# Re-definition of research-intensive industries and goods

## *NIW/ISI/ZEW-Lists 2012*

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# 0 Executive summary

This study presents the new lists of research-intensive industries on the basis of the current classification of economic activities (NACE Rev. 2) as well as foreign trade (SITC Rev. 4), which replace the older NIW/ISI-Lists from the year 2006. The new lists are based on the sectoral business enterprise R&D expenditures for production on the international scale in the years 2008 and 2009 (cross-section). Hereby, only highly aggregated economic sectors, mostly at the 2-digit level, are considered. For the definition of research-intensive industries, a threshold of 3% of R&D expenditure on sales, the threshold for the leading-edge technologies lies at 9%. Unlike in previous lists, the chemical and electrical industries do currently not count to the most research-intensive industries in a global perspective, as the R&D intensity for these sectors as a whole lags behind the industry average. Based on the more coarse-grained international list (2-digit level), new lists of research-intensive industries for Germany at the 3- and 4-digit level were developed, which allow more sophisticated analyzes of research-intensive sectors within the German economy. These 3- and 4-digit lists for Germany build on additional sources of information and data. It turns out that the group of industries that is taken into account in the new lists after the reevaluation has become slightly narrower. In quantitative terms, this becomes especially noticeable in the area of high-level technologies, while the leading-edge technologies have kept their relative structural weight within the manufacturing sector in Germany. In addition, first calculations on foreign trade show that the leading-technology segment occupies a slightly larger weight from a German perspective according to the new definition, although the overall trading volume of research-intensive goods has decreased.

The inclusion of China as a significant R&D, but even larger manufacturing industry location, entails that the manufacturing of computers and peripheral equipment is no longer assigned to leading-edge technologies and rather falls into the area of high-level technologies, which is in contrast to the stricter view of the OECD. Against the background of a rising international division of labor, R&D and production have experienced an extreme decoupling within this sector. When relating the global R&D expenditures in the sector, that still are mostly driven by the advanced industrial economies, to the global production volume – which is heavily influenced by China – this sector proves to be less research-intensive.

With the help of a multi-indicator approach, which includes further indicators for knowledge generation and innovative activity besides R&D and human capital intensity, we further investigated to what extent industries from the manufacturing and services sectors can be classified similarly. Overall, the analysis yields some interesting insights that can be used for future studies on the classification of industries and goods according to their research and knowledge intensity.

The category of leading-edge technology, for example, was confirmed as a separate and distinct group of economic activity that follows a very specific way of generating knowledge. The area of high-level technologies, however, could not be identified as a distinct group. Here, it seems that there is no clear-cut boundary to a series of less research-intensive industries in the field of the technical processing industry. The investigation also revealed that both, industrial and service sectors are represented in each industry type so that the sharp dichotomy of manufacturing industry and (knowledge-intensive) services is not mandatory. Nevertheless, most of the knowledge generation types have a clear focus on one of the two sectors. The knowledge generation type that is based on human capital investments is dominant in the service sectors, which confirms the importance of human capital indicators for mapping the knowledge intensity of service sectors.

# 1 Introduction

The Expert Commission for Research and Innovation (EFI) has commissioned the Lower Saxony Institute for Economic Research (NIW), the Fraunhofer Institute for Systems and Innovation Research (ISI) and the Centre for European Economic Research (ZEW) to compile updated lists of knowledge and technology-intensive goods and industries.

This adjusts the current "NIW ISI lists" - the last review was conducted in 2006 and was based largely on data from the years 2002 to 2005[1] - of research-intensive goods and industries as well as knowledge-intensive industries, both to the recent technological developments as well as to changes in industry and foreign trade classifications.

In order to compile those lists, a variety of very recent data according to the revised classifications of industries and goods is necessary, allowing the assessment of the R&D and knowledge intensity of industries and economic goods in an international perspective.

The recent information for evaluating the knowledge intensity of industries, whose demarcation essentially follows the human capital investment in the workforce, was available relatively soon after the conversion of the German classification of industries (WZ) from WZ 2003 to WZ 2008 (from the German perspective) and the conversion from NACE 1.1 to NACE 2 (in a European perspective). Accordingly, new lists of knowledge-intensive industries were already developed in 2010 and were published as a "Study on the German Innovation System", Nr. 19-2010.[2]

Due to critical gaps in the data, however, a prompt development of new lists of research-intensive industries and goods was initially not possible. In order to determine the global R&D intensity of industries, the information on sectoral R&D expenditures and production values needs to be available at least for the major economies in comparable classifications. These data are essential for an international classification of industries (by ISIC 4) – as being research intensive or not as well as an assignment of industries as belonging to high-level or leading-edge technologies – and simultaneously are the reference scale for the development of new and differentiated lists of research-intensive industries and goods in Germany.

By the middle of 2012, however, corresponding basic data were available only for the EU countries (excluding Greece and Luxemburg). In the fall of 2012, the OECD had provided data on R&D expenditures[3] and/or production by sector according to the currently valid international classification of industries (ISIC 4), at least for individual countries. Based on this information – supplemented by data from national sources – and with the help of further conversions and estimations, it was possible to develop a coarse-grained new list of research-intensive industries, which is based on the data on research activities and production for the global economy in the years 2008 and 2009. The selection of the respective industries is thus not based on the German R&D priorities and therefore especially suitable for international comparisons of research-intensive sectors.

In section 2, the newly developed lists are presented and discussed. Section 3 examines the extent to which the so far used underlying separation between industry and services on the one hand, and the separation of leading-edge, high-level and less research-intensive sectors within the industry on the

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1 Legler, Frietsch (2006).

2 Gehrke, Rammer, Frietsch, Neuhäusler (2010).

3 BERD: Business Enterprise Research and Development

other hand, are still appropriate within in a broader concept of "knowledge intensity". For this purpose, a multi-indicator approach, which goes beyond the indicators of R&D and human capital intensity and includes further indicators of knowledge generation and innovation, is employed to classify industries from the manufacturing and service sectors according to their research and knowledge intensity. The investigation is performed at the level of classes (4-digit) of the NACE 2 based on company-specific data of the German Innovation Survey (MIP).

# 2 Methodology and differences to the previous definition

## The NIW/ISI/ZEW list of research intensive industries for international comparisons 2012

At least since the early 2000s, the distribution of global R&D activities has changed significantly. Developed countries are facing increased R&D competition by populous and fast growing emerging economies. Particularly China has developed a massive self dynamic and nowadays has to be classified at the top of the world rankings due to the mere size of its R&D volume. The R&D expenditures of the Chinese economy were around 113 billion U.S. dollars, calculated in purchasing power parities in 2009. This equals about one-sixth of the R&D expenditures of the OECD countries in total (around 650 billion U.S. dollars). China thus scored second after the U.S, which accounted for almost 30% of R&D spending worldwide. Japan (104 billion U.S. dollars) and Germany (56 billion U.S. dollars) follow in positions three and four.[4] Although the Chinese R&D intensity of 1.8% (relative to GDP) still is well below the OECD average (2.4%), it has almost quadrupled since the mid-1990s.[5] In addition, the country has expanded its production capacity and its exports of industrial goods during this time and became the world's largest exporter of research-intensive goods in 2010. Especially in the area of data processing/electronics, the global production capacity from the Western and Asian developed countries has shifted more and more to China, so that it reaches by far the highest production and export shares in comparison.[6]

Against this background, the scale of previous analyzes was expanded when creating the **NIW/ISI/ZEW list of research-intensive industries for international comparisons 2012.** In addition to major OECD countries, China, Singapore and Turkey were included, although we had to resort at least in part on national sources particularly for data on China, but also in the case of the U.S. and Japan. These were combined with statistics from Eurostat and the OECD (STAN-industry data, ANBERD and BERD statistics) and refer to the data as of the years 2008 and 2009. Apart from only a few exceptions, the level of aggregation the "two-digit" level since the statistics for the "lowest common denominator" permit a deeper look into the three-digit level in only for a few sectors of the economy (Figure 2-1).

In contrast to the previous lists, chemistry (ISIC 4: 20) and the electrical industry (27) currently do not belong to the most research-intensive industries in a global perspective, because the R&D intensity for the entire industry lags far behind the industry average. This classification holds for both, with respect to the OECD countries per se and in relation to the extended country set including China. At least for chemistry, this development has already become apparent some time ago, as the R&D efforts in this sector are well below average in many major OECD countries (e.g. U.S., France, Great Britain, South Korea).[7]

The inclusion of China as a significant R&D, but still a larger site for production, leads, apart from the pure level effect (the sectoral intensities are somewhat lower in an overall perspective), only to one important change from the stricter OECD perspective: The manufacture of computers and peripheral equipment (ISIC 4: 262) does no longer count to the leading-edge technologies in the extended global

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4 OECD (2012): Main Science and Technology Indicators MSTI 1/2012, table 23.

5 Schasse et al. (2012).

6 Cordes, Gehrke (2012).

7 Rammer, Gehrke (2011, 2012).

count, but falls within the area of high-level technologies. In this sector, R&D and production have experienced an extreme decoupling in the international division of labor. Relating the global R&D expenditure within this sector – which still for a large part is accounted for by advanced industrial countries – to the global production volume, which is heavily influenced by China, shows that this sector is less research-intensive.

*Figure 2-1: NIW/ISI/ZEW list of research intensive industries 2012 from a global perspective (ISIC4)*

| | |
|---|---|
| **Leading-edge technology** | |
| 303 | Manufacture of air and spacecraft and related machinery |
| 21 | Manufacture of basic pharmaceutical products and pharmaceutical preparations |
| 252 | Manufacture of tanks, reservoirs and containers of metal |
| 26X | Manufacture of electrical and optical instruments (26 except 262: Manufacture of computers and peripheral equipment) |
| **High-level technology** | |
| 29 | Manufacture of motor vehicles, trailers and semi-trailers |
| 262 | Manufacture of computers and peripheral equipment |
| 28 | Manufacture of machinery and equipment n.e.c. |

Source: Calculated at the basis of several statistics from the OECD, Eurostat, NSF, as well as various national sources, compilation of NIW/ISI/ZEW.

The high-level technology sector includes industries and commodity groups, in which the proportion of internal R&D expenditure on production value falls between 2.5% to below 7%. The sector of leading-edge technologies includes industries and product groups with an R&D intensity of 7% or higher. Together, the two form the research-intensive sector of the industry, which is responsible for around three quarters of the global business R&D expenditures.

By far the highest R&D intensities are obtained for the manufacture of air and spacecraft and related machinery, the production of pharmaceutical products as well as the manufacture of arms and ammunition. These are areas which often are influenced by the government through subsidies, governmental demand or non-tariff barriers. By promoting the manufacture of those goods, not only technological but also rather independent governmental goals (national security, health, astronautics, etc.) are pursued.[8]

Considering only the R&D and production structures of the **largest advanced OECD countries (excluding China)** raises the bar for the **definition of research-intensive goods to 3%**. The average R&D intensity in the manufacturing sector thus was approximately half a percentage point higher in the OECD average of 2008/2009 than in 2003, which is the international year of reference that was used to compile the lists in 2006.[9]

The threshold for the leading-edge technology, which also includes the manufacturing of computers and peripheral equipment (ISIC 4: 262) in the view related to the advanced industrial countries, rises to **more than 9%**. The assignment of the other industries to high-level and leading edges technologies, respectively, is not affected by this "level effect".

8 Legler, Frietsch (2006).

9 Legler, Frietsch (2006).

Since Germany has to position itself especially towards other advanced economies in technology competition, these higher benchmarks were used for the derivation of the NIW/ISI/ZEW lists of research-intensive industries in 2012 (in a deeper sector classification) as described below.

## The NIW/ISI/ZEW list of research intensive industries in a deeper sector classification (NACE 2) for the analysis of the research intensive sector in Germany 2012

For a further differentiation of the research-intensive industrial sector for in-depth analyses from a German perspective, data sources were used that are not available at the international level and even are subject to confidentiality issues on the national scale. In order to meet these restrictions, information from different sources was combined. These are in particular

- unpublished statistics from the "Gesellschaft für Wissenschaftsstatistik im Stifterverband für die Deutsche Wissenschaft" on a deep industry level for the years 2007 and 2009 in the NACE 2 classficiation ,
- unpublished deep level (4-digit) information from the German "Kostenstrukturerhebung zu FuE" in the years 2008 and 2009 (NACE 2); for a rough estimate of the development of single industries additional specially developed statistics in the old classification of industries (NACE 1.1) for the previous years could be used,
- information from the "Mannheimer Innovationspanel", which from 2006 onwards includes data on sectoral R&D intensities in the new German classification of industries (NACE 2),
- patent analyses and expert surveys with experts from the Fraunhofer ISI.

In industries, whose technological development is essentially dependent on products and R&D is more difficult to detect, additional information on the qualification structure of employees was added.

Thus, for example parts of mechanical engineering have been identified as being R&D intensive because of their high proportion of scientists and engineers among their total employees, although there was no evidence for this classification based on the R&D intensity.

With all those additional resources, the highly aggregated list of research-intensive industries for OECD comparisons was differentiated to more detailed levels (three-and four-digit classifications) (Figure 2.2 and Figure 2.3). By weighting the German R&D structures with the (coarse-grained) international reference values single NACE 2 4-digit codes drop out, since they fall back heavily in an international comparison (although their production is above average R&D intensive from a German perspective). This particularly concerns subgroups of the chemical and electrical industries. On the other hand, other NACE 2 4-digit are included due to the high R&D intensity of German production, although this does not hold in an international comparison (such as the manufacture of rubber products, manufacture of rail vehicles).

When comparing the transition list of research-intensive industries from 2010, which was based on a mere conversion of the "old list" from 2006 to the new industrial classification NACE 2, with the newly created four-digit list of research-intensive industries 2012 (Table 2.1)[10], it can be shown that

[10] compare Gehrke, Rammer, Frietsch, Neuhäusler (2010).

- 10 industries which were classified as high-level technology in the transition list are no longer defined as R&D intensive after the re-evaluation:

| | |
|---|---|
| 20.16 | Manufacture of plastics in primary forms |
| 20.42 | Manufacture of perfumes and toilet preparations |
| 20.51 | Manufacture of explosives |
| 23.44 | Manufacture of other technical ceramic products |
| 24.46 | Processing of nuclear fuel |
| 27.12 | Manufacture of electricity distribution and control apparatus |
| 27.31 | Manufacture of fiber optic cables |
| 27.33 | Manufacture of wiring devices |
| 28.92 | Manufacture of machinery for mining, quarrying and construction |
| 33.20 | Installation of industrial machinery and equipment |

- five industries are newly classified as high-level technologies

| | |
|---|---|
| 20.52 | Manufacture of glues |
| 22.19 | Manufacture of other rubber products |
| 27.51 | Manufacture of electric domestic appliances |
| 28.95 | Manufacture of machinery for paper and paperboard production |
| 32.50 | Manufacture of medical and dental instruments and supplies |

- two industries have changed between leading-edge (LE) technology and high-level (HL) technology

| | |
|---|---|
| 26.40 | Manufacture of consumer electronics (2010 LE, 2012 HL) |
| 29.31 | Manufacture of electrical and electronic equipment for motor vehicles (2010 HL, 2012 LE) |

*Table 2.1: Total revenue, export revenue and employees in research-intensive industries as a percentage of total manufacturing 2011 according to the preliminary 'list 2010' and the current NIW/ISI/ZEW list of research intensive industries 2012*

| | total revenue | export revenue | emloyees |
|---|---|---|---|
| **Leading-edge technology** | | | |
| list 2010 | 8.2 | 10.3 | 8.2 |
| list 2012 | 8.6 | 10.5 | 8.6 |
| **High-level technology** | | | |
| list 2010 | 42.0 | 53.9 | 38.9 |
| list 2012 | 35.4 | 49.0 | 35.4 |
| **R&D-intensive manufacturing industries** | | | |
| list 2010 | 50.2 | 64.1 | 47.1 |
| list 2012 | 43.9 | 59.6 | 43.9 |

Source: Genesis-online, statistics for the manufacturing sector. – Calculation by NIW.

Overall, the range of considered industries has slightly narrowed after the re-evaluation due to changes in the classification of industries and the evaluation of recent current research structures. In quantitative terms, this becomes especially noticeable in the area of high-level technologies, while the leading-edge technology has kept its relative weight structure within the manufacturing sector (Table 2.1).

Yet, the share of high-level technology in relation to total revenue (four-digit) is about 6.5% lower than in the transition list of research-intensive industries from 2010. In the case of employment, a difference of 3.5 % can be observed. In the case of export revenue the difference (5%) is lower than in relation to total revenue. This indicates that the industries, which are no more classified as research intensive in the new list of 2012, are on average less export-oriented.

*Figure 2-2: NIW/ISI/ZEW-list 2012 of R&D-intensive manufacturing industries according to (the statistical classification of economic activities) NACE 2 (4 digits)*

**Leading-edge technology**

20.20 Manufacture of pesticides and other agrochemical products
21.10 Manufacture of basic pharmaceutical products
21.20 Manufacture of pharmaceutical preparations
25.40 Manufacture of weapons and ammunition
26.11 Manufacture of electronic components
26.20 Manufacture of computers and peripheral equipment
26.30 Manufacture of communication equipment
26.51 Manufacture of instruments and appliances for measuring, testing and navigation
26.60 Manufacture of irradiation, electromedical and electrotherapeutic equipment
26.70 Manufacture of optical instruments and photographic equipment
29.31 Manufacture of electrical and electronic equipment for motor vehicles
30.30 Manufacture of air and spacecraft and related machinery
30.40 Manufacture of military fighting vehicles

**High-level technology**

20.13 Manufacture of other inorganic basic chemicals
20.14 Manufacture of other organic basic chemicals
20.52 Manufacture of glues
20.53 Manufacture of essential oils
20.59 Manufacture of other chemical products n.e.c.
22.11 Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres
22.19 Manufacture of other rubber products
23.19 Manufacture and processing of other glass, including technical glassware
26.12 Manufacture of loaded electronic boards
26.40 Manufacture of consumer electronics
27.11 Manufacture of electric motors, generators and transformers
27.20 Manufacture of batteries and accumulators
27.40 Manufacture of electric lighting equipment
27.51 Manufacture of electric domestic appliances
27.90 Manufacture of other electrical equipment
28.11 Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
28.12 Manufacture of fluid power equipment
28.13 Manufacture of other pumps and compressors
28.15 Manufacture of bearings, gears, gearing and driving elements
28.23 Manufacture of office machinery and equipment (except computers and peripheral equipment)
28.24 Manufacture of power-driven hand tools
28.29 Manufacture of other general-purpose machinery n.e.c.
28.30 Manufacture of agricultural and forestry machinery
28.41 Manufacture of metal forming machinery
28.49 Manufacture of other machine tools
28.93 Manufacture of machinery for food, beverage and tobacco processing
28.94 Manufacture of machinery for textile, apparel and leather production
28.95 Manufacture of machinery for paper and paperboard production
28.99 Manufacture of other special-purpose machinery n.e.c.
29.10 Manufacture of motor vehicles
29.32 Manufacture of other parts and accessories for motor vehicles
30.20 Manufacture of railway locomotives and rolling stock
32.50 Manufacture of medical and dental instruments and supplies

Source: Collocation by NIW/ISI/ZEW.

*Figure 2-3: NIW/ISI/ZEW-list 2012 of R&D-intensive manufacturing industries according to (the statistical classification of economic activities) NACE 2 (3 digits)*

**Leading-edge technology**

| | |
|---|---|
| 20.2 | Manufacture of pesticides and other agrochemical products |
| 21.1 | Manufacture of basic pharmaceutical products |
| 21.2 | Manufacture of pharmaceutical preparations |
| 25.4 | Manufacture of weapons and ammunition |
| 26.1 | Manufacture of electronic components and boards |
| 26.2 | Manufacture of computers and peripheral equipment |
| 26.3 | Manufacture of communication equipment |
| 26.5 | Manufacture of instruments and appliances for measuring, testing and navigation; watches and clocks |
| 26.6 | Manufacture of irradiation, electromedical and electrotherapeutic equipment |
| 26.7 | Manufacture of optical instruments and photographic equipment |
| 30.3 | Manufacture of air and spacecraft and related machinery |
| 30.4 | Manufacture of military fighting vehicles |

**High-level technology**

| | |
|---|---|
| 20.1 | Manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms |
| 20.5 | Manufacture of other chemical products |
| 22.1 | Manufacture of rubber products |
| 26.4 | Manufacture of consumer electronics |
| 27.1 | Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus |
| 27.2 | Manufacture of batteries and accumulators |
| 27.4 | Manufacture of electric lighting equipment |
| 27.5 | Manufacture of domestic appliances |
| 27.9 | Manufacture of other electrical equipment |
| 28.1 | Manufacture of general-purpose machinery |
| 28.3 | Manufacture of agricultural and forestry machinery |
| 28.4 | Manufacture of metal forming machinery and machine tools |
| 28.9 | Manufacture of other special-purpose machinery |
| 29.1 | Manufacture of motor vehicles |
| 29.3 | Manufacture of parts and accessories for motor vehicles |
| 30.2 | Manufacture of railway locomotives and rolling stock |
| 32.5 | Manufacture of medical and dental instruments and supplies |

Source: Collocation by NIW/ISI/ZEW.

## The NIW/ISI/ZEW list of research intensive industries based on the Standard International Trade Classification (SITC Rev. 4)

In addition to the above described industry lists of research-intensive industries, also a new list of research-intensive goods has been developed, which allows foreign trade analysis on a deeper level than it would be possible on the basis of industries. In order to create the list, in a first step a large variety of potentially research-intensive goods, which results from their assignment to research-intensive industries, was recoded to the five-digit product group classification of the Standard International Trade Classification (SITC Rev.4) with the help of the respective commodity groups within the Harmonized System (HS 2007). The SITC is different from the Harmonized System only through the higher level of aggregation, yet it offers a structure that is better oriented towards statistical requirements. Each of the smallest subdivisions is defined by at least one subdivision of the HS 2007. In many cases, this direct connection does no longer exist for the SITC Rev. 3. Thus, the transition to a newly defined list by SITC Rev. 4 was urgently needed also from a statistical and methodical point of view.[11]

*Table 2.2: Exports and imports of R&D-intensive goods according to the NIW/ISI-list 2010 and to the NIW/ISI/ZEW-list 2012*

| Germany | list 2006 | list 2012 | 2012' in % of '2006' | list 2006 | list 2012 | 2012' in % of '2006' |
|---|---|---|---|---|---|---|
| | exports in bn US $ | | | imports in bn US $ | | |
| **Leading-edge technology** | 157.8 | 152.2 | 96 | 156.7 | 151.6 | 97 |
| **High-level technology** | 607.9 | 576.3 | 95 | 334.9 | 313.2 | 94 |
| **R&D-intensive goods, total** | 765.7 | 728.6 | 95 | 491.7 | 464.8 | 95 |
| **OECD-30*** | **list 2006** | **list 2012** | **2012' in % of '2006'** | **list 2006** | **list 2012** | **2012' in % of '2006'** |
| | **exports in bn US $** | | | **imports in bn US $** | | |
| **Leading-edge technology** | 1138.2 | 1081.5 | 95 | 1303.0 | 1237.9 | 95 |
| **High-level technology** | 3301.5 | 3082.1 | 93 | 2826.2 | 2707.1 | 96 |
| **R&D-intensive goods, total** | 4439.6 | 4163.5 | 94 | 4129.2 | 3945.0 | 96 |

* OECD without Estonia, Chile, Israel und Slovenia.
Source: OECD, ITCS - International Trade by Commodities Statistics. - UN, COMTRADE database. Calculation by NIW.

In a second step, the patenting activity for the commodity groups that have not been explicitly assigned up to that point, i.e. those in which a clear allocation to high-level and leading-edge technology was not possible, was analyzed over time with the help of a concordance to the International Patent Classification (IPC). Commodity groups which showed an above average growth in patenting activity within the time period of 1995-2010 or in recent years or had an above average share of patents on total patents were classified as research-intensive. Commodity groups, with an average or below-average patenting dynamics and a small share on total patent volume were classified as non-research intensive. With the help of additional surveys among ISI experts, information scientific activity (on a 5-digit industry level) as well as other information sources, the resulting list was in a final step evaluated and further reduced. The list was enhanced by single commodity groups, which were not assigned as being research-intensive based on their affiliation to industries, but identified as being research-intensive based on these other sources. Figure 2-4 shows the identified commodity groups of the SITC 4, summarized systematically beneath individual subgroups. The majority of the research-intensive commodity groups classified in 2006 is also reflected in the current list. Reclassifications between the technology segments have also partially been made: parts of the leading-edge technology are now classified as high-level technologies (e.g. certain drugs, power plant equipment, individual components from data processing). On the other hand, electrical equipment for engines and vehicles that once belonged to the high-level technology, are classified as leading-edge now. Furthermore, some commodity groups were added (e.g. household electrical appliances, pumps and compressors), while others are no longer classified as research-intensive (e.g., polymers, pyrotechnics).

The export and import volume of research-intensive goods in Germany as well as the OECD as a whole (here: OECD-30 without Estonia, Israel, Chile and Slovenia) is around 5 percentage points lower than in the old list from 2006 (see Table 2.2). Analogous to the shifts at the industry level, the leading-edge technologies have slightly increased on both sides of the trade balance. On the export side, this is also true for the OECD as a whole, on the import side, there are, relatively seen, slight advantages in the field of high-level technology.

[11] German Federal Statistical Office and Hoeppner (2005).

*Figure 2-4: NIW/ISI/ZEW-list 2012 of R&D-intensive goods according to the SITC 4*

## Leading-edge technologies

| **Radioactive material, atomic reactors** | | |
|---|---|---|
| 525 | | |
| 718.7 | | |

| **Pesticides and other agrochemical products** | | |
|---|---|---|
| 591 | | |

| **Biotechnology, pharmaceutical ingredients and preparations** | | |
|---|---|---|
| 515.76 | | |
| 516.91 | | |
| 541.3 | | |
| 541.5 | | |
| 541.6 | | |

| **Warships, weapons, ammunition** | | |
|---|---|---|
| 793.29 | | |
| 891 | *except* | *891.13* |

| **Air- and spacecraft** | | |
|---|---|---|
| 713.1 | | |
| 714.4 | | |
| 714.81 | | |
| 714.91 | | |
| 792 | | |

| **Data processing instruments, -facilities** | | |
|---|---|---|
| 752.2 | | |
| 752.3 | | |
| 752.7 | | |
| 752.9 | | |

| **Electronics** | | |
|---|---|---|
| 776.3 | | |
| 776.4 | | |
| 776.8 | | |

| **Telecommunication engineering** | | |
|---|---|---|
| 764 | *except* | *764.2* |

| **Electronic equipment for combustion engine and automobile** | | |
|---|---|---|
| 778.3 | | |

| **Electromedical engineering** | | |
|---|---|---|
| 774 | | |
| 899.61 | | |
| 899.67 | | |

| **Cutting-edge instruments for measuring, testing and navigation** | | |
|---|---|---|
| 871 | | |
| 874.1 | | |
| 874.4 | | |
| 874.7 | | |

| **Optical instruments** | | |
|---|---|---|
| 884.19 | | |
| 884.3 | | |

## High-level technologies

**Inorganic basic chemicals**

| | | |
|---|---|---|
| 281.4 | | |
| 522.1 | | |
| 522.2 | *except* | *522.21* |
| 522.3 | *except* | *522.33* |
| 522.4 | | |
| 522.62 | | |
| 522.63 | | |
| 522.64 | | |
| 522.65 | | |
| 522.66 | | |
| 522.68 | | |
| 524 | *except* | *524.96* |
| 667.41 | | |

**Organic basic chemicals**

| | | |
|---|---|---|
| 335.2 | *except* | *335.21* |
| 431.1 | | |
| 511 | | |
| 512 | *except* | *512.17* |
| 513 | *except* | *513.91* |
| 514 | | |
| 515.4 | | |
| 515.6 | *except* | *515.69* |
| 515.7 | *except* | *515.76* |
| | *except* | *515.79* |
| 516.92 | | |

**Essential oils**

| | | |
|---|---|---|
| 551 | | |

**Photochemicals**

| | | |
|---|---|---|
| 882.2 | | |
| 882.3 | | |
| 882.4 | | |

**Other specialty chemicals**

| | | |
|---|---|---|
| 598.5 | | |
| 598.63 | | |
| 598.64 | | |
| 598.67 | | |
| 598.8 | | |
| 598.9 | *except* | *598.98* |
| | | *598.99* |

**Pharmaceutical preparations**

| | | |
|---|---|---|
| 541.9 | | |
| 542 | | |

**Turbines, engines, non-electric motors and equipment**

| | | |
|---|---|---|
| 712 | | |
| 713.3 | | |
| 713.8 | | |
| 714.89 | | |
| 714.99 | | |
| 718 | *except* | *718.7* |
| 746 | | |
| 747.1 | | |
| 747.2 | | |
| 748.4 | | |
| 748.6 | | |

**Pumps and compressors**

| | | |
|---|---|---|
| 742 | | |
| 743.1 | *except* | *743.13* |

**Heat-, filter-, air and cleaning technology**

| | | |
|---|---|---|
| 741.71 | | |
| 741.72 | | |
| 741.73 | | |
| 741.84 | | |
| 741.85 | | |
| 741.86 | | |
| 741.87 | | |
| 741.89 | | |
| 743.6 | *except* | *743.69* |
| 743.95 | | |
| 745.2 | | |

**Agricultural machinery, tractors**

| | | |
|---|---|---|
| 721 | | |
| 722 | *except* | *722.3* |

**Machine Tools**

| | | |
|---|---|---|
| 695.63 | | |
| 731 | | |
| 733 | | |
| 735 | | |
| 737.43 | | |

## High-level technologies (continued)

| Rubber goods | | |
|---|---|---|
| 621.45 | | |
| 625 | *except* | *625.93* |
| 629 | | |

| Office machinery | | |
|---|---|---|
| 751.2 | *except* | *751.24* |
| 751.9 | | |

| Units and equipment for automatic data processing machines | | |
|---|---|---|
| 752.6 | | |
| 759.97 | | |

| Electric motors, generators and transformers | | |
|---|---|---|
| 716 | | |
| 772.6 | | |
| 773.13 | | |
| 773.18 | | |
| 773.22 | | |
| 773.24 | | |
| 773.29 | | |

| Electrical machinery, accessory and facilities | | |
|---|---|---|
| 771 | | |

| Electrical domestic appliances | | |
|---|---|---|
| 775.1 | | |
| 775.2 | | |
| 775.5 | | |
| 775.7 | | |
| 775.82 | | |
| 775.86 | | |
| 775.87 | | |
| 775.88 | | |
| 775.89 | | |

| Electric lighting, electrical equipment etc. | | |
|---|---|---|
| 778 | *except* | *778.3* |
| 813 | *except* | *813.92* |

| Broadcast and television engineering | | |
|---|---|---|
| 761 | | |
| 763 | | |
| 764.2 | | |
| 776.1 | | |
| 776.2 | | |

| Other special-purpose machinery | | |
|---|---|---|
| 723.35 | | |
| 723.37 | | |
| 723.43 | | |
| 723.44 | | |
| 723.47 | | |
| 723.93 | | |
| 723.99 | | |
| 724 | | |
| 725 | | |
| 726 | *except* | *726.35* |
| 727 | | |
| 728.2 | | |
| 728.4 | *except* | *728.42* |
| | *except* | *728.44* |
| 728.5 | *except* | *728.52* |

| Medical instruments | | |
|---|---|---|
| 665.91 | | |
| 741.83 | | |
| 872 | *except* | *872.35* |
| 899.6 | *except* | *899.61* |
| | *except* | *899.67* |

| High-value instruments for measuring, testing and navigation | | |
|---|---|---|
| 745.31 | | |
| 745.32 | | |
| 745.39 | | |
| 873 | | |
| 874.2 | | |
| 874.3 | | |
| 874.5 | *except* | *874.52* |
| 874.6 | | |
| 874.9 | | |

| Technical glass, glazing glass | | |
|---|---|---|
| 664.93 | | |
| 664.94 | | |
| 664.96 | | |

| Optical and photo-optical instruments | | |
|---|---|---|
| 665.95 | | |
| 665.99 | | |
| 881 | *except* | *881.35* |
| | *except* | *881.36* |
| 884.17 | | |

| Motor vehicles, engines and parts | | |
|---|---|---|
| 781 | | |
| 782 | *except* | *782.11* |
| 783 | | |
| 784 | | |

| Railway vehicles and equipment | | |
|---|---|---|
| 791 | | |

Source: Collocation by NIW/ISI/ZEW

# 3 Classification of industries according to their research and knowledge intensity - an integrated approach for manufacturing and service sectors

## Introduction

The aim of this section is to classify industries from the manufacturing and service sectors according to their research and knowledge intensity with the help of a multi-indicator approach. By using an integrated indicator set for manufacturing and service sectors, similarities in the research and knowledge intensity between industries from the two sectors can be identified. Based on these calculations, a classification that overcomes the distinction between manufacturing and services can be created. Thus, it becomes possible to investigate whether and which sectors of the service sector have a research and knowledge intensity that is comparable to the research-intensive industries in the manufacturing sector. Yet, this calls for a measurement concept of "research and knowledge intensity", which is able to detect the amount of knowledge generation that can lead to innovation and technological progress (in a broad sense, equally covering productivity and quality improvements in all economic activities) for all industries in a non-discriminatory manner.

The conceptual basis of the analysis is the idea that generation of new knowledge is possible in any area of economic activity, which can lead to innovation advances (in the sense of Schumpeter 1912), but that the specific processes for the generation of this particular knowledge may differ significantly depending on the area of economic activity. These differences result, inter alia, from differences in the importance of tangible and intangible production factors, different properties of the produced (tangible or intangible) goods and different knowledge bases on which the respective economic activity is based.

In order to measure the magnitude (and the novelty claim) of knowledge generation activities in the various industries in the face of these differences, neither the measurement concept of the R&D intensity (R&D expenditures in relation to the level of economic activity in an industry) nor the measurement concept via highly qualified personnel (employees with higher education in relation to all employees in an industry) appear to be adequate. The R&D intensity mainly captures activities for the generation of new technological knowledge, which is reflected in new technical artifacts, but is not sufficiently able to represent knowledge generation, which refers to the improvement of intangible processes and goods, as it is typical for service activities. The share of highly qualified personnel in turn is not suitable as a measure of the knowledge intensity of economic activities, which only have a lesser relation to science.

In order to develop appropriate indicators for the entire range of economic activities, given the heterogeneity of knowledge production processes, we will make use of two approaches of innovation research. On the one hand, the broader concept of innovation activities of enterprises, as set out in the Oslo Manual of OECD and Eurostat (2005), is used. The broader concept of innovation activities includes not only activities for the development and introduction of new technologies, but also of non-technical innovations, e.g. organizational or in terms of marketing of goods and services. Innovation expenditures are thus defined more broadly than R&D expenditures and include, among others, innovation-related expenditures on further education, marketing or design. On the other hand, the concept of intangible investment is used, which allows for a wider access to the investment of firms besides capital expenditures. It covers different categories of expenditures aimed at the generation of intangible capital goods, which may contribute to productivity gains. In addition to investments in technical knowledge (R&D) the concept also includes investments in non-technical knowledge, in computerbased information, such as software and databases, as well as in company-specific competitive advantages such as brand value, reputation, human capital and organizational capital.[12]

If one accepts the thesis that companies in different areas of economic activity invest in new knowledge in qualitatively different forms, a one-dimensional classification of industries according to a firm's research and knowledge intensity is not sufficient. Rather, it is necessary to distinguish different *types* of knowledge creation of which different paths are used in varying intensity in order to generate new knowledge. In order to identify such sectoral types of research and knowledge intensity, a three-step approach that is based on the common approaches in the literature[13], is used:

- In a first step, a set of indicators is defined, that is supposed to reflect different dimensions of knowledge generation and the implementation of this knowledge into innovations.
- In a second step, these indicators are consolidated into indices, each representing a specific dimension of knowledge generation activities, by using a factor analysis.
- In a third step, industries with similar knowledge generation activities are classified into sectors (or sectoral groups) with the help of a cluster analysis.

The data for the present study is based on company-specific information on knowledge generation activities in the period 2005 to 2011, which are taken from the "Mannheimer Innovation Panel" of the ZEW. This company-specific information is aggregated to industry specific information on the basis of the NACE 2 classification (class level, 4-digit). In total, 430 different industries from the manufacturing and services sectors are thereby classified according to their research and knowledge intensity.

The study presented here can be seen as a first, exploratory step towards a more comprehensive classification of industries according to their research and knowledge intensity. Yet, further studies will be necessary in order to test the robustness of the results and to relate them to an international context.

## Data and Methods

Building on the indicators developed for the measurement of innovation activities within enterprises[14] as well as the approaches used to measure *intangible investments*[15], two groups of knowledge generation activities are distinguished. Knowledge generation is thereby not limited to R&D activities, but includes all creative activities and investments of companies that are used to create knowledge-based competitive advantages:

- Investments in activities that contribute to the creation of intangible knowledge-based economic assets:
    - R&D (generation of technological knowledge)
    - creative activities for generating non-technical knowledge for innovation
    - development of human capital (further education)
    - brand values and corporate reputation

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12 Compare Corrado et al. 2005 and 2006.

13 Compare Pavitt 1984, Marsili 2001, Catellacci 2008, Peneder 2010.

14 OECD and Eurostat 2005, Kleinknecht et al. 2002.

15 Corrado et al. 2005 and 2006.

- Introduction of innovations differentiated according to their degree of novelty
  - product innovations, differentiated by innovations that are new to the market and innovations targeting the variety of goods
  - process innovations, differentiated by cost-reducing and quality-improving process innovations
  - marketing innovations
  - organizational innovations

Two types of indicators are used to determine sector-specific values on the basis of company-specific information:

- Participation of enterprises in knowledge generation activities (percentage of companies with specific activities on all enterprises) - these indicators especially measure the affinity of firms to invest in specific knowledge generation activities (especially in the group of small and medium enterprises (SMEs)).
- The intensity of knowledge generation activities (resources that are used for the generation of knowledge in relation to total available resources) - these indicators measure the importance of a specific knowledge generating activity within the economic activity of an industry.

The single indicators used for the analysis are shown in Table 3.1. Each indicator IN is calculated for each industry j (NACE 2 class) as the sum of knowledge activities (WA) for all companies i of industry j and all periods t divided by the correspondingly accumulated total activities (GA) of companies i in industry j within the observation period t:

$$IN_i = (\Sigma_{it} WA_{it,j} ) / (\Sigma_{it} GA_{it,j})$$

By using sums for the generation of indicators, the activities of the larger companies have a higher weight for the sectoral indicator value – given the use of intensities - than the activities of small firms.[16] Indicator values for the participation of companies in knowledge generation activities basically are determined by the behavior of SMEs, as all companies are counted as one observation regardless of their size. In total, 20 individual indicators are used. Ten indicators relate to the involvement of enterprises in knowledge generation activities and 10 indicators measure the intensity of their use of resources.

The data source for the calculation of the indicators is the Mannheimer Innovation Panel (MIP) of the ZEW.[17] Two survey waves from 2007 to 2012 are used, since only from the wave 2007 onwards an association of companies to industries according to NACE 2 is possible. In each wave, information for each previous year of observation is recorded (i.e. information for 2006 in the year 2008). The figures for business participation in innovation activities relate to the past three-year period (i.e. 2004-2006 in the year 2007). For individual variables, not only the values for the previous year t, but also for the year before t-1 are recorded (only in uneven survey years). This applies throughout to the indicators AKADIN, WEIBIN and MARKIN, in the 2007 wave of the survey also FUEAIN and FUEBIN. In even survey years, however, no information on WEIBIN and MARKIN is recorded. Data for market-

[16] We do not perform a weighting of the corporate activities in accordance to the importance of a company i for the total activity in industry j in year t, since extensive special analyses from the business register on the extent of the company's activities in the individual NACE classes broken down by company size classes would be necessary. In addition, the data for this differentiation is not accessible in the majority of cases due to confidentiality issues.

[17] Compare Peters und Rammer 2013, Rammer et al. 2005.

ing and organizational innovations also are not applicable in even years of the survey, so that the indicators INMAQU and INORQU are only available for three observation years (2006, 2008, 2010).

*Table 3.1: Indicators used for the classification of industries according to research- and knowledge intensity*

| *Indicator* | *Denotation* | *OP* | *AM* | *SD* |
|---|---|---|---|---|
| INPDQU | Share of enterprises with product innovations (%) | 06-11 | 42,2 | 23,0 |
| INPZQU | Share of enterprises with process innovations (%) | 06-11 | 37,0 | 18,3 |
| INMAQU | Share of enterprises with marketing innovations (%) | 08/06/2010 | 52,1 | 23,3 |
| INORQU | Share of enterprises with organizational innovations (%) | 08/06/2010 | 51,4 | 23,2 |
| FUEKQU | Share of enterprises conducting continuous R&D (%) | 06-11 | 27,0 | 23,5 |
| FUEGQU | Share of enterprises conducting occasionally R&D (%) | 06-11 | 13,4 | 8,2 |
| MNEUQU | Share of enterprises with market novelties (%) | 06-11 | 15,8 | 15,8 |
| SNEUQU | Share of enterprises with assortment novelties (%) | 06-11 | 19,2 | 17,3 |
| KOREQU | Share of enterprises with cost savings through process innovations (%) | 06-11 | 17,0 | 16,1 |
| QUALQU | Share of enterprises with quality improvements through process innovations (%) | 06-11 | 18,0 | 14,8 |
| FUEAIN | Share of R&D expenditure in relation to total revenue (%) | 05-11 | 1,4 | 3,45 |
| FUEBIN | Share of employees in R&D (%) | 05-11 | 5,8 | 12,8 |
| IASOIN | Share of other innovation expenditure[1)] in relation to total revenues (%) | 06-11 | 0,61 | 0,91 |
| AKADIN | Share of graduates to all employees (%) | 05-11 | 16,9 | 14,1 |
| WEIBIN | Expenditure for further training per employee per annum (€) | 05-10 | 450 | 414 |
| MARKIN | Share of marketing expenditure in relation to total revenue (%) | 05-10 | 1,46 | 1,91 |
| MNEUIN | Proportion of revenue generated with market novelties (%) | 06-11 | 2,21 | 3,75 |
| SNEUIN | Proportion of revenue generated with assortment novelties (%) | 06-11 | 2,06 | 3,46 |
| KOREIN | Cost savings through process innovation (%) | 06-11 | 1,62 | 2,02 |
| QUALIN | Percentage increase of turnover through quality improvements (%) | 06-11 | 0,89 | 1,38 |

OP: observation period, AM: arithmetic mean, SD: standard deviation. Basis: 430 NACE 2 (WZ 2008) classes.
1) Total innovation expenditure less R&D expenditure and expenditure for the acquisition of fixed assets.

Source: ZEW - Mannheimer Innovationspanel. Calculation by ZEW.

In the survey waves from 2007-2012, the following industries (NACE 2) were recorded on the basis of a stratified random sampling by size class, NACE 2 divisions and regions (Eastern and Western Germany) for all firms with at least five employees: 5-39, 46, 49-53, 58-66, 69-74, 78-82. In previous waves of the survey (up to 2004), other industries (based on NACE 1.1 or WZ03) were part of the random sample, namely the NACE 1.1 divisions 45, 50, 52, 70 and 71. Companies in these industries are still part of the extended random sample of the MIP for as long as they participate in the survey. From the wave of 2007 onwards, these companies were allocated to the relevant industries in NACE 2 (WZ08). Thus, analyses can also be performed for other NACE 2 divisions, namely, 41-43, 45, 47, 68 and 77.

Indicators for specific sectors (NACE 2 classes) can be calculated as long as at least 10 observations (combination of companies and years of observation) are present and values can be calculated for all 20 indicators. These conditions are fulfilled by 430 industries. In total, 85,108 observations from 28,396 firms are used for the analysis, i.e. on average there are three observation years per company (at a maximum of seven possible years of observation per company). The relatively low number of observations per enterprise is mainly the result of the regular refreshment and expansion of the MIP sample, so that a significant part of the companies has participated in the survey for the first time in the most recent survey waves.

## Results

A factor analysis over the 20 indicators (principal component analysis with varimax rotation) leads to the extraction of six factors with factor loadings of at least 1.0, which together explain more than 72% of total variance. The first factor, which alone explains 38% of variance, mainly represents the involvement of companies on technological innovation activities (including organizational innovations) (Table 3.2). A second factor primarily represents the amount of resources used for technological inventions (R&D and other innovation expenditures). A third factor covers the innovative performance or success with product- and process innovations. Factor number four mainly represents the importance of marketing activities (prevalence of marketing innovations, intensity of marketing expenditures). A fifth factor is mainly dependent on the human capital intensity (share of graduates, expenditures for further training). The sixth factor that has been identified is mainly driven by enterprises conducting R&D only occasionally. Of the 20 indicators used, only the share of cost savings through process innovation cannot be assigned to one of the six factors. This indicator has relatively high factor loadings (between 0.45 and 0.5) on factor 1 (technological innovation activities) as well as on factor 3 (success with product and process innovations). The Kaiser-Meyer-Olkin measure as well as Cronbachs Alpha prove that the results of the factor analysis are reliable.

*Table 3.2: Results of a factor analysis with indicators for knowledge generation at the level of NACE 2 classes: Factor loadings of a principal component analysis after varimax rotation*

| *Indicator* | *Factor 1* | *Factor 2* | *Factor 3* | *Factor 4* | *Factor 5* | *Factor 6* | *Unique* | *KMO* | *α* |
|---|---|---|---|---|---|---|---|---|---|
| INPDQU | **0.78** | 0.34 | 0.19 | 0.24 | -0.04 | 0.20 | 0.15 | 0,89 | 0,82 |
| INPZQU | **0.89** | 0.04 | 0.05 | 0.04 | 0.14 | 0.19 | 0.15 | 0,86 | 0,83 |
| INMAQU | 0.31 | -0.03 | 0.09 | **0.80** | -0.05 | 0.06 | 0.25 | 0,77 | 0,85 |
| INORQU | **0.57** | -0.12 | -0.13 | 0.41 | 0.31 | 0.20 | 0.34 | 0,88 | 0,84 |
| FUEKQU | **0.82** | 0.40 | 0.04 | 0.04 | 0.05 | 0.09 | 0.16 | 0,90 | 0,82 |
| FUEGQU | 0.12 | 0.07 | 0.06 | 0.01 | -0.07 | **0.92** | 0.12 | 0,61 | 0,85 |
| MNEUQU | **0.73** | 0.41 | 0.28 | 0.17 | -0.08 | -0.01 | 0.19 | 0,91 | 0,83 |
| SNEUQU | **0.80** | 0.29 | 0.28 | 0.23 | -0.06 | -0.03 | 0.14 | 0,87 | 0,83 |
| KOREQU | **0.90** | -0.06 | 0.09 | -0.05 | 0.12 | -0.04 | 0.16 | 0,86 | 0,83 |
| QUALQU | **0.89** | -0.01 | 0.17 | 0.06 | 0.11 | -0.01 | 0.16 | 0,90 | 0,83 |
| FUEAIN | 0.22 | **0.80** | 0.08 | -0.02 | 0.22 | 0.02 | 0.26 | 0,83 | 0,85 |
| FUEBIN | 0.23 | **0.71** | -0.03 | 0.02 | 0.04 | 0.02 | 0.43 | 0,86 | 0,85 |
| IASOIN | 0.14 | **0.61** | 0.27 | 0.26 | 0.18 | 0.16 | 0.40 | 0,85 | 0,85 |
| AKADIN | 0.03 | 0.33 | 0.01 | 0.03 | **0.75** | -0.05 | 0.32 | 0,71 | 0,85 |
| WEIBIN | 0.24 | 0.10 | -0.01 | 0.01 | **0.64** | -0.20 | 0.48 | 0,82 | 0,88 |
| MARKIN | -0.03 | 0.20 | 0.14 | **0.74** | 0.08 | -0.09 | 0.39 | 0,70 | 0,85 |
| MNEUIN | 0.25 | 0.35 | **0.65** | 0.13 | -0.16 | 0.02 | 0.35 | 0,83 | 0,85 |
| SNEUIN | 0.27 | 0.12 | **0.74** | 0.18 | -0.05 | -0.03 | 0.33 | 0,80 | 0,85 |
| KOREIN | 0.46 | -0.14 | 0.49 | -0.06 | 0.29 | 0.16 | 0.41 | 0,91 | 0,85 |
| QUALIN | 0.24 | -0.09 | **0.60** | 0.01 | 0.41 | 0.25 | 0.35 | 0,85 | 0,85 |
| *Eigenvalue* | *7.62* | *1.89* | *1.49* | *1.25* | *1.21* | *1.00* | | | |
| *Explained variance* | *38.1* | *9.5* | *7.5* | *6.3* | *6.1* | *5.0* | | | |
| *Total* | | | | | | | | *0,86* | *0,85* |

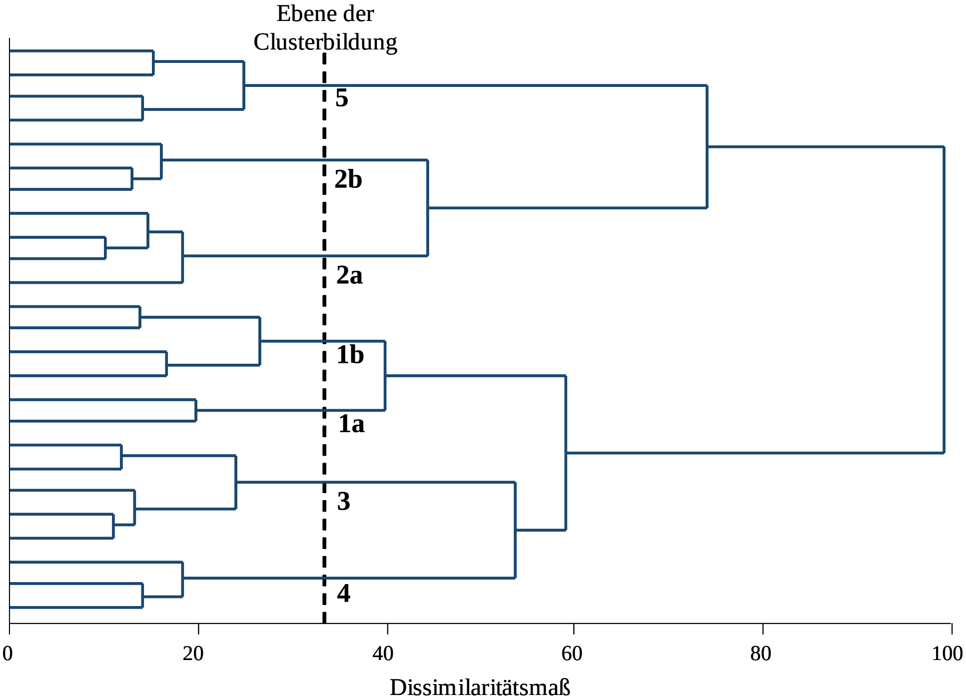
Unique: The share of variance that cannot be explained by the common factors, KMO: Kaiser-Meyer-Olkin measure, α: Cronbachs Alpha. Base: 430 NACE 2 classes. Factor loadings >0.6 are printed in bold.

Source: ZEW - Mannheimer Innovationspanel. Calculation by ZEW.

A hierarchical cluster analysis based on the six factors (via Wards Linkage and the Euclidian Distance as a distance measure) proposes a clustering by seven or five clusters (Figure 3.1). Large distances between the different aggregation levels can be found at seven clusters, five clusters and at three clusters. Since a hierarchical cluster analysis allows the aggregation of two clusters at a higher level of aggregation, we will use five clusters, with two of the five clusters being divided into two sub-clusters, for the interpretation.

In order to interpret the clusters, the mean values of the single indicators will be analyzed (Table 3.3). Cluster 1 subsumes the research intensive industries with a strong orientation towards technological innovations. With an average R&D intensity (FUEAIN) of 14%, sub-cluster 1a by far has the highest value on this indicator, whereas cluster 1b rather shows a mean R&D intensity of only 1.8%. Another difference between cluster 1b and cluster 1a can be found in the especially high orientation of companies towards process- and organizational innovations. Cluster 2, which is also divided into two sub-clusters, includes industries which mostly use expenditures into human capital (2a) or marketing activities (2b) as a strategy for knowledge generation. Cluster 3 especially includes industries that show a high innovation success with rather low investments into new technological knowledge. Cluster 4 is composed of industries, in which knowledge generation activities as well as the respective resource investments are rather low and R&D is mostly performed only occasionally. Finally, cluster 5 subsumes industries in which knowledge generation in general only plays a minor role.

*Figure 3-1: Dendrogram of the cluster analysis for clustering NACE 2 classes by their type of knowledge generation based on the results of a factor analysis*




Cluster analysis via Wards Linkage with the Euclidian Distance as a distance measure. Base: 430 NACE 2 classes.

Source: ZEW - Mannheimer Innovationspanel. Calculation by ZEW.

*Table 3.3: Indicator values differentiated by clusters*

| *Indicator* | *Cluster 1a* | *Cluster 1b* | *Cluster 2a* | *Cluster 2b* | *Cluster 3* | *Cluster 4* | *Cluster 5* |
|---|---|---|---|---|---|---|---|
| INPDQU | **78** | 63 | 35 | 40 | 58 | 44 | 20 |
| INPZQU | 51 | **56** | 35 | 31 | 49 | 37 | 20 |
| INMAQU | 65 | 58 | 51 | **77** | 64 | 50 | 36 |
| INORQU | 62 | **65** | 56 | 61 | 54 | 46 | 37 |
| FUEKQU | **74** | 49 | 22 | 18 | 35 | 26 | 7 |
| FUEGQU | 10 | 13 | 10 | 12 | 18 | **23** | 8 |
| MNEUQU | **47** | 29 | 11 | 11 | 27 | 14 | 4 |
| SNEUQU | **49** | 33 | 14 | 17 | 33 | 17 | 6 |
| KOREQU | 28 | **32** | 16 | 10 | 25 | 14 | 6 |
| QUALQU | 31 | **33** | 16 | 13 | 26 | 15 | 7 |
| FUEAIN | **14.0** | 1.8 | 1.0 | 0.9 | 1.4 | 0.9 | 0.1 |
| FUEBIN | **45.1** | 7.5 | 5.1 | 4.9 | 3.9 | 5.1 | 1.0 |
| IASOIN | **2.4** | 0.6 | 0.5 | 1.0 | 1.1 | 0.6 | 0.2 |
| AKADIN | 34 | 14 | **35** | 15 | 19 | 11 | 11 |
| WEIBIN | 798 | 495 | **1010** | 334 | 513 | 226 | 259 |
| MARKIN | 2.9 | 1.2 | 1.5 | **4.9** | 1.4 | 1.0 | 0.7 |
| MNEUIN | 5.2 | 3.0 | 1.0 | 1.5 | **7.3** | 2.5 | 0.4 |
| SNEUIN | 4.4 | 2.2 | 1.2 | 1.6 | **8.4** | 2.0 | 0.5 |
| KOREIN | 1.8 | 2.5 | 1.5 | 0.8 | **4.7** | 1.1 | 0.8 |
| QUALIN | 1.3 | 0.9 | 0.9 | 0.4 | **3.4** | 0.6 | 0.5 |
| *Number of NACE classes* | *15* | *90* | *59* | *37* | *33* | *79* | *117* |

All measures in %, except WEIBIN (in 1.000 €). Highest value printed in bold.

Source: ZEW - Mannheimer Innovationspanel. Calculation by ZEW.

Table 3.4 shows the assignment of the single NACE 2 classes to the seven sector types of research- and knowledge intensity that have been identified via the cluster analysis. The sector types consist of the following NACE 2 classes:

- Type 1a includes NACE 2 classes, whose knowledge generation activities are strongly oriented towards R&D (factor 2), and is largely consistent with the industries that have been identified as leading-edge branches on the basis of their share of internal R&D expenditures on total production. Within the cluster analysis the NACE 2 classes 01.64, 20.20, 20.52, 21.10, 21.20, 25.40, 26.30, 26.40, 26.51, 26.60, 26.70, 29.31, 72.11, 72.19 and 72.20 were grouped into this category. Differences to the classification of leading edge-technologies on the basis of the R&D intensity can be found for the classes 01.64 (seed processing for propagation), 20.52 (manufacture of glues) as well as the service sectors 72.11, 72.19 and 72.20 (research and development), which also belong to the top-group in the cluster analysis.[18] The classes 26.11 (manufacture of electronic components), 26.20 (manufacture of computers and peripheral equipment), 30.30 (manufacture of air and spacecraft and related machinery) and 30.40 (manufacture of military fighting vehicles), however, are not classified to the top-group here.

- Type 1b includes 90 classes, which mainly are characterized by a high involvement of companies in technological innovation activities (factor 1), while the relative importance of process innovation over product innovation is higher than in type 1a. The R&D intensity is at a medium level in most industries, although this type includes both research intensive and less research-intensive industries. The human capital intensity generally is low. The NACE 2 classes

[18] The classification by R&D intensity is only performed for industries of the manufacturing sector.

predominantly (76) belong to the manufacturing industry, whereby both, industries that are classified as high-level technologies due to their high R&D expenditures in relation to production volume (particularly in the fields of chemistry, mechanical engineering, electrical engineering, vehicle manufacturing), as well as industries that are not classified as research-intensive (such as food manufacturing, glass-, ceramic- and stone products industry and metal production and processing). As for the service industries insurances, rail transportation, postal services and parts of the technical wholesale industries are assigned to this type. In these industries, the generation of new knowledge is often aimed at the improvement of existing products and processes alongside known technological trajectories. The importance of high own R&D efforts often takes second place in comparison with the importance of accumulated know-how (also of skilled workers and not only academics). The classes assigned to high-level technologies can be found mostly in this type, yet they cannot be distinctly distinguished from the less research-intensive sectors with the multi-indicator approach used here.

- Type 2a essentially summarizes NACE classes with above-average human capital investment, whether in the form of a high proportion of academics among employees or in the form of very high investment in further training per employee. A total of 59 NACE classes belong to this type, including 12 from the manufacturing sector (particularly in the energy supply, but also in aircraft manufacturing) and 47 from services (especially technical services such as engineering, software, information services, telecommunications, banking, financial services, legal - and business consulting, management consulting, advertising, and some other creative services). While individual NACE classes have a very high R&D intensity, R&D plays a minor role in most industries of this type. Most industries of the knowledge-intensive services belong to this type. The common feature of the industries combined here is the central role of employees as carriers of innovation.
- Type 2b comprises 37 NACE classes - of which 14 are from the manufacturing sector - which are characterized by high investments in marketing activities (factor 4). Mostly these are industries related to the production of consumer goods (food, beverages, clothing, footwear, detergents and cosmetics) and the marketing of consumer goods (consumer goods wholesale, retail, publishing, telecommunication providers, movie rental, tour operators). The prevalence of technological innovations is comparatively low. The R&D intensity also is low in most NACE classes associated with this type, although some research-intensive industries (especially the production of detergents and cosmetics) belong to this type.
- Type 3 summarizes 33 NACE classes, mainly from the manufacturing sector (23, from different industries, including medical technologies, shipbuilding, PCB assembly) and individual service sectors (including in the areas of wholesale, logistics, public relations consulting, market research, technical laboratories) which together achieve high successes with product innovations (including product quality improvements through process innovations) (factor 3) and at the same time have comparatively few investments in R&D as well as a slightly below-average participation in innovation activities. This high "innovation efficiency" may on the one hand be due to relatively low "innovative heights", on the other hand due to the use of knowledge spillovers or knowledge acquisition.

*Table 3.4: Classification of NACE 2 classes to sectoral types of research- and knowledge intensity*

| *NACE* | *Type* | *NACE* | *Type* | *NACE* | *Type* | *NACE* | *Type* | *NACE* | *Type* | *NACE* | *Type* | *NACE* | *Type* | *NACE* | *Type* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01.11 | 4 | 14.19 | 5 | 23.32 | 4 | 27.20 | 1b | 33.13 | 1b | 46.21 | 5 | 52.10 | 5 | 68.32 | 2a |
| 01.64 | 1a | 14.20 | 4 | 23.41 | 4 | 27.31 | 1b | 33.14 | 4 | 46.31 | 5 | 52.21 | 3 | 69.10 | 2a |
| 05.10 | 4 | 14.31 | 4 | 23.44 | 1b | 27.32 | 4 | 33.15 | 5 | 46.32 | 5 | 52.22 | 5 | 69.20 | 2a |
| 05.20 | 1b | 14.39 | 1b | 23.51 | 1b | 27.33 | 4 | 33.16 | 2a | 46.33 | 2a | 52.23 | 3 | 70.10 | 5 |
| 06.10 | 2a | 15.11 | 4 | 23.61 | 4 | 27.40 | 1b | 33.17 | 5 | 46.34 | 5 | 52.24 | 1b | 70.21 | 3 |
| 06.20 | 2a | 15.12 | 4 | 23.63 | 5 | 27.51 | 3 | 33.19 | 5 | 46.37 | 2b | 52.29 | 5 | 70.22 | 2a |
| 08.11 | 5 | 15.20 | 2b | 23.64 | 1b | 27.90 | 1b | 33.20 | 4 | 46.38 | 1b | 53.10 | 1b | 71.11 | 2a |
| 08.12 | 5 | 16.10 | 5 | 23.65 | 1b | 28.11 | 1b | 35.11 | 2a | 46.39 | 5 | 53.20 | 5 | 71.12 | 2a |
| 08.91 | 1b | 16.21 | 1b | 23.70 | 5 | 28.12 | 3 | 35.12 | 2a | 46.41 | 5 | 55.10 | 2b | 71.20 | 3 |
| 08.92 | 5 | 16.22 | 1b | 23.91 | 1b | 28.13 | 1b | 35.13 | 2a | 46.42 | 5 | 56.10 | 5 | 72.11 | 1a |
| 08.93 | 5 | 16.23 | 4 | 23.99 | 4 | 28.14 | 1b | 35.14 | 2a | 46.43 | 2b | 56.21 | 5 | 72.19 | 1a |
| 09.10 | 5 | 16.24 | 5 | 24.10 | 1b | 28.15 | 1b | 35.21 | 3 | 46.45 | 4 | 56.29 | 1b | 72.20 | 1a |
| 09.90 | 5 | 16.29 | 4 | 24.20 | 1b | 28.21 | 1b | 35.22 | 2a | 46.46 | 1b | 58.11 | 2a | 73.11 | 2a |
| 10.11 | 5 | 17.12 | 1b | 24.31 | 1b | 28.22 | 1b | 35.23 | 1b | 46.47 | 2b | 58.12 | 2b | 73.12 | 3 |
| 10.13 | 5 | 17.21 | 5 | 24.32 | 1b | 28.23 | 1b | 35.30 | 5 | 46.49 | 5 | 58.13 | 2b | 73.20 | 3 |
| 10.20 | 1b | 17.22 | 1b | 24.33 | 1b | 28.24 | 3 | 36.00 | 5 | 46.51 | 5 | 58.14 | 2b | 74.10 | 5 |
| 10.31 | 3 | 17.23 | 5 | 24.34 | 4 | 28.25 | 1b | 37.00 | 5 | 46.52 | 5 | 58.19 | 5 | 74.20 | 5 |
| 10.32 | 2b | 17.24 | 3 | 24.41 | 1b | 28.29 | 1b | 38.11 | 5 | 46.61 | 5 | 58.29 | 4 | 74.30 | 2a |
| 10.39 | 4 | 17.29 | 4 | 24.42 | 1b | 28.30 | 1b | 38.12 | 2a | 46.63 | 1b | 59.11 | 4 | 74.90 | 2a |
| 10.41 | 4 | 18.11 | 4 | 24.43 | 2a | 28.41 | 1b | 38.21 | 5 | 46.65 | 5 | 59.12 | 4 | 77.22 | 5 |
| 10.42 | 2b | 18.12 | 5 | 24.44 | 1b | 28.49 | 1b | 38.22 | 5 | 46.69 | 5 | 59.13 | 2b | 77.29 | 1b |
| 10.51 | 1b | 18.13 | 3 | 24.45 | 1b | 28.91 | 3 | 38.31 | 4 | 46.71 | 2a | 59.14 | 5 | 77.33 | 5 |
| 10.61 | 1b | 18.14 | 4 | 24.51 | 4 | 28.92 | 1b | 38.32 | 5 | 46.72 | 5 | 59.20 | 5 | 77.39 | 5 |
| 10.62 | 1b | 18.20 | 3 | 24.52 | 4 | 28.93 | 4 | 39.00 | 5 | 46.73 | 5 | 60.10 | 2a | 78.10 | 5 |
| 10.71 | 4 | 19.20 | 1b | 24.53 | 4 | 28.94 | 4 | 41.10 | 5 | 46.74 | 3 | 60.20 | 2b | 78.20 | 5 |
| 10.72 | 4 | 20.11 | 1b | 24.54 | 4 | 28.95 | 1b | 41.20 | 3 | 46.75 | 5 | 61.10 | 2a | 78.30 | 5 |
| 10.73 | 4 | 20.12 | 1b | 25.11 | 5 | 28.96 | 1b | 42.11 | 2a | 46.76 | 4 | 61.20 | 2a | 79.11 | 2a |
| 10.81 | 1b | 20.13 | 1b | 25.12 | 5 | 28.99 | 1b | 42.21 | 5 | 46.77 | 5 | 61.90 | 2b | 79.12 | 2b |
| 10.82 | 1b | 20.14 | 1b | 25.21 | 3 | 29.10 | 1b | 43.11 | 5 | 46.90 | 5 | 62.01 | 2a | 79.90 | 2b |
| 10.83 | 2b | 20.15 | 1b | 25.29 | 4 | 29.20 | 4 | 43.12 | 5 | 47.11 | 2a | 62.02 | 2a | 80.10 | 5 |
| 10.84 | 4 | 20.16 | 3 | 25.30 | 3 | 29.31 | 1a | 43.21 | 5 | 47.30 | 5 | 62.03 | 2a | 80.20 | 5 |
| 10.85 | 3 | 20.20 | 1a | 25.40 | 1a | 29.32 | 1b | 43.22 | 5 | 47.51 | 2b | 62.09 | 2a | 80.30 | 5 |
| 10.86 | 1b | 20.30 | 1b | 25.50 | 4 | 30.11 | 3 | 43.31 | 5 | 47.52 | 2a | 63.11 | 2a | 81.10 | 5 |
| 10.89 | 1b | 20.41 | 2b | 25.61 | 1b | 30.12 | 4 | 43.32 | 5 | 47.53 | 2b | 63.12 | 2a | 81.21 | 5 |
| 10.91 | 4 | 20.42 | 2b | 25.62 | 5 | 30.20 | 1b | 43.33 | 5 | 47.59 | 2b | 63.91 | 4 | 81.22 | 5 |
| 10.92 | 4 | 20.51 | 4 | 25.71 | 3 | 30.30 | 2a | 43.34 | 5 | 47.62 | 5 | 63.99 | 2a | 81.29 | 5 |
| 11.01 | 5 | 20.52 | 1a | 25.72 | 1b | 30.40 | 1b | 43.39 | 5 | 47.64 | 2a | 64.11 | 1b | 81.30 | 5 |
| 11.02 | 2b | 20.53 | 4 | 25.73 | 4 | 30.91 | 3 | 43.91 | 5 | 47.71 | 2b | 64.19 | 2a | 82.11 | 5 |
| 11.05 | 2b | 20.59 | 1b | 25.91 | 4 | 30.92 | 2b | 43.99 | 5 | 47.73 | 1b | 64.20 | 2a | 82.19 | 5 |
| 11.07 | 2b | 20.60 | 3 | 25.92 | 1b | 30.99 | 2b | 45.11 | 5 | 47.78 | 2b | 64.30 | 2b | 82.20 | 5 |
| 12.00 | 1b | 21.10 | 1a | 25.93 | 4 | 31.01 | 4 | 45.19 | 5 | 47.91 | 2b | 64.91 | 2a | 82.30 | 5 |
| 13.10 | 4 | 21.20 | 1a | 25.94 | 1b | 31.02 | 4 | 45.20 | 2a | 49.10 | 1b | 64.92 | 2a | 82.91 | 4 |
| 13.20 | 4 | 22.11 | 1b | 25.99 | 4 | 31.03 | 4 | 45.31 | 2a | 49.20 | 1b | 64.99 | 2a | 82.92 | 5 |
| 13.30 | 4 | 22.19 | 4 | 26.11 | 1b | 31.09 | 4 | 45.32 | 5 | 49.31 | 5 | 65.11 | 1b | 82.99 | 2a |
| 13.91 | 4 | 22.21 | 4 | 26.12 | 3 | 32.12 | 2a | 45.40 | 2b | 49.32 | 5 | 65.12 | 1b | 85.32 | 5 |
| 13.92 | 4 | 22.22 | 4 | 26.20 | 1b | 32.13 | 3 | 46.13 | 3 | 49.39 | 5 | 65.20 | 2a | 85.59 | 2a |
| 13.93 | 4 | 22.23 | 5 | 26.30 | 1a | 32.20 | 4 | 46.14 | 5 | 49.41 | 5 | 66.12 | 2a | 86.10 | 4 |
| 13.95 | 4 | 22.29 | 4 | 26.40 | 1a | 32.30 | 4 | 46.15 | 2b | 49.42 | 5 | 66.19 | 2a | 86.22 | 1b |
| 13.96 | 4 | 23.11 | 1b | 26.51 | 1a | 32.40 | 4 | 46.16 | 5 | 49.50 | 2a | 66.21 | 2a | 86.90 | 2a |
| 13.99 | 4 | 23.12 | 4 | 26.52 | 3 | 32.50 | 3 | 46.17 | 5 | 50.10 | 5 | 66.22 | 2a | 90.04 | 3 |
| 14.11 | 4 | 23.13 | 1b | 26.60 | 1a | 32.91 | 3 | 46.18 | 4 | 50.20 | 5 | 66.30 | 2b | 93.11 | 2b |
| 14.12 | 2b | 23.14 | 4 | 26.70 | 1a | 32.99 | 2b | 46.19 | 2a | 50.30 | 5 | 68.10 | 5 | 95.11 | 5 |
| 14.13 | 2b | 23.19 | 1b | 27.11 | 1b | 33.11 | 5 | 46.21 | 5 | 50.40 | 5 | 68.20 | 2a | 95.22 | 5 |
| 14.14 | 4 | 23.31 | 4 | 27.12 | 1b | 33.12 | 5 | 46.31 | 5 | 51.10 | 2a | 68.31 | 2a | 96.01 | 3 |

Type 1a: very high R&D intensity, focus on product innovations; Type 1b: medium to high R&D intensity, focus on process innovations; Type 2a: medium to low R&D intensity, high human capital intensity, Type 2b: medium to low R&D intensity, high marketing intensity; Type 3: medium R&D efficiency, high innovation efficiency Type 4: medium to low R&D intensity, occasional R&D; Type 5: low research- and knowledge intensity.

Source: ZEW - Mannheimer Innovationspanel. Calculation by ZEW.

- Type 4 includes 79 NACE classes, most of which (70) belong to the manufacturing sector. These are characterized by low overall knowledge generation activities but a high importance of occasional R&D activities (factor 6) as an essential common feature. The R&D intensity is generally low, although some research-intensive industries (such as the production of food and textile machinery) belong to this type. In this group, there are many sectors of the textile and clothing industry, wood- and paper processing (including furniture and printing), plastics and metal processing, and processing of mineral products. Of the few service industries included, only two more significant ones, namely recording studios and movie production, are represented in this type.
- Type 5 includes 117 NACE classes, all of them characterized by low knowledge generation activities on all indicators considered. 47 NACE classes belong to the manufacturing sector, including most of the sub-sectors of the construction industry, water supply, waste disposal, the repair industry and the mining industry as well as individual sectors in the field of materials processing (including steel and metal construction, mechanical workshops, packaging paper manufacturing, lumber mills, meat processing, natural stone). Particularly low in this group is the participation of enterprises in technological innovation, suggesting a minor importance of innovation as a competitive factor.

Overall, the analysis revealed some interesting insights that can be used for future studies on the classification of industries and goods according to their research and knowledge intensity. This analysis also confirmed the category of leading-edge technology as an independent and well-defined group of economic activities following a very specific way of generating knowledge (high risk exposure due to very high R&D expenditures). The area of high-level, however, could not be identified as a clearly distinct group as well. With a broader view on knowledge generation activities, it rather seems that there is no clear distinction to a series of less research-intensive industries in the field of technical processing industry. Furthermore, for some industrial and service sectors, specific strategies of knowledge creation, based primarily on human capital and marketing investments were identified, that cannot be represented by a consideration of R&D intensity. Finally, there is a number of industries in the area of non-research-intensive industries, which have a low R&D intensity, but nevertheless carry out internal R&D activities, albeit only on an occasional basis and probably with a lower degree of novelty of the produced knowledge.

The analysis also revealed that in each industry type, both industry as well as service sectors are represented, so that the sharp dichotomy of (producing) industry (knowledge-intensive) services is not mandatory. However, most of the knowledge generation types have a clear focus on one of the two sectors, whereby the service sector is dominated by the knowledge creation type that is based on human capital investments, which confirms the importance of human capital indicators for mapping the knowledge intensity of service industries.

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# 5 Annex

*Table A 1: Matrix of correlation coefficients of the single indicators*

| *Indicator* | | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* | *15* | *16* | *17* | *18* | *19* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INPDQU | 1 | 1.00 | | | | | | | | | | | | | | | | | | |
| INPZQU | 2 | 0.73 | 1.00 | | | | | | | | | | | | | | | | | |
| INMAQU | 3 | 0.43 | 0.31 | 1.00 | | | | | | | | | | | | | | | | |
| INORQU | 4 | 0.41 | 0.50 | 0.43 | 1.00 | | | | | | | | | | | | | | | |
| FUEKQU | 5 | 0.80 | 0.79 | 0.29 | 0.40 | 1.00 | | | | | | | | | | | | | | |
| FUEGQU | 6 | 0.32 | 0.27 | 0.06 | 0.14 | 0.18 | 1.00 | | | | | | | | | | | | | |
| MNEUQU | 7 | 0.83 | 0.60 | 0.33 | 0.34 | 0.74 | 0.17 | 1.00 | | | | | | | | | | | | |
| SNEUQU | 8 | 0.87 | 0.67 | 0.41 | 0.38 | 0.75 | 0.15 | 0.86 | 1.00 | | | | | | | | | | | |
| KOREQU | 9 | 0.61 | 0.84 | 0.19 | 0.45 | 0.70 | 0.09 | 0.60 | 0.67 | 1.00 | | | | | | | | | | |
| QUALQU | 10 | 0.69 | 0.82 | 0.27 | 0.49 | 0.66 | 0.13 | 0.66 | 0.74 | 0.85 | 1.00 | | | | | | | | | |
| FUEAIN | 11 | 0.39 | 0.25 | 0.07 | 0.14 | 0.48 | 0.05 | 0.44 | 0.39 | 0.20 | 0.25 | 1.00 | | | | | | | | |
| FUEBIN | 12 | 0.37 | 0.21 | 0.13 | 0.17 | 0.44 | 0.03 | 0.37 | 0.31 | 0.16 | 0.18 | 0.53 | 1.00 | | | | | | | |
| IASOIN | 13 | 0.42 | 0.27 | 0.18 | 0.14 | 0.39 | 0.14 | 0.42 | 0.41 | 0.20 | 0.25 | 0.56 | 0.33 | 1.00 | | | | | | |
| AKADIN | 14 | 0.18 | 0.15 | -0.04 | 0.16 | 0.19 | 0.00 | 0.16 | 0.15 | 0.09 | 0.14 | 0.34 | 0.21 | 0.23 | 1.00 | | | | | |
| WEIBIN | 15 | 0.20 | 0.25 | 0.06 | 0.20 | 0.24 | -0.03 | 0.22 | 0.21 | 0.24 | 0.22 | 0.19 | 0.10 | 0.14 | 0.37 | 1.00 | | | | |
| MARKIN | 16 | 0.22 | 0.07 | 0.34 | 0.09 | 0.12 | -0.01 | 0.22 | 0.23 | 0.06 | 0.11 | 0.14 | 0.10 | 0.36 | 0.11 | 0.04 | 1.00 | | | |
| MNEUIN | 17 | 0.44 | 0.27 | 0.23 | 0.12 | 0.36 | 0.16 | 0.55 | 0.44 | 0.24 | 0.30 | 0.30 | 0.25 | 0.35 | 0.06 | 0.10 | 0.18 | 1.00 | | |
| SNEUIN | 18 | 0.43 | 0.31 | 0.32 | 0.16 | 0.30 | 0.12 | 0.41 | 0.51 | 0.28 | 0.36 | 0.21 | 0.18 | 0.28 | 0.09 | 0.11 | 0.14 | 0.53 | 1.00 | |
| KOREIN | 19 | 0.42 | 0.44 | 0.15 | 0.29 | 0.38 | 0.14 | 0.39 | 0.43 | 0.49 | 0.46 | 0.13 | 0.08 | 0.23 | 0.10 | 0.18 | 0.08 | 0.28 | 0.30 | 1.00 |
| QUALIN | 20 | 0.28 | 0.33 | 0.14 | 0.26 | 0.27 | 0.13 | 0.27 | 0.29 | 0.32 | 0.37 | 0.17 | 0.11 | 0.26 | 0.18 | 0.11 | 0.10 | 0.26 | 0.38 | 0.48 |

Base: 430 NACE 2 classes.

Source: ZEW - Mannheimer Innovationspanel. Calculation by ZEW.