

Gunther Tichy

## The innovation potential and thematic leadership of Austrian industries

### An interpretation of the Technology Delphi with regard to the old structures/high-performance paradox\*

The task of this study is twofold: First to classify the results of the Austrian Technology Delphi according to standard classifications of industry in order to facilitate their use by industrial economists and policy makers and secondly, to propose an explanation of the old structures/high-performance paradox. This paradox, familiar for quite some time to Austrian economists and most recently addressed by Peneder (1999), emphasises the contrast between the traditional low-tech structure of Austrian industry and the low R&D quota on the one hand, and Austria's excellent growth and productivity performance on the other. This contrast appears as a paradox for two reasons. Common-sense suggests that high income countries have comparative advantages in sophisticated high-skill high-quality products; while economic theory emphasises the significance of intangible investment, endogenous growth theory stressing the importance of investment in knowledge via learning by doing (Aghion and Howitt 1998), industrial economics stressing the significance of investment in R&D and marketing (sunk cost) to raise consumer's willingness to pay (Sutton 1991), or the theory of the firm emphasising the importance of firm-specific assets (1991). Austria, however, appears to invest little in R&D and in high technology and to produce and export medium rather than high technology. The share of technology-driven industries in production is one of the lowest in Europe, the share of mainstream industries one of the highest (see e.g. Polt et al 1999).

Solving this paradox is not only a challenge to theory, it is also of utmost significance for economic policy. Austria's low-tech orientation created no problems as long as the country profited from below-average wages and the steep increase in productivity exerted pressure on unit costs. It will, however, most likely pose a problem in the years to come, as Austria has already caught up in wages and industrial productivity.<sup>1</sup> Developing, producing, and exporting goods of an outstanding character to evade pure price competition and to allow a quality mark-up on prices represents the most important task (Aiginger 2000). The former Ministry of Science and Transport, therefore, commissioned a foresight research programme "Delphi Austria", comprising a Technology Delphi and a Society/Culture Delphi.

The Technology Delphi, which was carried out by the Institute of Technology Assessment of the Austrian Academy of Sciences, was specifically designed to deal with the future competitiveness of Austrian research and Austrian industry. It was launched in late 1996 and completed in early 1998. The results have been published in a 3-volume report (Delphi Report Austria 1998). In compliance with the task and the sophistication of Delphi exercises, the results were arranged (and published) according to problem-oriented field, not according to industries. This renders the integration of Delphi data into industry studies impossible. This paper attempts to join the Delphi hypotheses (assessments of innovation potentials) with ÖNACE and other widely used industrial classifications. 166 of the 271 Delphi hypotheses were classified according to ÖNACE,<sup>2</sup> comprising 15 of the 58 2-digit industries. As the aim of the Delphi was to be representative for those specific segments eligible for Austrian leadership in R&D or economic exploitation, not for industry as a whole, these are the 15 industries considered the most promising by Austrian experts.

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<sup>1</sup> In the last ten years (1988/98) industrial productivity increased by 7,6 % per year, markedly faster than in EU15-average (4,0 %), pushing Austria from the 11<sup>th</sup> to the 3<sup>rd</sup> place in the EU-hierarchy; labour cost per hour in manufacturing increased by 4,5 % per year in Austria and by 3,6 % in EU.

<sup>2</sup> Most of the hypotheses not classified are organisational ones.

## 1. The Austrian Technology Delphi

Methodologically, the Austrian Technology Delphi was designed as a Decision Delphi.<sup>3</sup> Unlike most other (classical) Technology Delphis the Austrian Delphi was not looking for emerging technologies, but for technologies and/or technological market niches with a potential for Austrian leadership in either R&D or economic or organisational application within the next 15 years. The approach was strictly problem-oriented. From a methodological point of view, this task could have been performed by expert groups as well, and some countries, as the Netherlands and Australia, actually decided to do so. In Austria, a Delphi approach was chosen for three reasons. Firstly, Delphi studies tend to show a better performance (Rowe and Wright 1999). Secondly, the number of experts in most fields is limited in small countries so that only a few or even only one person could have dominated the results. The third reason for choosing a Delphi methodology was that top experts seem to be over-enthusiastic and appear to over-emphasise the significance of their specific field (Shrum 1985, footnote 26, 38; BMFT 1993, 72f, 75; Delphi Report Austria vol. I, Fn. 38, 61), an expectation that proved correct when the Austrian data was further examined (Aichholzer 2000). The problems encountered when selecting experts and fields (hypotheses) were solved by choosing a heterogeneous sample of experts (one third from research, industry and administration/users each), in part by a co-nomination method and a strict bottom-up approach.

The search for fields (niches) with potential Austrian leadership was performed in *four rounds*, two of them based strictly on Delphi methodology. Great care, however, was taken in the two preceding unstructured rounds on account of their significance in setting the stage. Unlike many other Delphis, the questions (hypotheses) were not imposed by the monitoring team but developed in an unstructured open questionnaire, allowing the individual experts to identify the issues they felt were important: Therefore, in the *first round*, 315 top experts were asked to indicate the top fields in which Austrian research and industrial performance of today was relatively strong and with possible improvement or deterioration in the future (open questions; response rate 39 percent). The monitoring team carried out desk research on the indicated fields to determine whether they were consistent with emerging technologies in foreign Delphis and other national and international foresight exercises, studies on the strengths and weaknesses of these industries, technology indicators and a general assessment according to media analysis and trend research.<sup>4</sup> The seven most promising fields selected in this first round were Production and processing of organic food; Environmentally sound construction and new forms of housing; Lifelong learning; Medical technologies and supportive technologies for the elderly; Cleaner production and sustainable development; Mobility and transport; and Tailor-made new materials with a focus on metals.<sup>5</sup>

In a *second round*, aimed at further specifying the prospective fields, seven expert groups (one for each field) were appointed to determine the most promising areas within their fields and to specify them by means of some 40 hypotheses on specific technological and organisational innovations. These 7 times 40 hypotheses formed the basis of the Delphi questionnaires. They are a first selection of the most promising areas of potential Austrian success. In the following *two Delphi rounds*, these proposals were examined by a wider group of experts.<sup>6</sup> For any one of those hypotheses the seven respondent groups were asked to

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<sup>3</sup> Rauch (1979) distinguishes three types of Delphi studies: (1) The Classical Delphi as a tool to discover the group opinion of experts about future facts. It ensures that the future evolves according to some law or at least some regularity. (2) The Policy Delphi as a tool to clarify the positions of decision-makers; it deals with ideas and concepts, not with data and facts. (3) The Decision Delphi, a tool to co-ordinate decisions with relevance to the future, if the future does not follow a law but is influenced by a large number of small, uncoordinated decisions (the "tyranny of small decisions"). In a Decision Delphi reality is not predicted or described, it is made. Its main social function is to co-ordinate and structure the general lines of thinking in diffuse and unexplored fields of social relations and to transform future development in such an area from mere accident to carefully considered decisions.

<sup>4</sup> For details see Delphi Report Austria Vol. 1, ch. 3.

<sup>5</sup> Even stricter than in earlier Delphis the fields were deliberately selected not according to industries but according to problem-oriented technology fields.

<sup>6</sup> A total of 3748 experts received questionnaires (270 to 780 in any one of the 7 fields). 1127 questionnaires were used after the second Delphi round (90 to 220 per field).

indicate their specific professional knowledge, the respective degree of innovativeness, the importance and the chances of realisation using a scale of 1 to 5 (school grades). Furthermore, they were asked whether they believed that the respective innovation hypotheses had good chances with regard to Austrian leadership in R&D, organisational implementation, and economic exploitation respectively (percentage of agreeing respondents as a parameter), and the desirability of this innovation (yes/no). Given the preceding two rounds of the selection process, this first Delphi round (response rate 46 percent) was considered the *third round* for specifying potential areas of Austrian leadership. The answers were submitted to the usual test a second Delphi round (response rate 71 percent), actually providing the *fourth round* of promising fields specification. The analysis of the results must, therefore, consider the fact that the worst-assessed hypotheses are worst only among a selection of highly promising innovations.

At least *two important conclusions* resulted from the Delphi foresight exercise. First that the Austrian innovation system is not overly innovative. Most innovations are incremental and the planning horizon is rather short: The expert groups drafting the Delphi hypotheses were devised so as to have a time horizon of about 15 years in mind, and they were able to choose from among three stages of development of the respective innovation at the end of that period – “are developed”, “are available”, and “are in general use”. Given the long diffusion periods of innovations (if they are more than incremental), most hypotheses should have been of the first type – “are developed” in an advanced economy, and this fact was explicitly pointed out to the expert groups. However, only 12 percent of the selected hypotheses referred to this early (i.e. most innovative) stage, 37 percent to the second, and 51 percent to “general use”, a stage in which the whole diffusion process had already occurred. This last group includes radical innovations as an exception only. The Delphi respondents nevertheless considered these hypotheses to be by and large relatively innovative (on average 2.2 on a scale from 1 – best – to 5), implying a rather broad definition of “innovation”. This rather superficial concept of innovation is in full accordance with the results of the EU Innovation Survey (Leo 1999): An above-average share of Austrian enterprises reports innovations, but the innovation intensity and the share of new or improved products in Austria are definitely below the EU average.

As the *second, positive conclusion* of the foresight exercise several fields with good chances of achieving Austrian leadership were determined: Simulation models to develop new processes and products, high-tech steel and light-weight materials, recycling of composite or mixed materials, low-noise railway stock, clean technologies in metal and paper industries, wood as construction material, organic food, etc.<sup>7</sup>

## ***2. Regrouping the Delphi hypotheses according to frequently used industrial classifications***

To allow for a wider use of the results and to inquire into the Austrian structure-performance paradox the Delphi hypotheses were subdivided according to the typical classifications used in economic analysis.<sup>8</sup> These are:

- \* *Industries* according to the 2-digit ÖNACE classification: applying the rule that an industry must comprise at least 5 Delphi hypotheses, 166 of the 271 hypotheses could be allocated to 15 industries (agriculture, 8 manufacturing, and 6 service industries).
- \* Many industries were assigned less than five hypotheses; they had to be dismissed in the ÖNACE classification, as no interpretation is possible in such cases. To avoid this loss of information, the Delphi hypotheses for manufacturing were included in the usual *manufacturing industry groups* in a second step. Food and beverage (only 4 hypotheses), Intermediate products (65), Motor vehicles (12), and Investment goods (29).

<sup>7</sup> For further examples see Delphi Report Austria Vol. 2

<sup>8</sup> Applying the answers to the different fields – answered by various respondent groups – is possible, since a test with answers to common questions (“Megatrend questions”) revealed that the respondents were drawn from the same population (for details see: Delphi Report Austria Vol. 1, ch.7).

- \* Thirdly, the Delphi hypotheses were classified according to *Factor intensity groups* (Peneder 1999): Capital-intensive (34 hypotheses), Technology-driven (31), Labour-intensive (25), Marketing-driven (7), and Mainstream (5).
- \* A fourth classification according to labour qualification (Peneder 1999) comprises Low qualification (43 hypotheses), Medium blue collar (19), Medium white collar (28) and High (10).

*Tables 1 and 2 about here*

Tables 1 and 2 reveal that the Delphi hypotheses are very unevenly distributed across the industries. This is an important first result since the fields and the hypotheses of the Delphi inquiry were selected according to the chances of the respective innovations achieving Austrian leadership. The industries that were not selected, and, therefore do not show up in the results, offer little chances of innovations or Austrian success. The industries that were not selected count for three quarters of the value added. Comparing the share of Delphi hypotheses with the share in value added, Basic metals, Vehicles and Instruments appear most promising in manufacturing. Among services – one third of the selected industries –, Construction, Computer and related activities as well as Education stand out. Mainstream and Advertising intensive industries come out less promising, while good chances are given to Research-intensive and – unexpectedly – Capital- and Labour-intensive branches. Industries that rely on low-qualified labour have better chances of leadership than highly qualified ones. This indicates that industries are not the best units to study innovation and fields of potential competitiveness. Low-tech industries may sometimes offer better chances, even for high-tech innovations, than high-tech industries.

### **3. *Delphi results for ÖNACE industries***

A glance at charts 1 and 2 reveals marked differences between manufacturing and service industries. As the asymmetry indicates, Delphi hypotheses concerning services (left hand side) are generally assumed to be more innovative and more significant and more likely to gain organisational leadership, while those referring to manufacturing (right hand side) offer better chances of leadership in R&D and Economic exploitation. No significant differences in the degree of Innovativeness can be determined among the industries. As to the different dimensions of the assessment, Importance (of the hypotheses) receives the best marks,<sup>9</sup> followed by Innovativeness and chances of Realisation. Basic metals is the only industry that received poorer marks for Innovativeness than for Importance and chances of Realisation. As to chances of Austrian leadership, no clear pattern emerges. Generally, potential leadership in Organisational transposition is negatively correlated to potential R&D leadership to a strong degree and weakly to Economic exploitation leadership. This is due to the fact that technological innovations increase the chances for R&D as well as Economic exploitation, but decrease chances for Organisational implementation and vice-versa for organisational innovations.

Charts 1 and 2 about here

Ranked according to Innovativeness, the top position of Computers and related activities and of Instruments as well as the good position of Recycling are of no surprise given the structure of the Austrian industry. The top scores of Basic metals may have been expected at least by some experts. Unexpected are the top marks for innovation in Construction, the good marks for Education and Agriculture and the rather mediocre assessment of innovations in Vehicles and Health.<sup>10</sup> If, however, another measure of innovativeness is applied – the share of hypotheses of the first innovation stage (“are developed”) – a somewhat different sequence results. Instruments and Computers both rank first, followed by other

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<sup>9</sup> This should not come as a surprise since the task of the two preceding rounds was to select the most promising fields and thus the most promising innovations.

<sup>10</sup> Again it must be emphasised that this is a low rank among those selected as most promising!

Transport equipment, Recycling and Construction, with Basic metals merely in the medium range. Leadership in R&D is assessed best in Basic metals (93 percent of respondents expecting leadership), followed by Other transport equipment and Instruments; Computers ranked 10<sup>th</sup> only, with only 63 percent of respondents expecting leadership.

*Table 3 about here*

Most of the innovations ranked best with regard to Innovativeness and R&D leadership, while they are merely average at best with regard to their chances of Realisation and Economic exploitation. The best chance of Realisation in general is given to Fabricated metal products, followed by Health, Other transport equipment and Basic metals. Austrian leadership in Economic exploitation is most probable for Fabricated metal products, followed by Other transport equipment, and Basic metals. Health falls back to last place in this respect.

*Table 4 about here*

To provide a comprehensive picture, the indicators Innovativeness, Importance, and chances of Realisation were combined to one single index, the EVAL, while the probability of leadership in R&D, Organisational implementation, and Economic exploitation were combined to the LEAD index. To standardise the various scales of the indicators and to allow for the varying distances, the difference between the highest and lowest value of each indicator was divided into four equally distanced classes and aggregated.<sup>11</sup> Table 4 ranks industries according to this overall assessment. In general, EVAL and LEAD exhibit merely a slight correlation ( $r = 0,26$ ). Recycling and Other transport equipment received the best scores, falling into the top class of both EVAL and LEAD. Innovations in *Recycling* are considered to be the most important and they get a very good assessment in all other respects as well. *Other transport equipment* is less innovative than it is usually considered in Austria, but assessed excellently with regard to potential Austrian leadership in R&D and economic exploitation.

The second group of industries comprises Computer and related activities and Construction (class 1 in EVAL, 2 in LEAD) as well as Fabricated metal products and Chemical products (class 2 in EVAL, 1 in LEAD). *Computers* are considered innovative and important, with a fair chance of Austrian leadership but with little chances of Realisation. *Construction* is considered innovative, and leadership in R&D appears achievable, less so, however, in Realisation and Organisational implementation. The most innovative hypotheses in Construction refer to alternative ways of maintenance and disposal, isolation or co-operation in planning and construction. The high ranks achieved by *Fabricated metal products* results from the high scores received by Realisation and Economic exploitation. *Chemical products* are believed to have a chance of Austrian R&D leadership.

*Basic metals* rank first in Innovativeness, R&D-leadership, and Economic exploitation. The innovations in this industry are considered neither important nor especially desirable. *Instruments* are considered to be innovative, and leadership in R&D appears achievable, less so, however, in Realisation and Economic exploitation. *Agriculture* attained membership in class 2 with regard to Innovativeness, Importance, and potential leadership in R&D, reflecting the good position in organic food, and in class 3 in all other respects.

The bottom ranks are occupied by Vehicles, Health, Education and Electricity. The field *Vehicles* received good scores only for potential leadership in R&D, an assessment not untypical for a mature industry, but unexpectedly so given the Austrian preoccupations. The same is true for *Electricity*. *Education* and *Health* are both given little chance of attaining Austrian leadership with regard to Economic exploitation and R&D. Contrary to expectations, Education, however, is considered to be relatively innovative.

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<sup>11</sup> This implies equal weight (importance) of each indicator; according to this method some classes may remain empty if the distribution is strongly skewed.

*Chart 3 about here*

According to chart 3, no rank correlation exists between Innovativeness and the LEAD index. *Instruments* are the only industry considered to be innovative *and* eligible for Austrian Leadership. *Basic metals, Construction, and Computer and related activities* are considered to be innovative industries but less eligible for Leadership. *Chemical products, Other transport equipment, and Recycling* are in the first class of LEAD but only in the second of Innovativeness.<sup>12</sup> *Fabricated metal products* are among the best in LEAD but appear in the bottom class with regard to Innovativeness, while precisely the contrary is true for *Health and social work. Agriculture* attains an astonishingly good ranking in both respects. *Electricity, gas and water* as well as *Retails trade* fare worst in both respects.

*Table 5 about here*

A subdivision of respondents into Research, Business and others, foremost Administration, in table 5, shows a rather homogenous distribution. In two-fifths of all possible cases the assessments of all three respondent groups falls into the same class. Especially with regard to the two important aspects, R&D and chances of Realisation, the degree of unanimity is high (70 and 50 percent respectively). Entrepreneurs tend to assess Innovativeness marginally higher than Researchers, but are more cautious in assessing Importance and Realisation. The highest congruence of assessment among the three groups is in the sector Computer followed by Instruments and Construction, the lowest in the Chemical industry. In Computers the only discrepancy is a slightly more cautious assessment of Innovativeness by Researchers. As regards the Chemical and Basic metals industries, Researchers tend to be more cautious, especially with regard to EVAL, while they are more optimistic in assessing Recycling.

#### **4. Manufacturing industry groups**

The Delphi results are subdivided according to manufacturing industry groups – in addition to industries – for two reasons. Because those groups are frequently used in economic studies, and because the results have a broader base and hence are more significant, due to the larger sample in each group. 65 Delphi hypotheses are assigned to Intermediate products, 29 to Investment goods and 12 to Motor vehicles. Consumer goods are more or less lacking – Food and beverage was included to have at least one example – indicating that the experts do not expect major chances of Austrian leadership in this group. Again – as in the industries – Importance of the respective hypothesis gets the highest marks, followed by Innovativeness, chances of Realisation and Knowledge. Austrian leadership is considered to be achieved in R&D more likely than in Economic exploitation, and – rather obvious for manufacturing – Organisational transposition. Only R&D in Food and beverage deviates from this pattern, but the results of this group are not significant since they comprise only four Delphi hypotheses.<sup>13</sup>

*Table 6 about here*

According to table 6, *Investment goods* attain the best overall assessment, leading in Innovativeness, Importance, Desirability, and potential leadership with regard to R&D and Organisational transposition. 20 of the hypotheses (69 percent) belong to ÖNACE 33 (Medical, precision and optical instruments, watches), 5 (15 percent) to 35 (Other transport equipment) and 4 (14 percent) to 29 (Machinery and equipment n.e.c.). Instruments are considered to be less innovative with less chances of Realisation and less prone to Economic exploitation, while machinery is considered highly innovative, realisable and,

<sup>12</sup> Ranking is of course relative: Delphi working groups selected the hypotheses with the best chances of achieving Austrian leadership; the “worst” industries in the diagram (and the whole analysis) are therefore the worst among the best.

<sup>13</sup> It is included only because it is the sole representative of consumer goods in the whole Delphi exercise.

together with transport equipment, economically applicable. At the top in overall assessment are Low-noise equipment for railways, the Modular design of railway cars, and the Redesigning of solar collectors, allowing cheap mass production.

*Charts 4 and 5 about here*

The leading position of investment goods in Innovativeness is underlined by the share of Delphi hypotheses in the first development stage (“are developed”). 48 percent of the Investment good hypotheses belong to this category, compared to 25 percent of the Vehicle, and 12 percent of Basic products hypotheses. Only 34 percent of the Investment good hypotheses belong to the lowest innovation stage (“are in general use”) compared with 52 percent and 58 percent in the other two groups.

*Intermediate goods* come first in Realisation, R&D, as well as Economic exploitation and second in overall assessment (EVAL), Innovativeness and Desirability. More than one third of the hypotheses belong to ÖNACE 27 (Basic iron and steel, steel alloys), a little less than a quarter to 28 (Fabricated metal products) and 24 (Chemical and chemical products) respectively. ÖNACE 37 (Recycling) and 20 (Wood, products of wood and cork) comprise less than 10 percent, 21 (Pulp, paper and paper products) and 26 (Other non-metallic mineral products) less than 5 percent. The hypotheses regarding the Iron and steel industry are considered the most innovative and eligible for leadership in R&D with Economic applicability slightly above and chances of Realisation slightly below average. The experts considered a large number of hypotheses in this industry eligible for Austrian leadership, and the Delphi respondents evidently agreed. Iron and steel, therefore, comes out as the top candidate. Further evidence of Austrian competence in this field is the assessment of Fabricated metal products, an industry not considered to be as innovative but with very good chances in Realisation and Economic exploitation. Recycling is considered important with chances of leadership in Organisational transposition. The innovations in the Chemical industry hold the average in Innovativeness and are far below average in Realisation and R&D leadership.

The industry group *Motor vehicles, trailers and semitrailers* is identical to the respective industry (ÖNACE 34). It ranks lowest among the industry groups, in the first group only in potential R&D leadership. The relatively best score was given to Management of power propelling systems in Innovativeness, Importance, chances of Realisation and R&D leadership.

Only small differences can be detected in the assessments provided by different respondent groups. The assessment is almost unanimous with regard to Investment goods, less so for Vehicles, and the small and insignificant group Food and beverage. No simple optimism-pessimism pattern emerges apart from a slightly more optimistic stance towards Organisational transposition among Administrators, probably resulting from the fact, that they can help to support it.

## 5. *Factor intensity groups*

The classification of manufacturing industries according to factor input has been used more widely since integration and globalisation increased competition between countries with widely varying factor endowment and factor prices. The classification used here was proposed by Peneder (1999) and is based on US factor content data. The Labour-intensive, Capital-intensive, and Research-intensive groups comprise about 30 Delphi hypotheses each. The results, therefore, can be taken as representative. This is not the case for the Mainstream and Advertising-intensive groups, comprising five and seven rather untypical hypotheses respectively. The fact that the experts could not find starting points in these groups with regard to potential leadership in the future and, therefore, did not formulate Delphi hypotheses in these fields, points towards a serious structural weakness of Austrian industry: Mainstream and Labour-intensive industries dominate (see table 2) and are more important in Austria than in other European countries.

*Charts 6 and 7 about here*

Charts 6 and 7 as well as table 7 underline this problematic aspect. The hypotheses regarding Research-intensive industries necessarily received the highest marks for Innovativeness. However, Respondents consider themselves best informed about Mainstream industries, least about Research-intensive industries. Evidently, even experts are not as familiar with Research-intensive industries as with more traditional ones. They consider the few hypotheses about innovations in Mainstream sectors most important and desirable, they expect the best chances of Realisation in Labour-intensive and the worst in Research- as well as in Advertising-intensive sectors. Potential leadership in R&D and in Economic exploitation is seen both in Capital intensive and Labour intensive sectors.

*Table 7 about here*

*Labour-intensive manufacturing* ranks highest of all in chances of Realisation, Economic exploitation, and LEAD. Ten of the 25 hypotheses belong to ÖNACE 28 (Fabricated metal products) with very good chances of Realisation, five to 35 (Other transport equipment) with good marks for Importance, four to ÖNACE 20 (Wood, products of wood and cork), considered to be relatively innovative, and two each to ÖNACE 26 (Other non-metallic mineral products), 27 (Basic metals) and 34 (Motor vehicles, trailers, and semi-trailers). To qualify these results we should not forget, however, that high-tech or at any rate medium-tech innovations can be found in labour-intensive sectors as well. Ceramic materials (ceramic functional agents), aspects of Welding, or Low-noise railway stock are examples in the Delphi.

The few hypotheses referring to *Mainstream industries* receive the best scores for Importance and Desirability(!), and are practically equal to the leading Research-intensive industries in Innovativeness. They also rank second (EVAL + LEAD) both in Realisation and Economic exploitation. This implies both a rather traditional stance among Austrian experts and the existence of at least a few promising segments in this traditional sector.

*Research-intensive industries* rank first only in Innovativeness but even here the lead over Mainstream industries is negligible. They are second in Importance, potential R&D leadership and Organisational transposition, but the innovations aimed at are less likely to be realised and economically exploited as those of any other industry. 20 of the 31 hypotheses stem from ÖNACE 33 (Medical, precision and optical instruments, watches), with good marks in Organisational transposition, bad marks in Importance and average marks in all other dimensions. Six hypotheses belong to ÖNACE 24 (Chemical and chemical products), considered to be innovative and important, but with reservations as to Realisation and Economic exploitation. Five innovations belong to ÖNACE 34 (Motor vehicles, trailers, and semi-trailers), regarded as not innovative but rather good in the other dimensions.

The overall assessment of the Research-intensive industries does not appear to give them good chances in Austria which is rather disconcerting for a high income country. Table 8 provides additional evidence comparing the two indicators of innovativeness used in this study, i.e. the mark for Innovativeness given by the respondents and the stage of innovation. The stage of innovation indicates clearly that important innovations arise predominately in the Research-intensive sector, while the respondents give only marginally better marks for Innovativeness in these industries. 45 percent of the innovations in research-intensive sectors are “radical” in the sense that they are expected to be merely “developed” 15 years from now. Only one third of this sector’s innovations are “incremental” (“in general use”). In contrast, more than half of the other groups’ innovations are “incremental”. The share of medium innovations (“available”) is highest in the Labour-intensive sector (40 percent), a sector not normally considered to be innovative. These innovations refer to advanced uses of wood, advanced metal processing and vehicles. Three conclusions result. Firstly, given the fact that the Delphi fields and the Delphi hypotheses were deliberately selected to find niches of potential Austrian leadership, good chances for Austrian competitiveness exist in low-tech fields as well. Secondly, even the experts appear to have a rather broad definition of “innovation” and give good marks for Innovativeness even for incremental innovations, a fact typical for the Innovation Survey as well (Leo 1999). Thirdly even experts do neither notice nor appreciate the innovative potential of radical innovations.

*Table 8 about here*

*Capital-intensive industries* have best chances of achieving R&D leadership and receive rather good marks for their Innovativeness and Economic exploitation. In the general assessment, however, they rank fourth only due to low marks in Importance, chances of Realisation, and Organisational transposition. 20 of the 34 hypotheses refer to ÖNACE 27 (Basic metals), leading in Innovativeness and potential Realisation, six to ÖNACE 24 (Chemical and chemical products) with potential leadership in Organisational transposition, five to 34 (Motor vehicles, trailers, and semi-trailers), two to 21 (Pulp, paper and paper products), and one to 17 (Textiles).

Again, the scores do not differ significantly among the groups of Delphi respondents. Some differences appear in Capital-intensive industries on the one hand and in Organisational transposition on the other, the Administration being more optimistic in both cases. Researchers tend to be slightly more pessimistic in general, Administrators slightly more optimistic.

## 6. *Qualification groups*

Finally, the Delphi hypotheses were grouped according to Peneder's (1999) qualification-of-labour groups. The distribution of hypotheses among these groups is already revealing. 43 percent of the hypotheses selected by experts with regard to their innovation potential and chances of Austrian leadership refer to Low-qualification industries, only 10 percent to High-qualification industries. Interestingly, both are considered to be innovative. The Low-qualification industries also have good chances of obtaining Austrian leadership in R&D and adequate chances of achieving leadership in Economic exploitation. High-qualification industries lead in Importance and Desirability as well, but the results are hardly convincing due to the limited number of hypotheses and their lack of representativeness. Industries with Medium blue collar qualification are considered least innovative and least eligible for Austrian R&D leadership, but likely to attain leadership in Economic exploitation. Industries in which Medium white collar qualification are assessed just as inconspicuous in any respect.

Most interestingly, the differences in scores from the respondent groups are more significant in this classification. They differ most in Medium-qualification industries and least in High-qualification industries. On average, Researchers give the best marks to Medium-qualification industries, Administrators to High- and Low-qualification industries. Entrepreneurs take a medium position in any case. Researchers tend to assess Innovativeness lower and the chances of R&D leadership and Organisational transposition higher, while Administrators are more pessimistic with regard to Organisational transposition and more optimistic as to Innovativeness and Realisation.

*Table 9 about here*

The assessment reveals that high- and low-qualification industries are considered equally innovative, with low-qualification industries even more likely to attain R&D leadership. Innovations in high-qualification industries qualify as more important and more desirable but less familiar to experts and less prone to Economic exploitation. This does not mean that Austria has no chances in High-qualification industries, as even innovations with the worst marks are worst only among a selection of the most promising ones. Nevertheless this fact points to the solution of the Austrian old structures/high-performance paradox, at least an important part thereof. The results of the Delphi analysis are strongly indicative of Austrian chances in medium- to high-tech market niches of medium- to low-qualification industries. Most of the innovations in these industries refer to the materials sector. Those with the highest innovation marks are metallic foams, thermal management, gradient nanomaterials, particle reinforced steels, ceramic functional materials for engines and the like.

## 7. Conclusions

Making the Delphi results applicable to several industry classifications allows us to analyse which industries, input factors, or qualifications are considered most innovative, important or realisable, and which promise the best chances of achieving Austrian leadership with regard to R&D, Organisational implementation, or Economic exploitation. The results are unexpected and surprising, apparently partly confirming and partly explaining the Austrian old structures/high-performance paradox. The top marks for Innovativeness are awarded to Low- and High-qualification industries, Mainstream and Research-intensive industries, Computer and related activities, Instruments as well as Basic metals and Construction. For innovations in Basic, Mainstream, and Low-qualification industries experts emphasise the additional advantage of easier realisation. As to Austrian R&D leadership, Delphi respondents detect rather better chances for Low labour-qualification industries, especially for Basic materials, Chemicals, Vehicles, and Other transport equipment. Pretty much the same is true for Austrian leadership in Economic exploitation.

Embarrassing is the opinion considering innovations just as likely and equally important in high-tech as in low-tech industries that is shared by all groups of experts. Part of this can be explained by the not very ambitious concept of innovation. Even experts appear to regard bare marginal improvements as innovations and they underestimate radical innovations. The actual explanation, however, lies deeper. The widely accepted dichotomous view of industry, restricting innovations to high-tech branches, does not appear to be empirically based. The traditional industry classifications are, therefore, inadequate to deal with aspects of technology. The variance within the industries exceeds those in-between. Technical progress and advances in productivity occur in low-tech industries as well as in high-tech industries, and quite often innovations in low-tech industries are of a high-tech nature. Insofar, the old structures/high-performance paradox is apparently a paradox of preoccupation, not one of reality. It is based on an innovation paradigm which may reflect U.S.-American structures, not European ones.

The purpose of an innovation system is to capture, diffuse, and magnify spillovers of technical and organisational knowledge. The types of (transferable) knowledge and potential spillovers determine the nature of the system, which necessarily differs from country to country. European innovations (and the economic development of European countries) depend more on the further development of specific fields of long-standing knowledge (Carlsson 1997), on co-operation with customers, organisational networks, and detection of market niches. It is more important to direct receiver competence (absorptive capacity) towards customers and suppliers rather than universities. Heidenreich (1999) emphasises that European competitiveness relies on experience-based knowledge stocks, incremental innovation patterns, and diversified quality production rather than on science-based innovations, so typical of the US. Europe is world-wide leader in “embedded software” and is paralysed in “packed software” (BoozAllen&Hamilton 2000). The European concept of “diversified quality production” (Sorge and Streek 1988) has been empirically tested by Aiginger (2000). He found that Europe's competitive advantage and EU's trade surplus in fact rest entirely on a “quality premium”, not on high-tech.

Given this specific European innovation paradigm, the Austrian old structures/high-performance paradox is part of an European pseudo-paradox based on the unjustified lack of differentiation between innovation and technical progress in research intensive high-tech industries. Austria, however, appears to be a pronounced variant of this model. “Among European countries, *Austria* stands out as having a particularly low share of EU value added in technology-driven industries which repeatedly (...) suggests that Austria is most similar to countries such as Spain and Portugal. ... The fact that, in 1997, the labour productivity of total manufacturing in Austria was 46 percent above that of Spain and 69 percent above that of Portugal illustrates that similar patterns of specialisation can still comprise very different kinds of activities.” (Peneder 1999, 244). Austria's high share of basic and mainstream industries rests on a solid long-maintained knowledge base in several fields, which is usually regarded as medium technology (e.g. advanced materials, vehicle components, machinery, bio-food). The concentration on intermediate rather than consumer goods assigns prime importance of receiver competence towards commercial customers.

No wonder, therefore, that the Austrian innovation pattern shows the “European” characteristics in pronounced form. More than half of the Delphi hypotheses refer to intermediate products. In many cases, they deal with the introduction of high-tech processes or methods into industries classified as basic/mainstream/low-tech according to traditional schemes. Insofar, the Austrian “old structures” are quite modern in many cases, and their “high performance” does not necessarily constitute a paradox. The Delphi exercise nevertheless revealed that the time horizon of Austrian innovators is rather short and their pretensions modest. Insofar, elements of a paradox and some danger for the future may remain. Path-dependence, incremental improvement and dominating customer relations prevent radical innovations (Christensen and Rosenbloom 1995) and delay structural change. Old structures/low-performance could result in the future.

## Literature

- Aghion, P. and P. Howitt, 1998, *Endogenous growth theory*, Cambridge, Mass.: MIT Press.
- Aichholzer, G., 2000, Over-enthusiastic experts? Some results of the Austrian Technology Delphi, mimeo.
- Aiginger, K., 2000, *Europe's Position in Quality Competition*, Commissioned by the European Commission, DG Enterprise for the Competitiveness Report 2000, mimeo: Austrian Institute of Economic Research.
- BMFT (Bundesministerium für Forschung und Technologie), 1993, *Deutscher Delphi Bericht zur Entwicklung von Wissenschaft und Technik*, Bonn.
- BoozAllen&Hamilton and Ministry of Economic Affairs-The Netherlands, 2000, The competitiveness of Europe's ICT Markets.
- Carlson, B., 1997, On and off the beaten path: the evolution of four technological systems in Sweden, *International Journal of Industrial Organization* 15(6), 775-99.
- Caves, R.E., 1991, *Corporate mergers in international economic integration*, in Giovannini, A., Mayer, C., eds, *European financial integration*, Cambridge: Cambridge University Press, 136-60.
- Christensen, C.M. and R.S. Rosenbloom, 1995, Explaining the attacker's advantage: technological paradigms, organizational dynamics, and the value network, *Research Policy* 24, 233-57.
- Delphi Report Austria, 1998, *Technologie Delphi I – III*, Studie des Instituts für Technikfolgen-Abschätzung im Auftrag des Bundesministeriums für Wissenschaft und Verkehr, Wien.
- Heidenreich, M., 1999, Gibt es einen europäischen Weg in die Wissensgesellschaft? *Soziale Welt Sonderband 13* (G. Schmidt und R. Trinczek, Hg, Ökonomische und soziale Herausforderungen am Ende des zwanzigsten Jahrhunderts, Baden-Baden: Nomos).
- Leo, H., 1999, Österreichs Innovations- und Forschungsleistung im internationalen Vergleich, *Monatsberichte des Österreichischen Instituts für Wirtschaftsforschung* 72 (6), 435-43; english version .....
- Peneder, M., 1999, The Austrian paradox: “Old” structures but high performance? *Austrian Economic Quarterly* 4(4), 239-47.
- Polt, W. et al, 1999, *Österreichischer Technologiebericht 1999*, Wien: Österreichisches Institut für Wirtschaftsforschung und Österreichisches Forschungszentrum Seibersdorf.
- Rauch, W., 1979, The Decision Delphi, *Technological Forecasting and Social Change* 15, 159-69.
- Rowe, G. and G. Wright, 1999, The Delphi technique as a forecasting tool: issues and analysis, *International Journal of Forecasting* 15(4), 353-75.
- Shrum, W., 1985, Quality judgement of technical fields: bias, marginality and the role of the elite, *Scientometrics* 8, 35-57.
- Sorge, A., and W. Streek, 1988, Industrial relations and technical change: the case for an extended perspective, in R. Hyman and W. Streek, eds, *New technology and industrial relations*, Oxford: Blackwell, 19-47.
- Sutton, J., 1991, *Sunk cost and market structure. Price competition, advertising, and the evolution of concentration*, Cambridge, Mass.: MIT Press.



Table 1: Classification of Delphi hypotheses according to industry groups

Industry groups (ÖNACE)	# of hypotheses	% of hypotheses	% of value added	Manufacturing industry group	# of hypotheses	% of hypotheses	% of value added
Agriculture (01)	12	7	1				
Chemical products (24)	14	9	2	Food and beverage	4	4	9
Basic metals (27)	23	14	1	+ Intermediate products*	65	59	43
Fabricated metal products (28)	15	9	2	+ Motor vehicles	12	11	6
Recycling (37)	5	3	0	+ Investment goods*	29	26	19
Vehicles (34)	12	7	1	Other manufacturing	-	-	23
Instruments (33)	20	12	0				
Other transport equipment (35)	5	3	0				
Electricity, gas, water (40)	5	3	3				
Construction (45)	16	10	8				
Retail trade (52)	5	3	4				
Computer & related act. (72)	13	8	1				
Education (80)	12	7	0				
Health and social work (85)	5	3	3				
Other industries	0	0	-				
Sum of classified hypotheses	162	100	-		110	100	-
Unclassified	109		74				-
Total	271		100				100

\* Includes Delphi hypotheses from additional ÖNACE industries not included in the left-hand column (as they comprise less than 5 items)

Table 2: Classification of Delphi hypotheses according to frequently used manufacturing industry groups

Industry groups	# of hypotheses	% of hypotheses	% of value added	Factor intensity groups	# of hypotheses	% of hypotheses	% of value added	Labour qualification groups	# of hypotheses	% of hypotheses	% of value added
Food&beverage	4	4	9	Mainstream	5	5	26	Low	43	43	36
Intermed. prod.	65	59	43	Labour-intens.	25	24	19	Med. blue collar	19	19	27
Motor vehicles	12	11	6	Capital-intens.	34	34	17	Med. white collar	28	28	23
Investm. goods	29	26	19	Advertising-int.	7	7	25	High	10	10	14
Other	--	--	23	Research-int.	31	31	14				
Total	110	100	100		102	100	100		100	100	100

Table 3: Delphi assessment according to ÖNACE industry groups

Industry (ÖNACE)	<i>knowledge</i>	Mark as to			Probability of leadership as to			<i>Desirability</i>
		innovati- veness	impor- tance	chance of realisation	R&D	organisat. transpos.	economic exploitation	
Agriculture (01)	2.77	2.23	1.91	2.65	66.57	51.23	57.97	88.80
Chemical products (24)	3.15	2.19	1.88	2.49	78.13	41.02	59.76	93.77
Basic metals (27)	3.05	2.06	2.09	2.44	93.10	11.76	72.38	93.07
Fabricated metal products (28)	3.02	2.44	2.00	2.19	71.07	32.71	83.62	95.71
Instruments (33)	3.14	2.09	1.8	2.54	83.57	43.03	52.95	94.73
Vehicles (34)	3.20	2.36	2.06	2.55	79.26	26.57	68.23	88.90
Other transport equipment (35)	3.22	2.19	1.77	2.39	87.40	24.96	76.42	97.02
Recycling (37)	2.88	2.14	1.58	2.49	52.64	61.52	67.06	97.46
Electricity, gas, water (40)	2.76	2.41	2.24	2.82	74.68	30.96	63.34	87.90
Construction (45)	2.61	2.10	1.78	2.59	67.61	39.12	70.01	92.68
Retail trade (52)	2.28	2.38	1.86	2.54	10.48	80.74	69.42	90.60
Computer & related act. (72)	2.72	1.99	1.62	2.54	54.83	62.68	50.28	97.68
Education (80)	2.34	2.13	1.82	2.70	36.58	76.63	39.04	93.43
Health and social work (85)	2.35	2.52	1.64	2.37	16.46	93.44	34.40	96.20

Table 4: Ranking of ÖNACE industry groups (4 indicator classes)\*

	Class of				Class of Austrian leadership in				<i>Class of desirability</i>
	innovati- veness	impor- tance	reali- sation	EVAL	R&D	organis. implem.	econ. exploit.	LEAD	
Recycling (37)	2	1	2	1	2	2	2	1	1
Computer (72)	1	1	3	1	2	2	3	2	1
Other transport equip (35)	2	2	2	1	1	4	1	1	1
Basic metals (27)	1	3	2	2	1	4	1	2	2
Fab. metal prod.(28)	4	3	1	2	2	3	1	1	1
Chemical products (24)	2	2	2	2	1	3	2	1	2
Instruments (33)	1	2	3	1	1	3	3	1	2
Construction (45)	1	2	3	1	2	3	2	2	3
Retail trade (52)	3	2	3	2	4	1	2	3	3
Agriculture (01)	2	2	3	2	2	3	3	2	4
Vehicles (34)	3	3	3	3	1	4	2	2	4
Health (85)	4	1	2	2	4	1	4	4	1
Education (80)	2	2	4	2	3	1	4	4	2
Electricity (40)	4	4	4	4	1	4	2	2	4

\* 1 best, see text

Table 5: Assessments of different respondent groups (ranks\*)

	Mark as to									Probability of leadership in									Desirability		
	innovati- veness			importance			realisation			R&D			organis. transpos.			economic exploitation					
	R	E	A	R	E	A	R	E	A	R	E	A	R	E	A	R	E	A	R	E	A
Agriculture	<u>3</u>	<u>1</u>	<u>3</u>	2	2	3	<u>4</u>	<u>4</u>	<u>4</u>	2	2	2	2	3	3	2	3	3	<u>4</u>	<u>4</u>	<u>4</u>
Chemical products	<u>3</u>	<u>1</u>	<u>2</u>	3	3	2	<u>3</u>	<u>3</u>	<u>2</u>	1	1	1	3	3	4	2	3	3	2	2	1
Basic metals	2	1	1	3	4	3	<u>2</u>	<u>2</u>	<u>2</u>	1	1	1	4	4	3	2	1	1	<u>3</u>	<u>2</u>	<u>1</u>
Fabricated metal products	4	3	4	3	3	2	1	1	1	2	1	2	4	4	4	1	1	1	2	1	1
Instruments	<u>2</u>	<u>1</u>	<u>4</u>	2	2	3	<u>3</u>	<u>3</u>	<u>3</u>	1	1	1	3	3	3	3	3	2	2	2	2
Vehicles	<u>3</u>	<u>2</u>	<u>4</u>	3	4	3	2	3	3	1	1	1	3	4	3	2	2	2	<u>3</u>	<u>4</u>	<u>2</u>
Other transport equipment	3	2	2	2	2	1	2	2	3	1	1	1	4	4	4	1	1	1	1	1	2
Recycling	1	1	2	<u>1</u>	<u>1</u>	<u>1</u>	2	3	2	2	3	2	2	2	3	1	2	2	1	1	1
Electricity, gas, water	4	3	4	4	4	4	4	4	4	2	1	2	4	4	4	2	2	3	4	4	3
Construction	<u>1</u>	<u>1</u>	<u>1</u>	2	2	2	<u>3</u>	<u>3</u>	<u>3</u>	2	2	2	3	3	4	1	2	2	2	3	2
Retail trade	4	3	4	2	3	2	2	3	3	4	4	4	1	1	1	1	2	2	4	4	3
Computer & related activities	2	1	1	<u>1</u>	<u>1</u>	<u>1</u>	<u>3</u>	<u>3</u>	<u>3</u>	2	2	2	2	2	3	3	3	3	1	1	1
Education	2	2	1	3	2	2	4	4	3	3	4	3	1	1	2	4	4	4	2	2	2
Health & social work	4	4	3	<u>2</u>	<u>3</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>1</u>	4	4	4	1	1	1	4	4	4	2	2	1

Shaded areas: unanimity; underlined: small differences; bold and underlined: large differences

R: Researcher; E: Entrepreneurs; A: Administration and others

\* see text

Table 6: Delphi assessments according to manufacturing groups

	know- ledge	Mark as to			Class of EVAL*	Probability of leadership in			Class of LEAD*	Desira- bility
		innova- tiveness	impor- tance	reali- sation		R&D	organis. transpos.	economic exploitation		
Intermediate products	3.04	2.19	1.96	2.40	2	79.89	28.09	72.35	1	94.31
Motor vehicles	3.20	2.36	2.06	2.55	4	79.26	26.57	68.23	2	88.90
Investment goods	3.09	2.10	1.78	2.49	1	83.59	38.16	60.12	1	95.28
Food and beverage	2.70	2.19	1.91	2.65	3	56.20	36.03	70.93	4	89.55

\* see text

Table 7: Delphi assessment according to factor intensity groups

	know- ledge	Mark as to			Class of EVAL*	Probability of leadership in			Class of LEAD*	Desira- bility
		innovative ness	impor- tance	realisation		R&D	organis. transpos.	economic exploitat.		
Mainstream	2.79	2.11	1.70	2.31	1	75.50	30.10	77.78	1	96.50
Labour-intensive	3.03	2.24	1.89	2.25	1	82.38	22.79	82.38	1	96.25
Capital-intensive	3.15	2.18	2.11	2.50	2	84.84	20.40	70.29	4	92.11
Advertising-intens.	2.81	2.51	2.13	2.58	3	58.91	45.57	72.73	4	92.53
Research-intens.	3.15	2.10	1.80	2.55	4	83.48	41.32	52.61	4	93.11

\* see text

Table 8: Different indicators of innovativeness

	Mark as to innovativeness	Stage of innovation 15 years, hence						total #
		"developed"		"available"		"in general use"		
		#	%	#	%	#	%	
Research-intensive	2.10	14	45 %	7	23 %	10	32 %	31
Mainstream	2.11	2	(40 %)	-	-	3	(60 %)	5
Capital-intensive	2.18	6	18 %	10	29 %	18	53 %	34
Labour-intensive	2.24	2	8 %	10	40 %	13	52 %	25
Advertising-intensive	2.51	-	-	3	(43 %)	4	(57 %)	7

Table 9: Delphi assessment according to labour qualification groups

	know-ledge	Mark as to			Class of EVAL*	Probability of leadership in			Class of LEAD*	Desirability
		innovati-veness	impor-tance	realisa-tion		R&D	organis. transpos.	economic exploitation		
Low	3.06	2.11	2.12	2.50	1	88.17	14.23	71.25	4	92.47
Medium blue	3.04	2.32	1.94	2.36	4	77.83	29.16	77.09	1	93.65
Medium white	3.11	2.14	1.87	2.50	1	80.32	39.38	60.84	2	94.11
High	3.17	2.11	1.66	2.45	1	80.11	42.94	51.11	4	95.66

\* see text

Chart 1: Delphi assessment - ÖNACE-industries

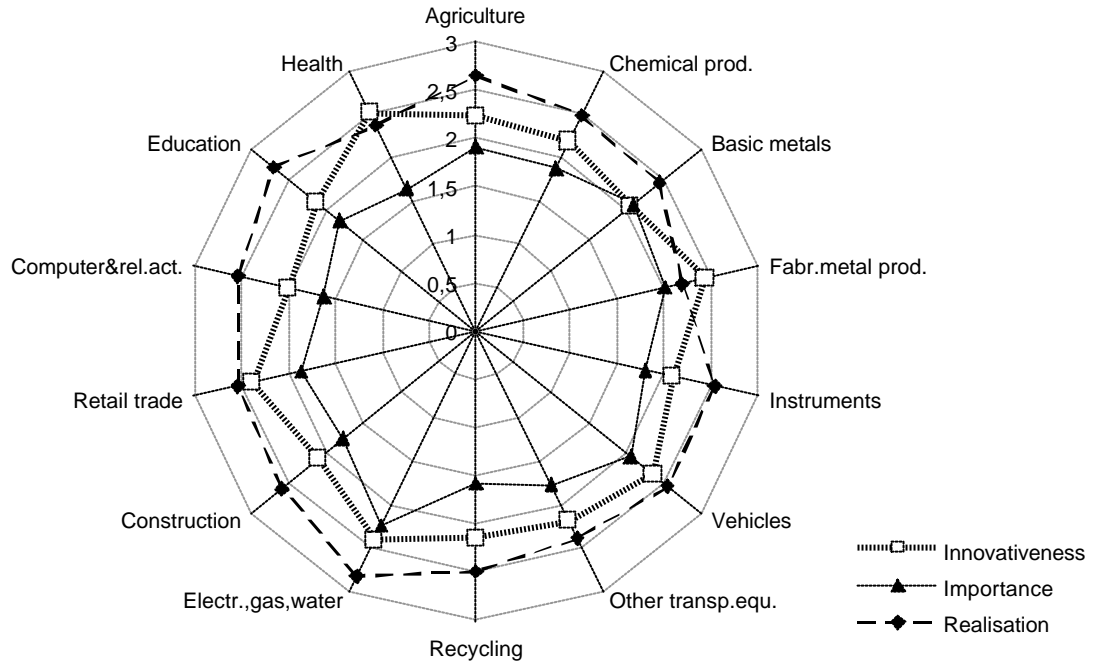
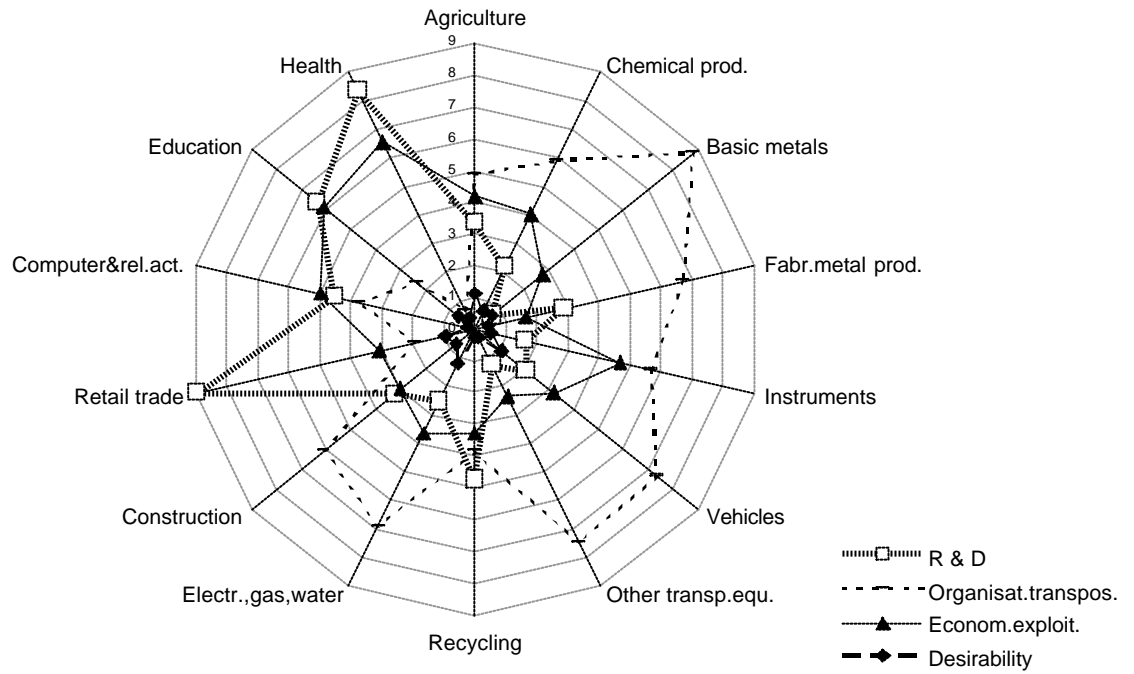


Chart 2: Delphi leadership - ÖNACE-industries



To make the different measurements comparable the data was multiplied by  $(100 - x)/10$

Chart 3: Innovation and LEAD

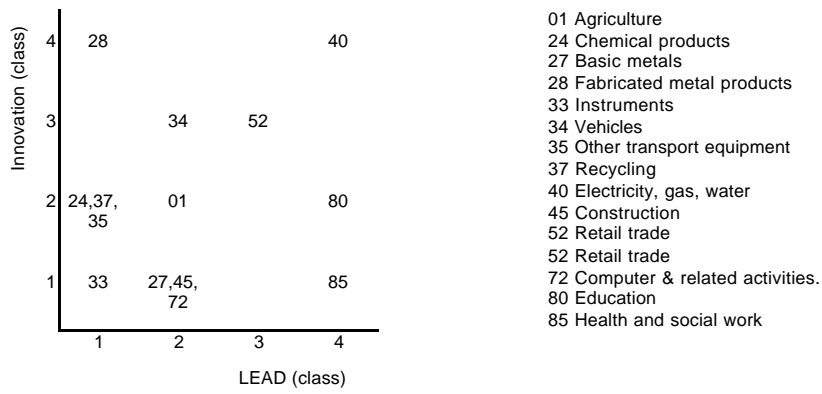


Chart 4: Delphi assessment - Manufacturing groups

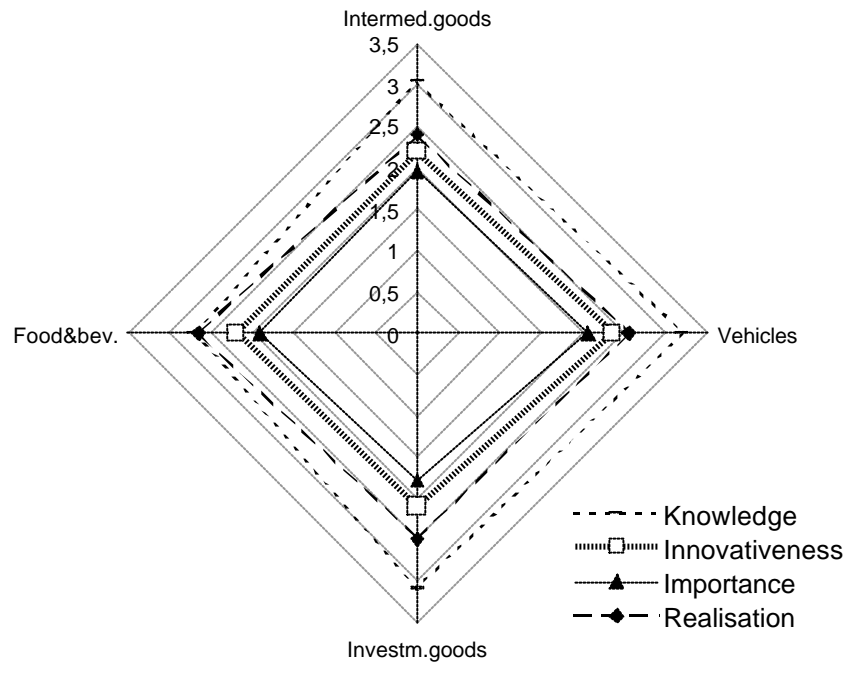
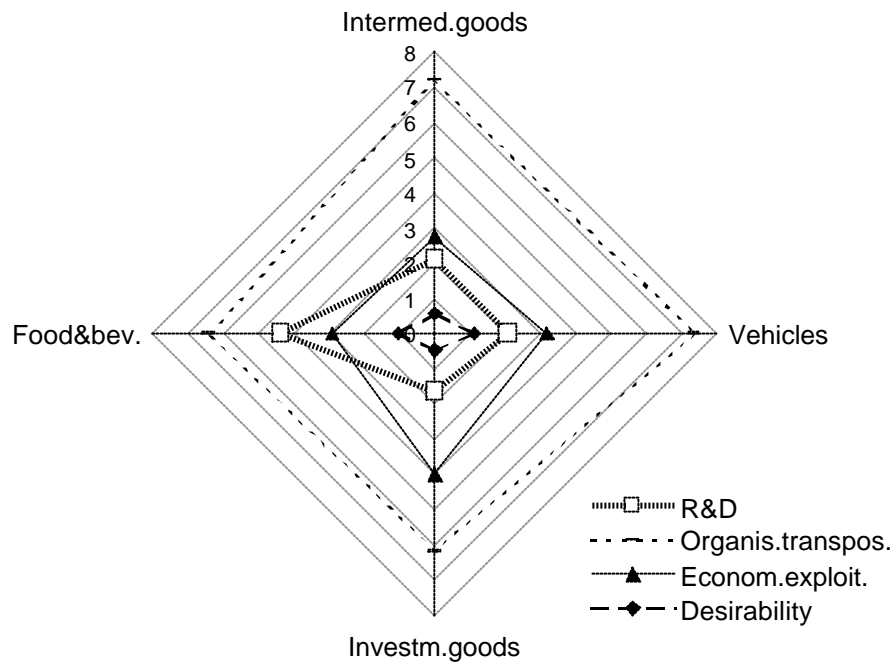


Chart 5: Delphi leadership - Manufacturing groups



To make the different measurements comparable the data were multiplied by  $(100 - x)/10$

Chart 6: Delphi-Assesment - Factor intensity groups

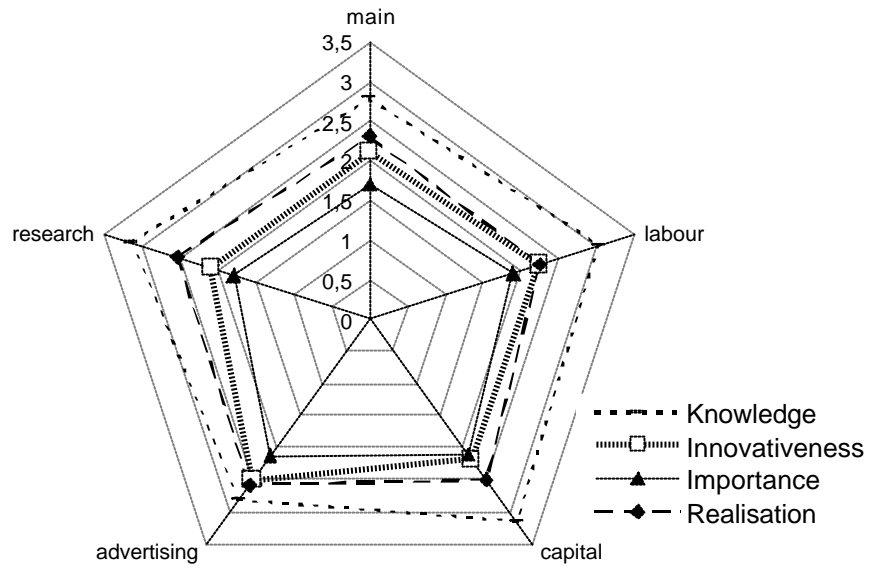
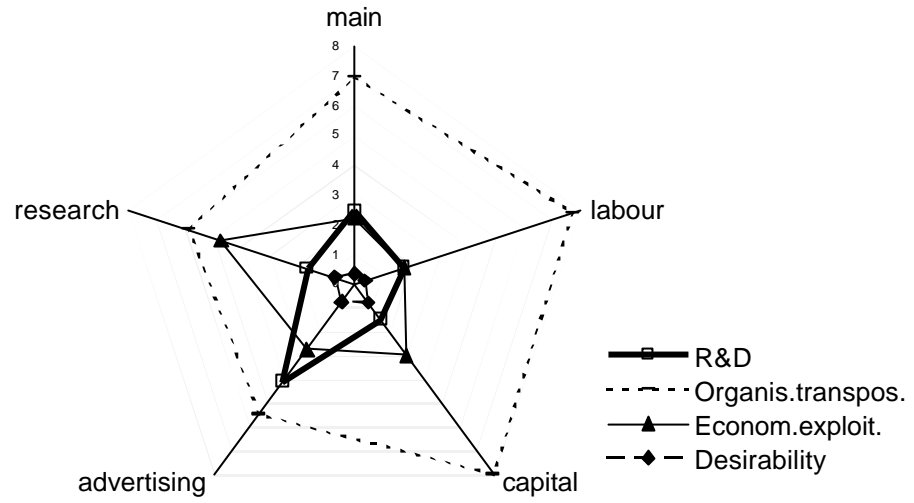


Chart 7: Delphi leadership - Factor intensity groups



To make the different measurements comparable the data were multiplied by  $(100 - x)/10$