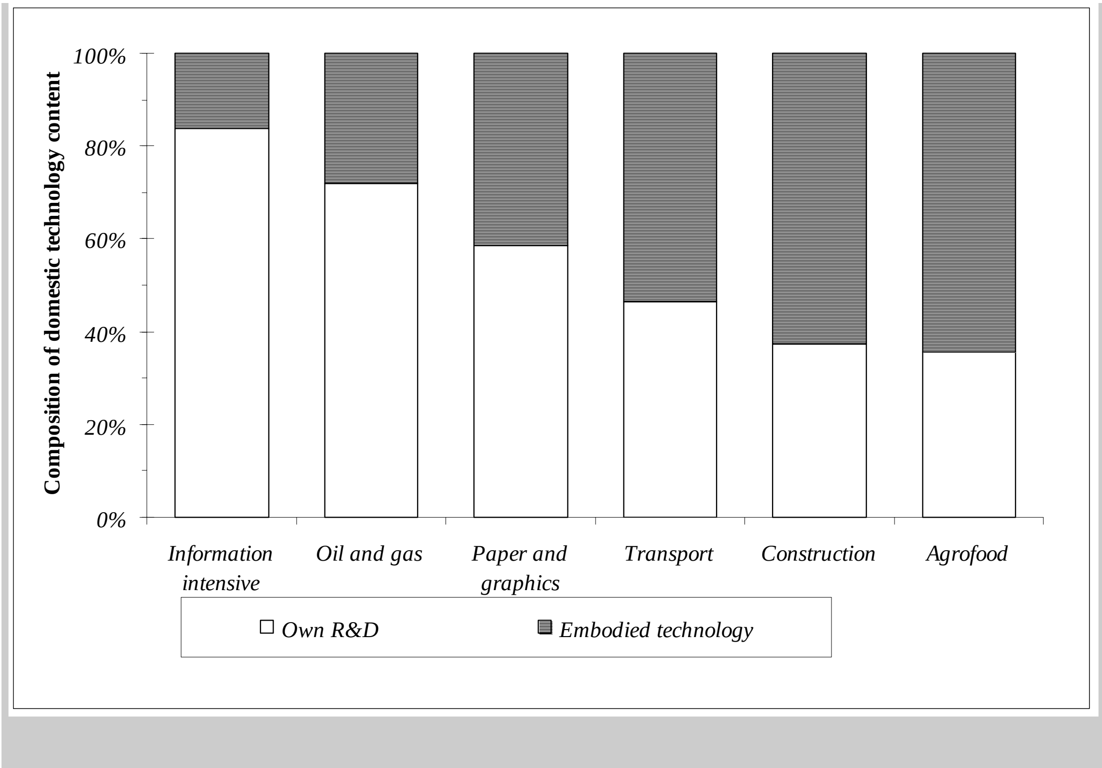


Table 7 summarises the effect of including embodied technology in terms of two indicators; technology intensity as total technology content relative to gross product, and a technology multiplicator defined as the ratio of own and indirect R&D. The information network has a technology intensity of more than 5%, almost exclusively due to the direct effect of R&D. Furthermore embodied technology deposits in information sectors are mainly through intra-cluster trade flows. In contrast, intra-cluster technology flows play a minor role in all other clusters, while technology inputs from the information network represents at least $^1/_3$ of technology imports to these clusters. In the agrofood and construction cluster technology imports are nearly twice as large as internally generated technology.

*Table 7 Technology intensity of core clusters*

| | *Information intensive* | *Oil and gas* | *Paper and graphics* | *Transport* | *Construction* | *Agrofood* |
|---|---|---|---|---|---|---|
| *Technology intensity* | 5,20% | 1,65% | 2,73% | 1,83% | 2,50% | 1,77% |
| *Technology multiplicator* | 0,19 | 0,39 | 0,70 | 1,15 | 1,68 | 1,81 |

In summary we may distinguish broad patterns of each cluster according to the relative dominance of factor inputs and embodied technology in each profile. These patterns are interpreted as of fingerprints of gross modes of innovation and technical change at cluster level.

| | *Embodied technology* | *Capital* | *R&D* | *KIBS* | *HEP* |
|---|---|---|---|---|---|
| *Agrofood* | *** | ** | 0 | -- | --- |
| *Construction* | *** | - | 0 | * | - |
| *Transport* | * | *** | --- | -- | --- |
| *Oil and gas* | --- | 0 | *** | ** | *** |
| *Paper and graphics* | 0 | --- | * | ** | *** |
| *Information intensive* | --- | --- | *** | *** | *** |

The three clusters of agrofood, construction and transport are dominated by 'implicit' modes of technical change, primarily through embodied use of capital goods and intermediate inputs. Overall these clusters rely only weakly on 'explicit' modes as use of higher educated personnel, R&D performance and KIBS inputs. The relative weighting of capital intensity and intermediate technology flows suggests that technical change in the transport cluster is closely tied up to technical change embodied in capital goods, while the technical change in the construction cluster relates more to non-capital intermediate inputs, including softer KIBS-inputs.

This situation is reversed for the three clusters of paper and graphics, oil and gas and information intensive activities. Given the high and low capital intensity of resp. the oil and gas cluster and the other two, we may broadly distinguish between hard and soft modes of these explicit innovation patterns.

## 5. Conclusions

We have outlined a procedure for identifying aggregate clusters on the basis of input-output tables. With supplementary data we have been able to characterise gross features of innovation patterns at the level of these six clusters. The indicated overall mode of innovation and technical change in the agrofood and construction clusters are through intermediate technology imports, while the transport cluster is more dependent on technical change embodied in capital equipment. We may term these patterns as implicit, or embodied, modes of technical change and innovation.

The structure of technology flows described above is based on intermediate trade flows. By not including inter-sectoral transactions of capital investments, we avoid double-counting capital goods in the innovation profiles above. However, this choice may imply a under-estimation of technology flows, in particular for the three clusters where embodied flows are most important. The underlying data show that technology flows into these clusters from relatively high-tech sectors as chemicals and machinery production are significant. Together with information and KIBS inputs they account for more than 2/3 of technology imports into the clusters. An inclusion of investment flows will further enhance this share.

We noted that the agrofood cluster appeared to be isolated from trade flows with other sectors and clusters, which given the fairly low intensities of explicit dimensions of innovation raised a question of the generation of technical change. Induced technology flows changes this picture; the high technology multiplicator value for the cluster implies that it is much more heavily involved in inter-cluster technology flows. For both this and the transport cluster we expect additional enhancement of technology flows with inclusion of investment flows, further increasing the reliance of capital embodied technical change and their technology intensity.

Though capital intensive, technical change in the oil and gas cluster is more directly related to extensive use of firm-based R&D and professionalised personnel. KIBS inputs, mostly related to sub-contracted technical engineering, is also a significant aspect of the oil and gas cluster. The low technology intensity is to a large extent a reflection of the high capital intensity and the importance of ground rent in this cluster.

The low capital and high technology intensities of the paper and graphics and information cluster implies domination of a softer, or more intangible, mode of innovation. Overall the paper and graphics cluster rely on its stock of professional personnel and KIBS inputs, while the aggregate fingerprint of the information activities rely heavily on all three explicit dimensions of innovation inputs.

There are two basic limitations to our approach. Firstly we have focussed solely on traded transactions as the mode of interaction between firms. Through this we have internalised the user-producer links which are a vital part of the environment of individual firms, whereas we have kept other forms of interaction outside the analytical framework. Secondly, we have identified innovation modes at the level of clusters, which of necessity treats intra-cluster diversity and complementary divisions of innovation modes weakly. The consistent, and perhaps surprising result of this work is that even at the aggregate level of input-output-based clusters it is possible to discern clear patterns of differentiation of innovation modes.

As a consequence of this there are two kinds of lessons for innovation and technology policies that may be drawn. One is in the negative, the fact that there is a considerable differentiation in innovation modes at this level implies directly that the strong emphasis of industry-neutral, or non-selective, innovation oriented economic policies is misguided. These policies are not selective in implementation at firm level, the variation in innovation modes at cluster level suggests that impacts of intendedly neutral policies will vary even at this level. A case at hand may be the use of R&D tax credits or KIBS based policies of technology diffusion.

A second lesson is the existence of innovation patterns at the level of clusters point to an avenue towards cluster-based innovation policies, where policy formulation already at the outset may integrate central dimensions of the systemic interaction underlying innovation and technical change. Such inter-sectorial approaches to innovation policies may inform policy formulation on intra-cluster complementary relations of sectors and functions, within a framework of general innovation modes of patterns at the cluster level.

# Appendices

## A.1. Production sectors in the Norwegian National Accounts

The account structure of the Norwegian systems of national accounts is organised around five mutually exclusive institutional sectors describing the total economy;

*22 Households' production for own consumption (the household sector)*

*23 Market activities (the market sector)*

*24 Central government and administration (the government sector)*

*25 Municipal government and administration (the local authority sector)*

*26 Non-profit institutions serving households (the PNP-sector)*

To each institutional sector there corresponds a set of up to 149 industries or production sectors, with a total of 179 combined institutional-production sectors used. Data for the institutional sectors of central and local government are based on annual public state and municipalities accounts (Stats- og Kommuneregnskapene), while data for the remaining non-public sectors are based on industrial and other surveys organised and performed by the Statistics Norway.

In this paper the five institutional sectors have been aggregated to two categories, a 'private' sector, integrating the household, the market and the PNP-sectors, and a 'public' sector covering the government and the local authority sectors. In the cluster descriptions production sectors are distinguished by a 3-digit code, roughly corresponding to the related NACE classification, with the 'public' production sectors identified with a preceding *P*. The resulting input-output table is described in terms of 161 production sectors.

## A.2. Clusters and their sectoral content

*The agrofood cluster*

| *SNA production sector* | *NACE classification* | *Description* |
|---|---|---|
| *10* | *011 + 012 + 013* | *Agriculture* |
| *14* | *014* | *Agriculture and husbandry service activities* |
| *51* | *0501* | *Fishing* |
| *52* | *0502* | *Fish hatcheries and fish farming* |
| *151* | *151* | *Meat and meat products* |
| *152* | *152* | *Fish products* |
| *153* | *153* | *Fruit and vegetables* |
| *154* | *154* | *Mfg veg. and animal oils and fats* |
| *155* | *155* | *Dairy products* |
| *156* | *156* | *Grain mill products, starches* |
| *157* | *157* | *Prepared animal feed* |
| *158* | *158* | *Other food products* |
| *159* | *159* | *Beverages* |
| *242* | *2415 + 242* | *Fertilisers, nitrogen compounds and pesticides* |
| *351* | *35111 + 35112 + 35113 + 35116 + 35117 + 3512* | *Building and repair of ships* |
| *551* | *551 + 552* | *Hotels and accommodation* |
| *553* | *553 + 554 + 555* | *Restaurants and catering* |

*The oil and gas cluster*

| *SNA production sector* | *NACE classification* | *Description* |
|---|---|---|
| *P730* | *73* | *Public sector research and development* |
| *P742* | *742 + 743* | *Architectural, engineering activities and related technical consultancy, technical testing and analysis* |
| *P745* | *745 + 746* | *Labour recruitment, investigation and security* |
| *111* | *111* | *Extraction of crude oil and gas* |
| *112* | *112* | *Service activities incident to 111* |
| *232* | *232* | *Refined oil products* |
| *287* | *284 + 285 + 287* | *Other fabricated metal products* |
| *300* | *30* | *Office machinery and computers* |
| *334* | *334 + 335* | *Optical instruments, watches and clocks* |
| *352* | *35114 + 35115* | *Building and rep. oil platforms and modules* |
| *608* | *603* | *Pipeline transport* |
| *742* | *742 + 743* | *Architectural, engineering activities and related technical consultancy, technical testing and analysis* |

*The construction cluster*

| *SNA production sector* | *NACE classification* | *Description* |
|---|---|---|
| *P410* | *41* | *Water utilities* |
| *P453* | *45212 + 4523 + 4524 + 4525* | *Construction and civil engineering* |
| *100* | *10* | *Mining of coal and lignite* |
| *140* | *14* | *Other mining* |
| *201* | *201* | *Sawmilling, planing of wood* |
| *202* | *202* | *Panels and boards* |
| *203* | *203* | *Builders' carpentry and joinery* |
| *204* | *204 + 205* | *Other wood products* |
| *243* | *243* | *Paints, varnishes* |
| *246* | *246* | *Other chemical products* |
| *261* | *261* | *Glass and glass products* |
| *262* | *262 + 263 + 264* | *Ceramic products* |
| *265* | *265* | *Cement, lime and plaster* |
| *266* | *266 + 267 + 268* | *Articles of concrete, lime and plaster* |
| *281* | *281 + 282 + 283* | *Structural metal products, tanks, containers, steam generators, a.o.* |
| *297* | *297* | *Domestic appliances* |
| *311* | *311 + 312* | *General electrical machinery* |
| *313* | *313* | *Insulated cable and wires* |
| *314* | *314 + 315 + 316* | *Other electrical equipment* |
| *451* | *451* | *Site preparation* |
| *452* | *45211 + 4522* | *Erection of buildings and frames* |
| *453* | *45212 + 4523 + 4524 + 4525* | *Construction and civil engineering* |
| *454* | *453 + 454* | *Building installation and completion* |
| *455* | *455* | *Renting of construction equipment* |
| *700* | *701 + 70202 + 703* | *Real estate activities* |
| *704* | *70201* | *Services from own property – households + calculated production own housing* |

*The transport cluster*

| *SNA production sector* | *NACE classification* | *Description* |
|---|---|---|
| *P601* | *601* | *Public railway transport* |
| *P631* | *63111 + 63113 + 6312 + 6321 + 6323 + 63401 + 63403 + 63409* | *Support and auxiliary services to road and air transport* |
| *P632* | *63112 + 6322 + 63402* | *Public support and auxiliary services to marine transport* |
| *340* | *34* | *Motor vehicles* |
| *353* | *352* | *Railway vehicles* |
| *354* | *353* | *Aircraft* |
| *355* | *354 + 355* | *Other transport equipment* |
| *502* | *502 + 50403* | *Maintenance of motor vehicles* |
| *601* | *601* | *Railway transport* |
| *602* | *60211* | *Regular bus transport* |
| *603* | *6022* | *Taxi operation* |
| *604* | *6023 + 6024* | *Other passenger and freight transport by road* |
| *605* | *60212* | *Tramway transport* |
| *611* | *61101 + 61102* | *International marine transport* |
| *613* | *61103 + 61104 + 61105 + 61106 + 61109 + 612* | *Domestic marine transport* |
| *620* | *62* | *Air transport* |
| *631* | *63111 + 63113 + 6312 + 6321 + 6323 + 63401 + 63403 + 63409* | *Support and auxiliary services to road and air transport* |
| *632* | *63112 + 6322 + 63402* | *Support and auxiliary services to marine transport* |
| *633* | *633* | *Travel agencies and tour operators* |
| *711* | *711 + 712* | *Renting transport equipment* |

*The paper and graphics cluster*

| *SNA production sector* | *NACE classification* | *Description* |
|---|---|---|
| *211* | *2111* | *Pulp* |
| *212* | *2112* | *Paper and paperboard* |
| *213* | *212* | *Articles of paper and paperboard* |
| *221* | *221* | *Publishing* |
| *222* | *222* | *Graphical services and printing* |
| *223* | *223* | *Recorded media* |
| *372* | *372* | *Recycling non-metal waste* |
| *921* | *921 + 923 + 924 + 925* | *Picture and video, library, archives and museums, news agencies* |

*Information intensive activities*

| *SNA production sector* | *NACE classification* | *Description* |
|---|---|---|
| *P670* | *67* | *Auxiliary activities to financial intermediation* |
| *321* | *321 + 322* | *Electronic communication equipment* |
| *641* | *641* | *Post and courier* |
| *642* | *642* | *Telecommunications* |
| *651* | *6511* | *Central banking* |
| *652* | *6512* | *Other monetary intermediation* |
| *655* | *652* | *Other financial intermediation* |
| *661* | *6601* | *Life insurance* |
| *662* | *6602* | *Pension funding* |
| *663* | *6603* | *Non-life insurance* |
| *670* | *67* | *Auxiliary activities to financial intermediation* |
| *720* | *72* | *Computer and related activities* |
| *730* | *73* | *Research and development* |
| *741* | *741* | *Legal, accounting and auditing services* |
| *744* | *744* | *Advertising* |
| *745* | *745 + 746* | *Labour recruitment, investigation and security* |
| *748* | *748* | *Misc. business activities nec.* |
| *922* | *922* | *Radio and television* |

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Telephone +47 2247 7310
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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.