2015

MAIN FOCUS
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Innovation Indicator

acatech
NATIONAL ACADEMY OF SCIENCE AND ENGINEERING

BDI
The Voice of German Industry

Fraunhofer ISI

ZEW
Zentrum für Europäische Wirtschaftsforschung GmbH
Centre for European Economic Research

On the German-language website for the Innovation Indicator, you will find a detailed methodological report and further background material. Also, using „My indicator“ you can compare individual economies there. The site is available on all devices from desktop PCs to smartphones.

www.innovationsindikator.de

Scan the QR code and directly access the site.

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Preface

Since the Federation of German Industries (BDI) and the Deutsche Telekom Stiftung published the first Innovation Indicator ten years ago, it has been informing policy-makers and society continuously and concisely about Germany's innovative capacity in an international comparison, and about a framework for a successful innovation system. The Innovation Indicator depicts Germany's innovative capacity compared to its main rivals in a ranking based on transparent influencing factors which are collected in an up-to-date manner.

Such a world ranking of innovative economies might have its methodological limitations: this year, for example, the pack chasing the leader are in parts very close to each other – so close that individual differences in the ranking order are difficult to interpret. Also, this system of indicators does not reflect all the complex inter-relationships of international innovation competition. The methodology that we, together with the Fraunhofer Institute for Systems and Innovation Research (ISI) and the Centre for European Economic Research (ZEW), continue to develop, still gives an important overview of international innovation activity, success factors and hampering parameters.

In any case, the results of the indicators analysis never stand alone: they always need to be evaluated against the concretely experienced backgrounds in science, industry, politics and society and enriched by the latest information and expert assessments. Our new partnership will also contribute to this: in the anniversary year, acatech – National Academy of Science and Engineering and the BDI are jointly publishing the Innovation Indicator for the first time. At the same time, we are extending the range of our print and online formats by an English edition, because the Innovation Indicator has long garnered interest internationally.

With the Innovation Indicator we want to enter into a dialog with you about Germany's future as a location for business and science. In this sense, we wish you an interesting read and look forward to future discussions with you.

Henning Kagermann
President
acatech

Ulrich Grillo
President
Federation of German Industries

Key results

A look at the economies

- **Germany** is asserting itself in the international innovation competition in a difficult global economic environment and in the Innovation Indicator it remains at the front of the pursuer group. Other Euro area countries such as France have significantly greater problems maintaining a connection to the top group. Among Germany's strengths are high-tech exports, technology-based innovations as well as the close cooperation between science and industry. There is a great demand for innovation and a wide range of high quality products in this country. The performance of the German education system has continued to improve, but still lags behind that of the top group. With regards to demographic development, the need for highly qualified junior staff, particularly in the STEM area, represents a major challenge to the innovation system. New technologies and current policy objectives such as the Digital Agenda, Industrie 4.0 or the *Energiewende* (energy transition) depend on both experts from the academic field and highly qualified and skilled workers. Germany's future claim must be to ascend to a top position in innovation competition. Germany cannot afford a standstill in the efforts to improve its framework conditions for innovation.
- **Switzerland** remains the frontrunner in the Innovation Indicator but has, however, lost points because research and development expenditures have fallen.
- **Belgium** has established itself in the top group. The country is characterized by a well-functioning, well-balanced innovation system.
- The **US** economy has further improved its innovative capability. On the other hand, the US continues to lose ground in science and education.
- **Sweden** falls back this year due to lack of investment in education and research. It now belongs to the large group in the midfield.
- **South Korea,** by comparison, continues an upward trend. The country scores with highly innovative companies and a more efficient science system.
- **China** cannot improve and remains behind the midfield. The reason: the People's Republic's exports are faltering, the economy is cooling down. The long-term consequences are not yet foreseeable. Reforms in the scientific system and the economy are either absent or have no effect. With the importance of China as a market, as well as its global links, a minimally dynamic development in China will continue to have a knock-on effect on Germany's innovative economy.

The Federal Palace in Bern: according to the results of the Innovation Indicator Switzerland remains the most innovative country in the world.

On the importance of small and medium-sized enterprises

The group of small and medium-sized enterprises (SMEs) is very heterogeneous. They range from the so-called hidden champions, medium-sized world market leaders with an often impressive innovation performance, to many small businesses that produce innovations sporadically or with a low demand for technology. Although Germany has many SMEs, which are technologically at the top, German SMEs are on average not more innovative than SMEs in other countries. Expenditures on research and development (R&D) of SMEs in Germany account for 0.31 percent of GDP – Switzerland, Austria, Denmark, Finland or South Korea reach almost three times this value.

At first glance – considering the sheer numbers – SMEs play only a secondary role for the German innovation system: the contribution of SMEs to R&D expenditure in the German economy was only around 16 percent. In the US, the SME share of R&D expenditure is 19 percent, in Sweden, South Korea and Taiwan about 27 percent. There are two explanations: first, Germany has many relatively large and very innovative large enterprises. Thus, the share of SMEs in the total R&D expenditure of the economy quickly turns out lower arithmetically than in countries with a few large companies. Second, German SMEs which conduct R&D spend less on it, on average, than SMEs in other countries.

Concerning hidden champions though, Germany has a distinctly special position: no other country has so many medium-sized world market leaders. Almost half of the world's hidden champions come from Germany. Industries such as mechanical engineering, electrical engineering and metalworking bring forth very many such companies. In a world of constantly more differentiating value chains, a high export orientation is a success factor.

No other economy has as many small and medium sized world market leaders as Germany. One example: Herrenknecht AG from Schwanau. Their tunnel boring machines are used around the world.

Hidden champions combine three features: a high readiness to export on the part of top management, a strong focus on customer requirements, and focus on niche markets. That Germany in particular has so many hidden champions is also due to the smallness of the domestic market for many niche applications: in order to achieve efficient production volume, the global market has to be served. This niche-oriented strategy simultaneously leads to the fact that only a few hidden champions manage the leap to a global corporation. Because global market volume is limited, so are growth opportunities.

Recommendations for action

How Germany improves

Better conditions for innovative entrepreneurial activities

With its new High-Tech Strategy, the federal government is pursuing consistency in its innovation policy, but at the same time is also emphasizing new facets: internationalization, participation and transparency, the validation of results from public research, and digitization. The interdepartmental approach of the High-Tech Strategy is to be seen as positive, while the effects of the new, well-reasoned approaches and their programmatic and operative implementation are yet to show.

In order to ensure high effectiveness and efficiency of public research funding, impact analyses should be regularly conducted according to standard evaluation criteria. In addition, the criteria according to which research funding is distributed to the individual fields of the High-Tech Strategy should be made transparent.

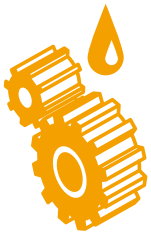
Above all, increased investments in data and transport infrastructures are needed to meet the ambitious goals addressed in the Digital Agenda. In this, the speed of implementation is of paramount importance: the international competition for digital transformation exerts great pressure on Germany as a location for innovation.

It is particularly important that the participating players join together quickly to engage in the implementation mode. In particular, the enterprises should not delay their innovation efforts by waiting until policy-makers provide corresponding support funds.

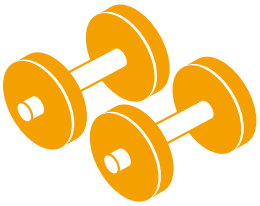
Politicians must for their part improve the framework conditions for innovative entrepreneurship. This includes not least the realization of the digital European single market. A small domestic market due to a lack of integration of European markets might prove an obstacle to innovation. Innovation policy must not be limited to the narrow area of education, research and knowledge transfer, but rather must also take into account that labor, tax and energy policy strongly influence the national innovation capability.

European research funding can be an important driver of the development of the German science and innovation landscape. The new research framework program – Horizon 2020 – has a large budget available; at the same time there is a clearer commitment to excellence and to promotion based on competence rather than proportional representation.

Projects with European funding are particularly advantageous for Germany because of their international dimension: the strong export orientation of the economy and the high level of international networking and efficiency of research facilitate access for German companies and research institutions considerably. The innovation policies of federal and state governments should place their programs' emphasis on synergies with the European promotion.



Significantly strengthen education and science



Education and science form a crucial foundation for the success of an innovation system. Skills in science, technology and business are the basis for the ability to adapt to new challenges in the course of life. But it is precisely in the field of STEM subjects (science, technology, engineering and mathematics) that the educational system is in need of further action: the interest of pupils in STEM subjects continues to decrease, the shortage of teachers in STEM subjects is becoming an increasing problem and the drop-out rates in some STEM fields of study are still above average.[1]

Federal and state governments need to coordinate more in the field of higher education. It must under no circumstances be limited to only a redistribution of existing funding or even a reduction of funds. On the contrary, one goal must be an increase in funding. The continuation of the pacts and the resulting planning certainty are important federal policy priorities – the federal states now have to take them up constructively and actually use them to strengthen the universities.

At the organizational level incentives and conditions for excellent research and teaching must be strengthened. To this end, the performance-oriented allocation of funds should be strengthened at both the institutional and the individual level. Here the idea of excellence in basic research should be central. “Lighthouses” in this field in particular are an important source of inventions and thus ensure the economic performance capability of Germany as a location in the area of future breakthrough innovations. They must not be neglected in favor of a strong application in research funding.

Furthermore, the next generation of scientists must be given better opportunities to develop their own research profiles. This chiefly includes the wide-spread implementation of a full-scale tenure-track system, that is a career system in which young scientists, after they have proven their scientific merit, can be taken on into permanent employment. This would not only create more stable career paths, but also strengthen the independence of young scientists. Furthermore, the conversion of small-scale chair structures to a department organization of faculties should be considered. This would allow existing cooperation potentials within the faculties to be better exploited. It would further increase the strategic capability of the faculties, which can support profile-building processes of the universities.

There is also a need for action in the promotion of cooperation between science and industry. This applies particularly to SMEs. Although quite successful programs exist, the application processes are, however, often demanding, so that SMEs are deterred. The bureaucratic hurdles have to be lowered here. Innovation policy should also especially promote the phase of transition from publicly funded research to commercial exploitation of research results with suitable conditions, for example for startups and to mobilize private capital.

Realize the principle of easy access for SMEs

SMEs face greater difficulties than large enterprises in the implementation of innovative ideas: R&D projects are costly. SMEs have often difficulties to finance them internally. External financing is often difficult, since external capital providers find it difficult to assess the performance capability of SMEs. And if a project fails, it can easily endanger the existence of the entire company. The resource weakness of SMEs is at the same time opposed by a strength in implementation: they are usually better able than large companies to bring innovations to market quickly. Publicly supporting innovation activity in SMEs makes a lot of sense economically: Firstly, it mobilizes additional innovation potential. Secondly, it leads to rapid innovation successes. And thirdly, it can contribute significantly to an increase in the technological performance of the economy, especially when innovative SMEs and science are brought together.

An essential starting point for the strengthening of SMEs is financing. Currently German SMEs on average expend less on research and innovation than their counterparts in most other European countries. Unlike in many other countries German SMEs often have to finance their total expenditure on research and innovation from their own resources, because the public support programs reach only a part of the SMEs. This applies especially to SMEs that operate no formal R&D. They represent the majority of innovative SMEs in Germany and pursue quite promising innovation strategies. Most other countries in the Innovation Indicator, in contrast, offer indirect support, usually in the form of tax incentives. Such a broadly effective instrument is missing in Germany. Many innovation projects in SMEs are therefore financially subcritical or only achieve a lower level of innovation.

When designing R&D support based on tax incentives, the incentivizing effects of this instrument must be in the foreground. Moreover, in all measures of R&D and innovation support the principle of easy access should apply: application procedure and the administration of funded projects must be designed to be as simple and unbureaucratic as possible.

A second important starting point is the skilled labor situation. Regarding access to highly qualified labor SMEs are structurally disadvantaged. The demographic development additionally aggravates the shortage of skilled workers. Professionals who immigrate from foreign countries could improve this situation. SMEs, however, have to overcome hurdles in the recruitment of highly qualified immigrants: easier bureaucratic procedures and support in the resulting administrative procedures would help. A general threshold reduction in gross annual salary in the context of the “EU Blue Card” scheme could compensate for the structural disadvantage for SMEs.

However, it is by no means ensured that SMEs will in the future contribute to the same extent as in the past to securing Germany’s leading position in the innovation competition. Especially in the industries which have been successful so far, Germany only has a low number of startups which fundamentally change the markets through innovations and thus further accelerate the structural change of an economy – for example in the context of the digital transformation. The innovation policy support strategies need to focus more strongly on these essential players in the innovation system. Open digital platforms provide new opportunities for SMEs and startups to bring their innovation to bear in the emerging digital ecosystems and to network with other actors.[2]

1 See for example young STEM barometer (MINT Nachwuchsbarometer) 2014 and 2015 (Eds.: acatech/Körber Foundation)
2 See also the report on Smart Service World (www.acatech.de/smart-service-welt)

Introduction

New products, processes and services that prevail in markets, or improving the quality of existing products and processes, are referred to as innovations in an economic respect. Innovation is the key to competitiveness and growth for most companies and entire industries. Germany is especially reliant on innovations in order to secure the growth of its economy and prosperity, as well as the public sector's capacity to act in the face of demographic change.

From an economic perspective, a variety of factors and influences promote private innovation or even render it possible. There are also numerous players – companies, research institutions, funding agencies, educational institutions, but also innovation financiers and buyers and users of innovations, who often improve and adapt services and products themselves – so-called user-led innovation. The interplay of these factors, influences and actors constitute the national innovation system.

A well-functioning innovation system allows companies to be innovative, and thus secures jobs and prosperity. However, the companies as providers of innovative goods and services face competition – and this is also true in a broader sense for innovation systems. It is important that companies and organizations as well as politics or public organizations can assess and pinpoint Germany's position in the global competition for innovation. Only then can they take measures to secure or improve the situation. For this purpose, a differentiated analysis and international comparisons are indispensable.

The Innovation Indicator has exactly this goal. On behalf of acatech – National Academy of Science and Engineering and the Federation of German Industries (BDI), 35 economies are examined to determine how innovation-oriented and capable they are. The Innovation Indicator is prepared by the Fraunhofer Institute for Systems and Innovation Research (ISI) in Karlsruhe in cooperation with the Centre for European Economic Research (ZEW) in Mannheim. It compares the innovation performance of 35 countries based on 38 individual indicators.

Basic principles of the Innovation Indicator are:

1. Model-based approach to the selection of indicators: each of the 38 indicators was selected based on its statistically verified explanatory value for the national innovation performances. In this way, both clarity and the relevance of the results is ensured.
2. Sub-division of the indicators according to input / output and sub-systems (industry, education, science, state, society): this allows detailed analysis of the strengths and weaknesses of individual countries and thus targeted recommendations for action.
3. Incorporating hard and soft indicators: innovation activities depend not only on directly measurable factors, such as the available financial and human resources, but also on rather soft, not directly measurable factors such as societal attitudes. The Innovation Indicator also collects relevant data of these soft factors to reflect innovation systems in their entirety. This sets it apart from many similar indicator systems.
4. Timeliness of the results by using forecasting and extrapolation methods (Now-Casting) for the individual indicators: all indicators relate to 2014.

Challenges in measurement

The Innovation Indicator is a so-called composite indicator, in which individual sub-indicators, relevant for the innovation system, are compacted by weighting to a summary measure. The Innovation Indicator uses an equal weighting in order to keep the calculation transparent and comprehensible. However, other weighting methods would be feasible and have been used in comparable analyses. To analyze the robustness of the results to different weights, the authors of the study use modern statistical simulation methods. Here, the results prove to be extremely robust and the classifications of the analysis to be reliable.

Thus, although different weighting methods lead to slight differences in the actual performance of the countries, clearly recognizable assignments to certain groups of economies emerge, however, largely independent of the respective weighting. It can therefore be stated with great certainty whether a country, for example, is one of the pursuers or in the leading group. Accordingly, the interpretation of the ranking positions will focus mainly on this group membership and stable long-term development trends. Minor changes to the previous years, as well as shorter gaps between countries should not be over-interpreted.

Dynamic environment

Innovation systems are highly dynamic: they change constantly and often in ways difficult to predict. These changes can have a serious impact on the functioning of the innovation system. This in turn provides measurement models such as the Innovation Indicator with major challenges, because it captures the economy's innovative capabilities based on a previously defined set of indicators. Unexpected developments and structural changes, as for example those in the wake of the digital transformation of the economy, on the one hand, require a constant critical examination of the appropriateness of the indicators used.

On the other hand, the approach of purely quantitative indicators must always be complemented by qualitative assessments that seek to anticipate developments that may be reflected in measurable figures only in years to come. For these reasons, the Innovation Indicator follows the approach of supplementing the quantitative results with qualitative assessments in a targeted manner, which explicitly seek to take into account both the current policy context as well as possible future developments.

Structure of the survey

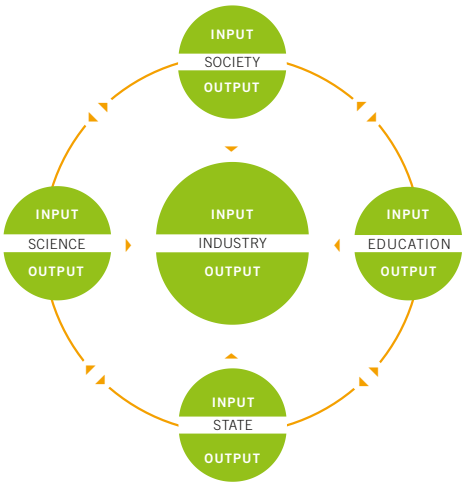
The previous chapters summarize the key findings and point to some key future challenges for innovation policy and the innovation system. The first main chapter presents the results of the indicators of 35 countries from the overall perspective and discusses the positions of selected countries – including, of course, Germany in particular. This is followed by results for the various sections of the innovation system: industry, science, education, state and society.

The focus theme of this year's Innovation Indicator deals with small and medium-sized enterprises (SMEs) in the innovation process and their particular characteristics and needs. The topic will be discussed from different perspectives. On the one hand, we discuss research-intensive SMEs and their innovation patterns. On the other hand, we analyze the specific features of companies with no or only little own formal research and development, which are nevertheless active in innovation. Another focus is on medium-sized hidden champions. These are companies with high export orientation, a strong global market position and dynamic development, which are little known to the general public. In addition, the performance of SMEs in Germany and Japan is compared and the stronger international position of German SMEs is discussed.

Website with more information

The report summarizes the main results of the analyses based on 2014 data. Profiles for individual countries or comparisons between different economies can be created on the German language website **www.innovationsindikator.de.** There a detailed documentation of the methods and indicators used is also available.

Main elements of the Innovation Indicator model



Source: authors' own illustration

Results

Germany still has room for improvement

35 countries in an innovation comparison

The innovation competition is becoming more intense. The leading group is slowly losing their lead over the group of pursuers. The particularly innovative countries are moving closer together. Switzerland remains in the lead.

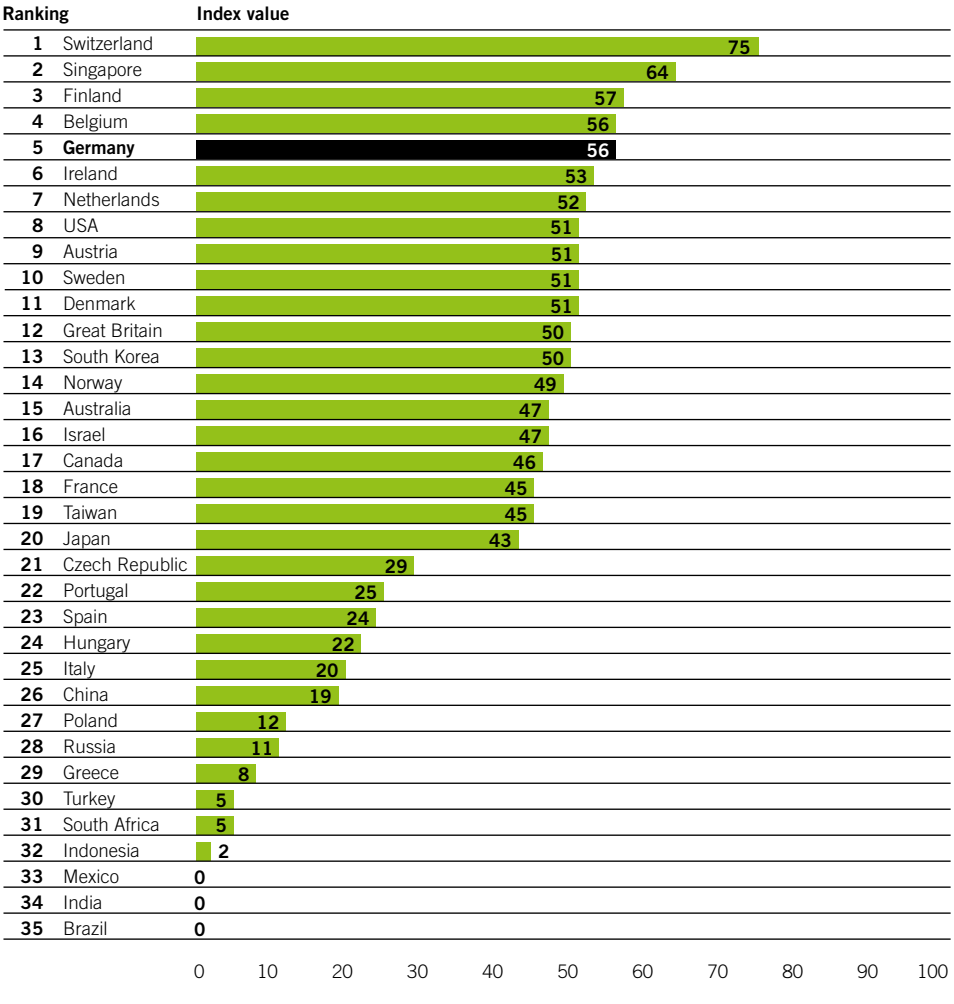
The Innovation Indicator uses a variety of indicators which condense the different dimensions of innovation into a single measure. The results show that groups of similarly performing countries have emerged. The group membership remains fairly stable over time, while shifts can take place within the groups, which can be explained by short-term economic fluctuations as well as minor changes in the performance capability of the sub-systems. When things get tight, even small alterations can have great impacts on the rankings.

According to the results Germany may not be part of the absolute top in the international innovation comparison, as should be its aspiration, but instead is part of the directly pursuing group. Noteworthy is the fact that Germany performs best in the Innovation Indicator in comparison with the large economies, although countries like the US or Great Britain are to be found only slightly behind Germany in the pursuer group.

The Innovation Indicator utilizes normalized indicators throughout, in order to evaluate the innovation capability of a country as independently as possible from its size. The target values prosperity or gross domestic product are for instance measured in relation to population size. To ensure wealth and growth of an economy through innovations, the goal must be to achieve the best possible results per capita. This is depicted by the Innovation Indicator.

For large economies this results in an even greater challenge, as they must achieve a high performance across the board. Smaller countries can more easily achieve specialization advantages. Naturally, the thematic and sectoral profiles of larger countries are broader, therefore their portfolios include themes in which their performance capability is less pronounced or in which innovation plays a smaller part. The index values of the Innovation Indicator reflects the manifold and complex dimensions of innovation. The study creates a uniform scale for measuring the innovation performance and capability of 35 economies.

Overall result of the Innovation Indicator



Industrie 4.0 was one of the top topics at this year's CeBIT. Partner country was among others China, which, after the United States has the largest IT market in the world.

Once again – as has been the case since the investigation period began in 1990 – the results identify Switzerland as the most innovative country worldwide. Together with Singapore it forms the leading group. As the sensitivity analysis proves, both countries are always in the lead, no matter how the individual indicators are weighted.

In a longer-term perspective, however, it becomes apparent that Switzerland was only able to increase its lead until the beginning of the 2000s. Since then the gap to the other countries has narrowed. The other countries are catching up. The differences in performance capability are diminishing not only in the midfield, but especially at the top. Germany, in the fifth position this year, belongs to the pursuer group behind Switzerland and Singapore. Germany has thus managed to stay on course despite difficult economic times and a worldwide climate not ideally conducive to innovations. The world economy grew only to a small extent in 2014, principally because China's development was less dynamic than expected. As the Peoples' Republic has become increasingly important worldwide for innovative products, this was not without consequences: the interwoven economic relationships in sectors such as the automotive industry, electrical engineering and consumer electronics have for a long time meant that Europa feels the effects if the Chinese economy cools down. The American economy on the other hand has not yet recovered to an extent to which it could compensate for developments in the Chinese market.

This scenario – reversed – occurred in the recovery phase following the sharp decline in economic output in 2009: growth in China was able to clearly mitigate weaknesses of the US economy. Thus Germany's economy was able to survive these tough times well. Now the difficult times have also reached China's economy and negative impacts on Germany's economy seem impossible to avoid. In the current year 2015 the prognoses for China also seem anything but rosy. In addition, the difficulties in Europe remain. The European Single Market, the most important market for German products and in particular for innovative high-tech goods displays a rather restrained dynamic.

Innovation world champion soon?

Whether Germany will succeed in the coming years in moving up to the top group and fulfil its claim of being one of the leading innovation nations, depends on the one hand, on whether the topic of innovation continues to remain a top priority on the agenda of relevant players in science, industry, politics and society. In particular, these considerations should not be restricted to the narrow range of education, research and knowledge transfer. Rather, the innovation capacity of the German economy is influenced to a considerable extent by the decisions in other policy areas, such

as labor, tax and energy policy. Thus the question must be addressed, how innovative activity can better play a more central role in all economic and social policy decision-making processes.

Topics like digitalization, the modern workplace or sustainability of the energy supply are still high up on the political agenda. Concrete implementation of projects has already partly commenced. These activities extend beyond the Digital Agenda and Industrie 4.0 closely connected with it: issues like the renewal of the energy supply, mobility and environmental protection are also equally affected. In any case, these challenges call for joint efforts to create optimal framework conditions for innovations in these areas. Governments and policy-makers are especially called upon when it comes to the continuous improvement of infrastructures for education, research and knowledge transfer as well as promoting competition as a top priority vehicle in the process of discovering new solutions.

The group of pursuers following the top group in the innovation competition is led by Finland, Belgium and Germany. Belgium, which was able to continually expand its innovation capacity since the middle of the past decade and has maintained this level in the past years, has established itself as an especially innovative country. Behind Germany the frontrunners of the midfield start, comprising Ireland, the Netherlands, the USA, Austria and Sweden, and extending to Denmark, Great Britain, South Korea and Norway.

In this group, Ireland has stabilized after its years of crisis. The USA presents a somewhat different picture. Admittedly, the economic crisis has been largely overcome. This means positive impulses of the innovative performance of the US economy, especially for the Internet economy. In addition, they certainly have an enormous potential – not least on account of the size of the domestic market – for example against the background of the digital shift, to significantly advance the development of new business models. What could slow the USA down, however, is the relative stagnation in two crucial areas of the innovation system. For education and science in the USA – by comparison with most of the other countries – are still on a slight downward slope. Austria was able to advance to the front midfield group. Austria improved in education and science and profits from the fact that several other countries lost points.

Sweden loses ground

Sweden is now in the upper midfield. At the end of the 1990s and during the entire first decade of the new millennium Sweden belonged to the top group. Since 2001, a negative development has been observed. Essentially, the causes are to be found in the sub-indicators education, government and industry. The Swedish education system has clearly lost out on quality which is visible in the PISA results. In addition the budgets for public services such as education and administration have not been substantially increased since the middle of the 2000s, which is why performance as a whole has declined.

Sweden's ranking as the sensitivity analyses show, is based on an unfavorable constellation of indicators. These analyses thus confirm an imbalance based on a few single indicators and do not point to a general loss of performance in the whole innovation system – at least not yet. Recently, the country has been pursuing a new strategy, which is based among others on the German High-tech Strategy. For the future certainly more is to be expected of Sweden than this year's place at the end of the pursuer group. South Korea's ranking improved this year. The country presents itself as a strong, emerging economy, which so far has only been able to present its strengths in a few areas like information and communication technologies.

Germany must have the aspiration to become the world's leading innovation nation.

China fails to catch up with the midfield.

The country is working on broadening its technological basis, for instance in materials technology and biotechnology, thus demonstrating its role as an innovation-oriented and developed economy. South Korea's somewhat improved index scores result primarily from the improved result in the science sub-indicator. With the exception of international co-publications, South Korea improved its performance in all other sectors of the sub-indicator science. South Korea achieved especially good scores in the expenditures for research and development in publicly funded research institutions and for patent applications stemming from public research.

Overall ranking of countries 2000–2014

Rank	2000	2005	2010	2013	2014
1	Switzerland	Switzerland	Switzerland	Switzerland	Switzerland
2	Sweden	Sweden	Singapore	Singapore	Singapore
3	USA	USA	Sweden	Finland	Finland
4	Finland	Finland	**Germany**	Belgium	Belgium
5	Belgium	Singapore	Finland	Sweden	**Germany**
6	Singapore	Netherlands	Netherlands	**Germany**	Ireland
7	Israel	Canada	Norway	Norway	Netherlands
8	Canada	Denmark	Austria	Netherlands	USA
9	France	Belgium	USA	Ireland	Austria
10	**Germany**	**Germany**	Belgium	Great Britain	Sweden
11	Netherlands	Norway	Canada	Taiwan	Denmark
12	Denmark	Great Britain	Taiwan	Denmark	Great Britain
13	Great Britain	Austria	Denmark	USA	South Korea
14	Norway	Israel	France	Austria	Norway
15	Japan	France	Great Britain	Canada	Australia
16	Australia	Australia	Australia	Australia	Israel
17	Austria	Ireland	Ireland	France	Canada
18	Ireland	Japan	South Korea	South Korea	France
19	South Korea	South Korea	Israel	Israel	Taiwan
20	Taiwan	Taiwan	Japan	Japan	Japan
21	Czech Republic	Czech Republic	Czech Republic	Czech Republic	Czech Republic
22	Russia	Spain	Hungary	Spain	Portugal
23	Hungary	Hungary	Spain	Portugal	Spain
24	Spain	India	Portugal	China	Hungary
25	India	Italy	China	Hungary	Italy
26	Italy	China	Italy	Italy	China
27	Poland	Russia	India	Russia	Poland
28	Indonesia	Poland	Russia	Greece	Russia
29	China	Portugal	Poland	Poland	Greece
30	Greece	Greece	Greece	South Africa	Turkey
31	Portugal	South Africa	Indonesia	Indonesia	South Africa
32	Brazil	Indonesia	South Africa	Turkey	Indonesia
33	Mexico	Brazil	Brazil	India	Brazil
34	Turkey	Mexico	Mexico	Brazil	India
35	South Africa	Turkey	Turkey	Mexico	Mexico

The lower midfield begins with Australia, Israel and Canada. France also belongs to this group, but has no quantifiable improvements to show for the – mostly half-hearted – reforms of its innovation system in the past years. Admittedly, some approaches were made to decentralize innovation policy respectively the innovation policy instruments. Also, an attempt to strengthen especially small and medium-sized enterprises (SMEs), for example by means of tax incentives for expenditure on research and development was made. In the public research sector, an attempt was made to promote applied research more vigorously by the dissolution of the *Grands Programmes* and the establishment of the Agence Nationale de la Recherche (ANR). Despite that, on the whole, it was not possible to break down the entrenched structures in science and industry. France is not able to advance and thus falls behind in the longer perspective in the international comparison.

Taiwan has significantly dropped behind this year. This is related to the direct dependence on an ailing China and increasing weaknesses in the areas of education and government. Japan also lies at the lower end of the lower midfield. This ranking may contradict the commonly perceived image of a particularly innovation-oriented nation. The reasons are – as in the previous years – very low scores in the areas society and science, which reflects the country's low international networking.

China misses the connection

The clearly outstripped field of stragglers is composed of Southern and Eastern European countries: the Czech Republic, Portugal, Spain, Hungary and Italy. China once again failed to catch up with the midfield. There is a slight upward tendency for the output indicators. The ratio between input and output in China's economy is however not yet completely balanced. On the whole, productivity in the country remains at a low level. Past investigations in the Innovation Indicator had already predicted that China had a long way to go to catch up with the midfield. The latest results confirm this expectation: China requires further efforts and structural adaptations in the research and science system. Poland and Russia,

with a wide gap to China, head a group of countries which have until now only achieved a low innovation performance. Greece also belongs to this group. Following Greece are Turkey, South Africa and Indonesia. Bringing up the rear are Mexico, India and Brazil. These three countries fall even further behind in the international comparison and have a score of 0. This means that on the average of the 38 single indicators they do not reach the level of the worst country of the reference group (USA, Japan, Germany, the United Kingdom, France, Italy, Switzerland).

Excursus

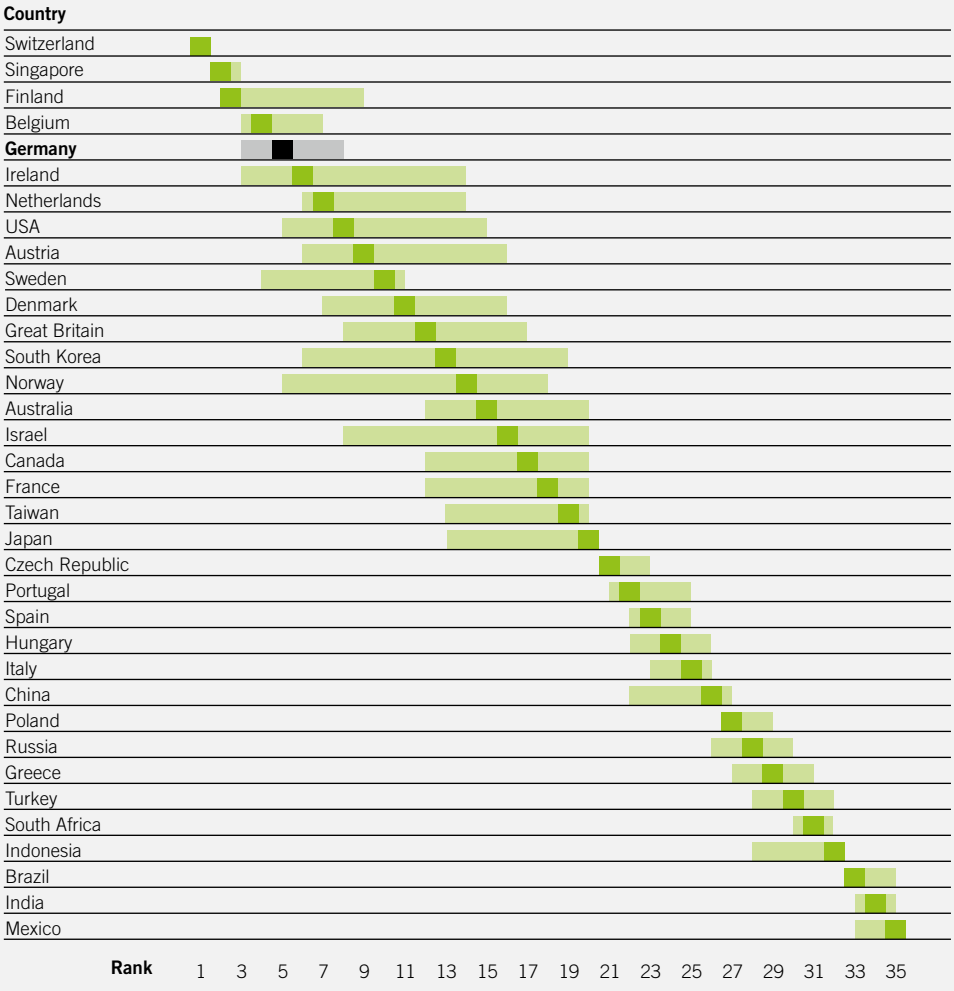
Sensitivity analysis

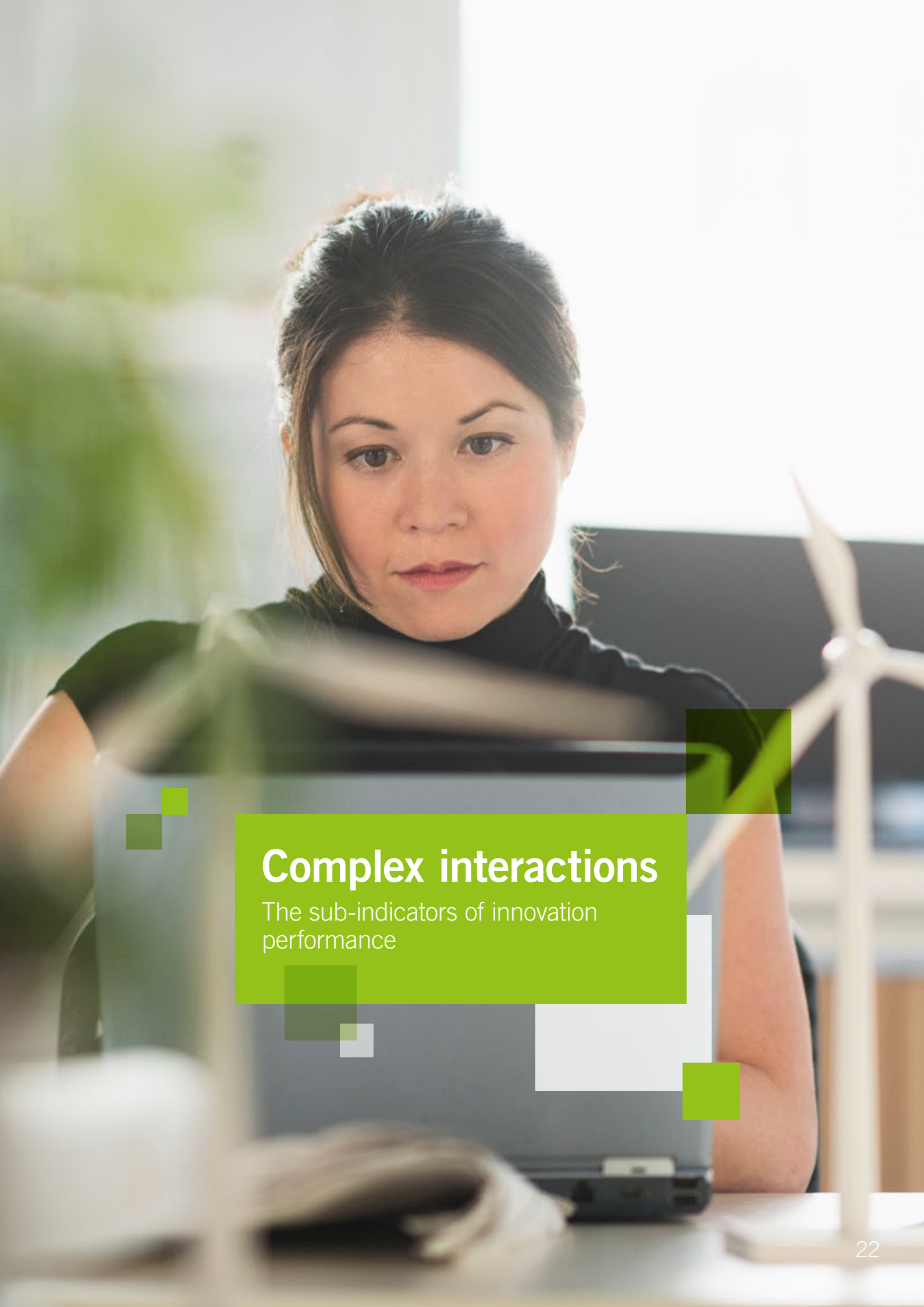
The results and rankings of composite indicators strongly depend on the selected aggregation weights. Therefore, it is of great importance to investigate the robustness of the results obtained with a change of the underlying weights.

For this, sensitivity analyses are carried out, in which, instead of an equal weighting, random generators determine the weighting. This results in random weight constellations with the condition that the weights used all have values greater than zero which lead to a single specific ranking of countries.

This ranking, which results from random weightings is recorded and the process is repeated many times. At the end, in this way you get simulated variation intervals for the rankings of the individual countries that make it possible to examine the robustness of the results.

Results of the sensitivity analyses on the weighting of the single indicators of the Innovation Indicator





Complex interactions

The sub-indicators of innovation performance

Intelligent scientists, a vivid economy and a society open towards new technological developments and innovations: there are many factors influencing the innovation capability of a country. Five sub-systems in the Innovation Indicator reflect this complexity and enable a more nuanced comparison between different countries.

Industry

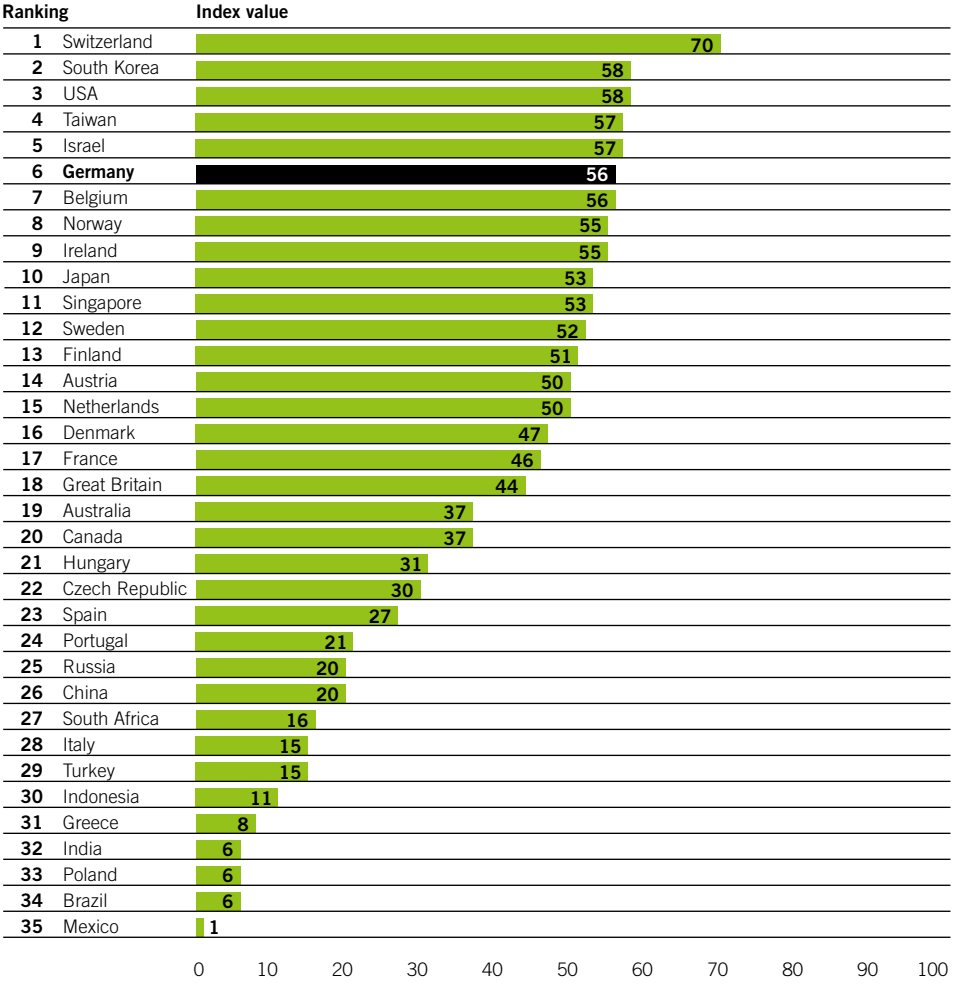
Industry is the pivotal point of the innovation system. Correspondingly this field combines the highest number of individual indicators. Here Switzerland is clearly at the top. In this category the country was able to improve compared to the previous year – counter to the general Swiss trend uniting all the indicators. The pole position is still significantly supported by the Swiss industry. However, the other sub-areas also show that Switzerland has a high level innovation system in every regard.

South Korea leads a very wide midfield. In the overall ranking the strong industry boosts South Korea significantly. Unlike Switzerland, however, South Korea has a less prominent profile in the other areas of the innovation system, so that in the overall comparison it is only enough for a place in the upper midfield.

The top contenders include the USA, which also has a highly innovative industry. The high number of points in this sub-indicator fits with the image often drawn of the USA. The potential for development and implementation of new business models is certainly enormous in the US economy. However, industry alone does not represent the innovation capability of a country. For mid- and long-term success in regards to innovations, other sub-areas are also significant. In the past years the USA have lost ground in some sub-indicators in comparison with other countries, especially in science.

For Germany too the results presented here are evidence of a strong innovation orientation of the economy and a high performance capability compared internationally. The strengths of the German economy, such as exports and technology-based innovations are reflected in the good results of various individual indicators like patent registrations and value added per hour worked.

Result of the sub-indicator industry



The Japanese economy is under pressure.

Belgium, Norway and Ireland are at a similar level to Germany or the US. The gaps between the countries following directly behind Switzerland are very small. Ireland in 9th place and South Korea in second place are only three points apart. A group consisting of Japan, Singapore, Sweden as well as Finland, Austria and the Netherlands are slightly separated from the direct pursuers. These countries are characterized by a high stability of their figures. The only exception is Japan which is falling behind in industry. It significantly shrunk in 2014 as did several individual indicators.

The bottom of the midfield consists of Denmark, France and Great Britain. Australia and Canada follow with a gap of seven points – which in turn are clearly ahead of Hungary and the Czech Republic. Although both countries maintain their positions their industries have markedly lost in innovation strength.

Spain in 23rd place maintains contact with this group and distances itself from Portugal, Russia and China – which all reach a similar level – with a clear gap. China is unable to markedly and sustainably improve the innovation capability of its industry. This has negative effects on the overall development of China. The planned restructuring of industry towards an innovation-oriented economy will be difficult under these circumstances. China is followed by South Africa, Italy and Turkey, at a similar level. These countries are separated by some distance from Indonesia and a larger distance to the last placed countries Greece, India, Poland, Brazil, and Mexico.

The Swiss economy remains the non plus ultra in the Innovation Indicator. A scene in the laboratory of the technological enterprise Sias, which is specialized on the development, engineering and production of automatic pipetting robots.

Science

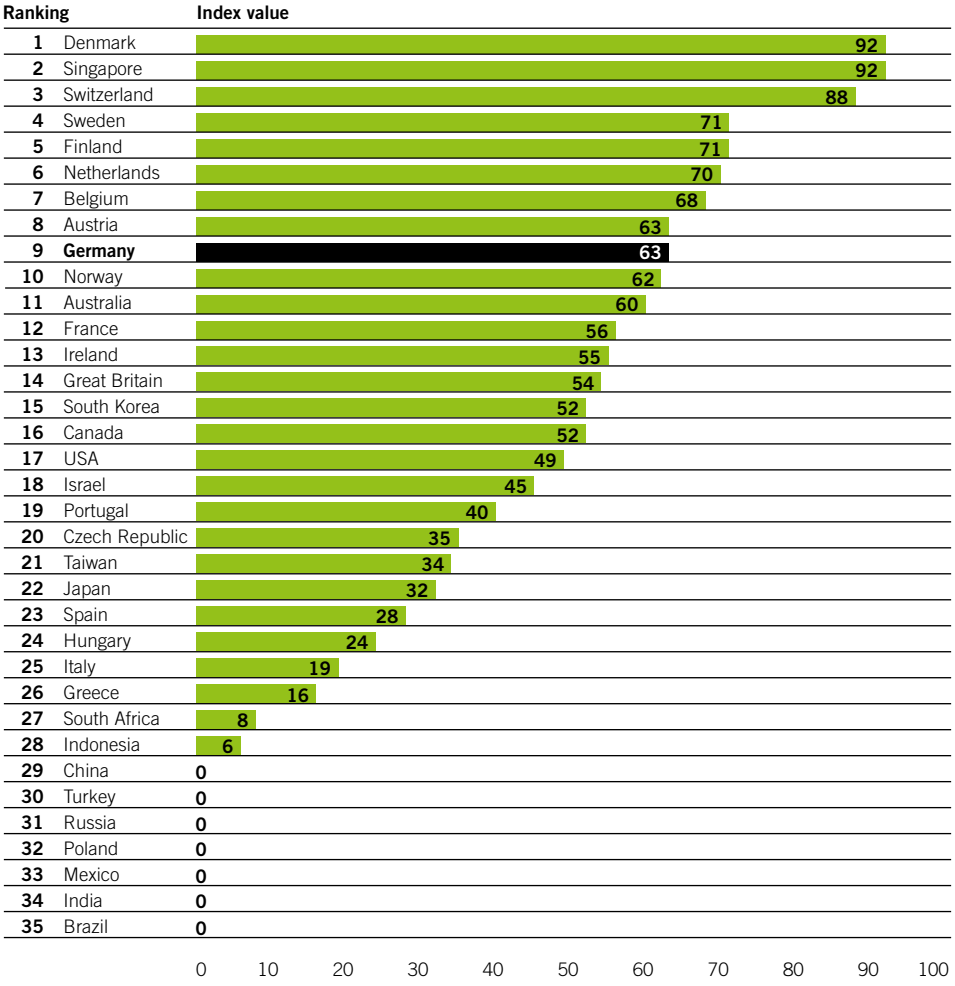
The scientific system is also an essential pillar of any innovation system. The fundamental knowledge that companies can use as an input to develop innovations often stems from the sciences. Essential knowledge and technology transfers take place between industry and science. Apart from that, science is a focal point for the training and education of personnel in research and development departments of firms.

When comparing the science systems Denmark and Singapore win. Followed by Switzerland, which for a long time was at the top but lost its leading position as some countries have been catching up massively in the last few years. The country did not maintain the high level of number of researchers, the high expenditure for public research and the high marks in the evaluation by experts. Leader Denmark, on the other hand, increased in individual indicators such as patent registration from public research and therefore moved to the top in the sub-indicator science.

All three countries are positioned close to each other, however, clearly separated from the pursuing group consisting of Sweden, Finland, the Netherlands, and Belgium. There is a gaping distance between Belgium and the following Austria on place 8. With an index value of 63 points overall the Alpine republic achieves the same score as Germany.

Germany maintains its good level in science for the third consecutive year, but is unable to to move upward. A step in the right direction is the extension of the Higher Education Pact 2020 (agreement between states and federal government), although it is still too early to judge them, as well as the agreement between the federal and the state governments concerning financial matters. The conditions for a future-oriented cooperation between federal and state governments are given by the change[3] of paragraph 91b of the constitution at the beginning of 2015. The modified law now enables a long-term financing of universities not only by the states, but also by the federal government.

Result of the sub-indicator science



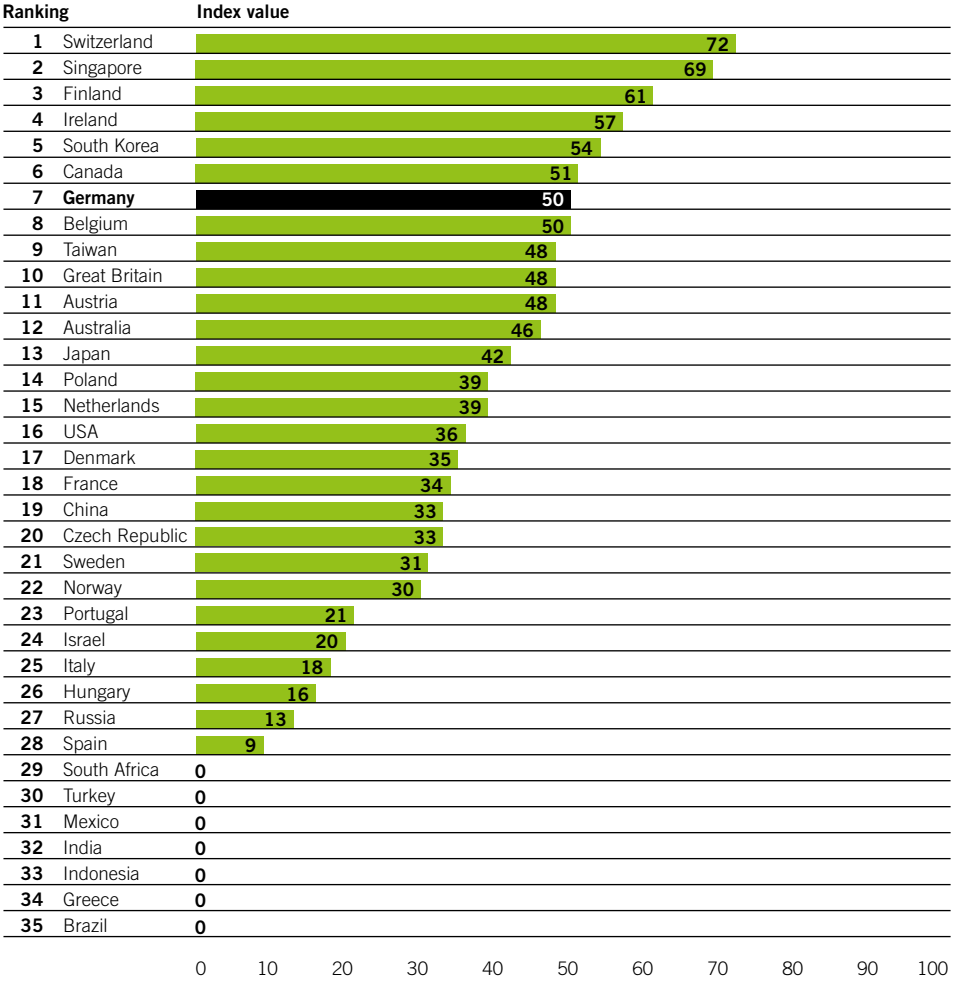
It is important that Germany's efforts in the areas of science, research and development do not abate under any circumstances, otherwise a fast descent in the international comparison of the innovation systems is to be expected. Apart from the question of financing nowadays, however, there are also other challenges which impede reaching a higher level. Focusing on excellence, accompanied by a performance-oriented allocation of funds may have increased in the last years. Seen in international comparison, there still is room for improvement here. Performance incentives should be certainly consequently increased.

3 www.bmbf.de/de/17975.php

Additionally there is the challenge of offering more autonomy in the development of their individual research profiles to the many young scientists. Especially fully-fledged tenure-track-systems could contribute to this.

Behind Germany in the midfield rank Norway, Australia and with some distance France, which together with Ireland, Great Britain, South Korea and Canada can be pooled into a group of countries with similar performance capabilities in the science systems. In the USA the long-term downwards trend of the science system – after last achieving stable results in this sub-indicator – is continued. The main reason for the overall bad result is the weak performance of big parts of the universities. In the USA a small group of internationally leading and famous research universities are followed by a great lot of mediocre organizations. Announcements of the Obama administration on innovation policy goals as well as the utilization of new production technologies (National Strategic Plan for Advanced Manufacturing) could, however, mean improvements for the science system. The countries following rapidly have decreasing index values. Israel with 45 point places 18th behind the USA, still clearly ahead of Portugal. Portugal on the other hand has a big lead on the countries Czech Republic, Taiwan and Japan. These are followed by Spain, Hungary, Italy and Greece as well as, with a larger gap, South Africa and Indonesia.

Results of the sub-indicator education



Education

The education system is the basis for industry and science by imparting fundamental knowledge and organizing vocational training. Switzerland and Singapore rank at the top in this sub-indicator and have a distinct lead on Finland, Ireland and Korea. Behind follows a group of countries including Germany. These are Canada, Belgium, Taiwan, Great Britain, Austria and finally Australia whose education systems in sum all achieve a similar performance capability and make similar contributions to the innovation ability.

After having been the weakest link in the innovation system of Germany for many years, recently there have been positive developments. Obviously changes like the reform of curricula and expansion of child care, including all-day schools, are bearing fruit. The indicator of the expert evaluation of the German education system increased, just as the PISA results did. Proven strengths in Germany remained, among others, the dual model of vocational training as well as the number of dissertations in technical and science subjects. However, the demographic problem, especially concerning the highly qualified, is still pressing.

Apprentices at Rolls Royce in Germany: the dual model of vocational training is and remains one of the strengths of the German education system.

Additionally, there are fewer employees in Germany with university degrees compared to other countries. While this is partially alleviated through the highly skilled vocational qualifications. Looking towards new issues and technologies such as digitalization, Industrie 4.0 or new materials together with the demographic development, a lack of highly qualified labor – meaning both university graduates, master craftsmen and technicians – could pose a stumbling block. Even if the long-term developments overall are can be interpreted as a move into the right direction, an index value of 50 points and a clear gap to the leading countries are not satisfactory for Germany as an innovation location. Industry and public research depend on highly qualified personnel, as this is the only way they can maintain their international competitiveness.

Behind Australia the bottom midfield follows, led by Japan, closely followed by Poland and the Netherlands. After somewhat of a gap you can find a very heterogeneous group consisting of the USA, Denmark, France, China and the Czech Republic. Norway and Sweden finally round off the midfield. The reason for Sweden's placement is the insufficient investments in the education system. The current public debate focusing on a decline in quality exemplifies this. A group of stragglers in regards to the education system consists of Portugal, Israel and Italy. Hungary, Russia and Spain follow. The educational systems of the other economies cannot be properly evaluated and compared with the indicators used here.

In Sweden there is talk of a decline of quality in the education system.

State

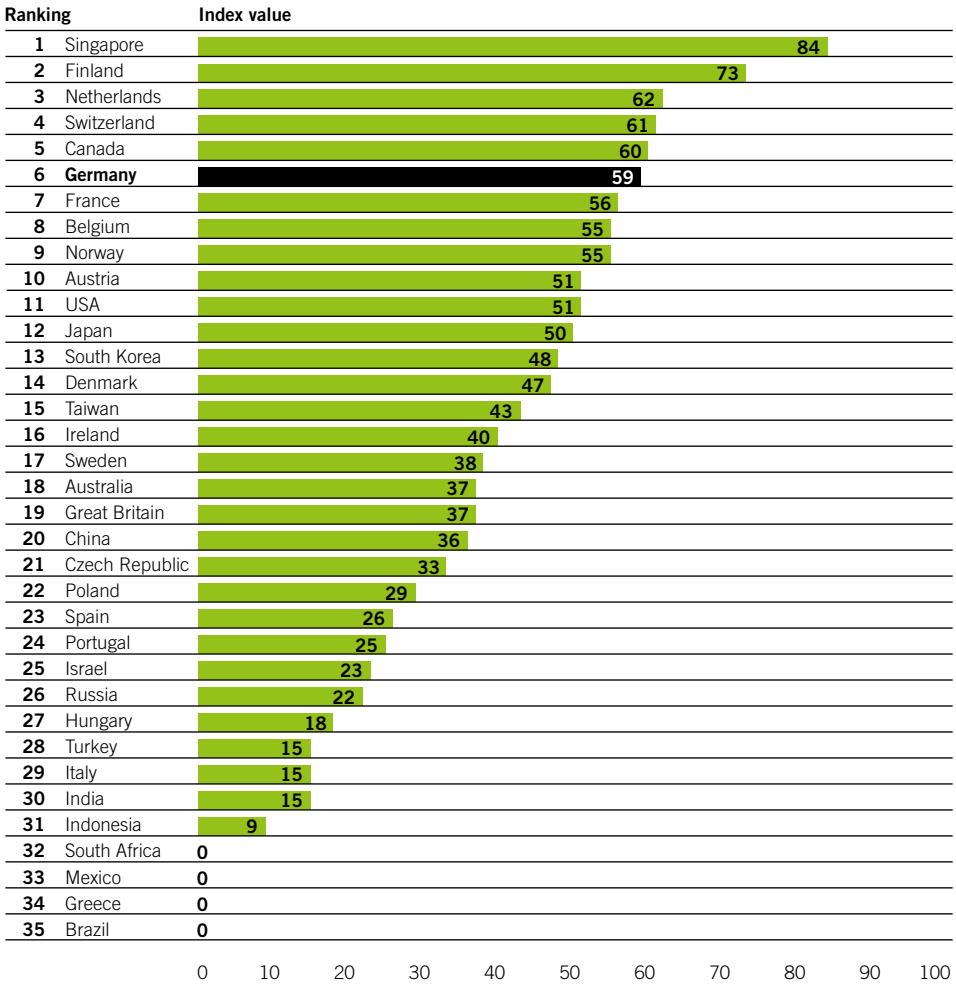
The state provides the essential framework conditions for innovations in various ways:

- through direct and indirect support of research in science and industry,
- public demand for new technologies and innovative products,
- regulations and control and
- providing the infrastructure.

According to the results of this year's Innovation Indicator Singapore – with a clear head start on Finland – has the most favorable conditions for innovations. Especially helpful are the large investments in science and education as well as an overall very well performing education system. With some distance a group consisting of the Netherlands, Switzerland, Canada and Germany follows. In Germany, the federal and the state governments have improved the framework conditions for innovations through effective measures. They concentrated mostly on public research promotion. To improve the conditions, especially for small and medium sized enterprises, however, remains an important task. This year's focus topic of this report (small and medium sized enterprises) analyzes the situation in Germany in more detail and provides specific starting points for political action.

Behind Germany come France, Belgium and Norway, followed by Austria and the USA. Both are slightly ahead of Japan, South Korea and Denmark. China is in 20th position. Although the country has a pronounced public demand for high-tech, the investments in research and development are too low. Even tax promotion of research no longer achieves sufficient effects. The Czech Republic, Poland, Spain, Portugal, and Israel follow. Russia, Hungary, Turkey, Italy, India and Indonesia clearly lag behind the other countries. South Africa, Mexico, Greece and Brazil bring up the rear.

Result of the sub-indicator state



Society

In its new High-Tech Strategy the federal government emphasizes the importance of transparency and participation for a successful innovation system more than previously. The Innovation Indicator also includes societal factors in its evaluation. The reason: openness towards new technologies and a public interest in innovations are relevant not only for the acceptance and distribution of innovative products and services. Even as early on as the phase of creating ideas and knowledge, society's openness towards technology and innovations is necessary.

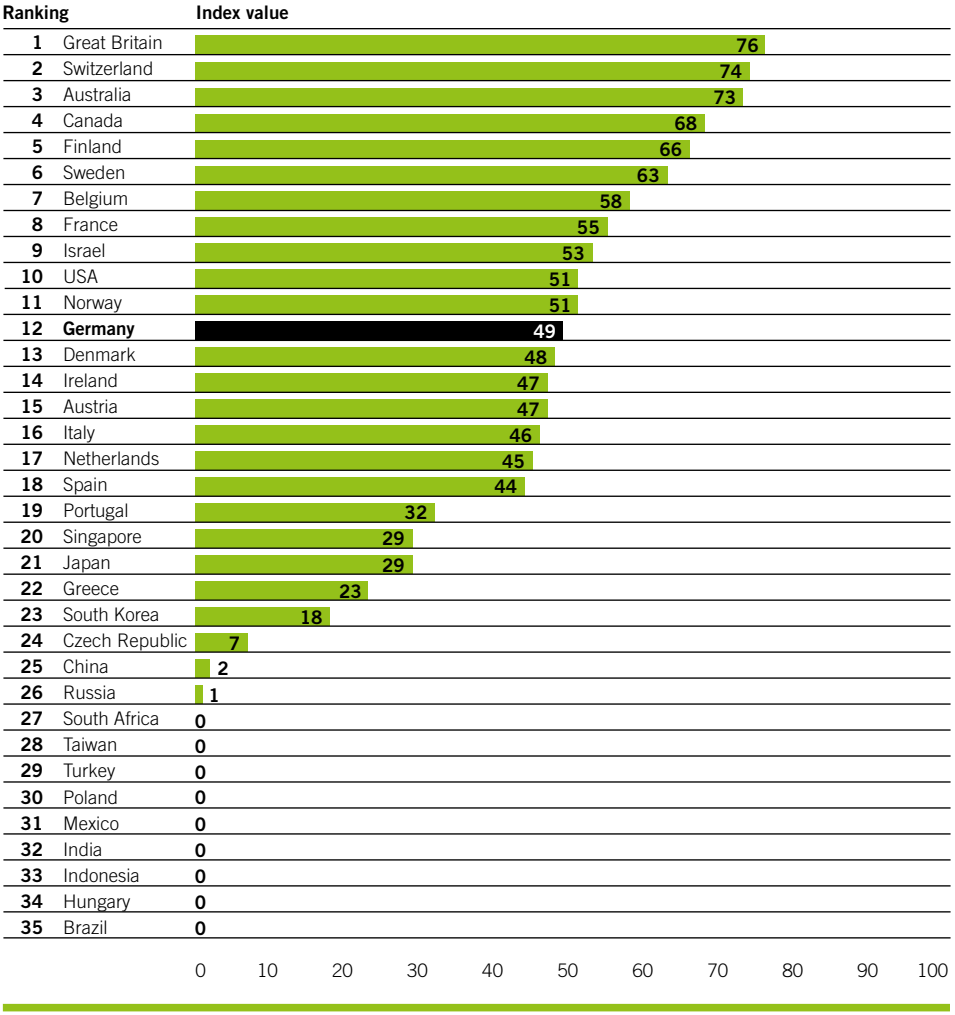
A direct measurement of societies' affinity or the readiness to take risks would be desirable. Unfortunately, these dimensions are difficult to measure in an internationally comparable way. Alternatively, the following four individual indicators can be used as a sign for the contribution and the importance of societal factors on innovation:

- The share of post-materialists shows how far the customers' preferences are positioned towards quality and price differentiation – both important factors on the demand side.
- The share of working women is relevant since it gives information about the utilization of the existing creative and innovative potential of the population.
- The press releases on science and technology show which importance these topics have in the broader public.
- Life expectancy has feedback effects on the innovation capability and innovation orientation at two locations. On the one hand it is an indicator for the productivity and experience of the people, both of which are important for successful innovations. On the other hand a high average life expectancy contributes to a high appreciation of quality and long-term innovation aspects as opposed to short-term consumption aspects.

Societal changes occur very slowly. Accordingly, the positions in the sub-indicators society are fairly stable, at least in the top area. Great Britain together with Switzerland and Australia is at the top. Canada, Finland as well as Sweden form the pursuing field. The upper midfield begins with Belgium and France, Israel, the USA and Norway can be counted among it. One can find Germany in the midfield, meaning there is a lot of improvement potential as far as societal framework conditions for innovations are concerned. Also in the midfield are Denmark, Ireland, Austria, Italy, the Netherlands and finally Spain too. Portugal, Singapore, Japan, Greece and South Korea are stragglers. There is a wide gap to the Czech Republic, China and Russia.

Conspicuous about the sub-system society, is that the Anglo-Saxon countries make the top places, while the Asian ones land at the back. Great Britain, Finland, Italy and Belgium achieve high values for post-materialists, while the Asian countries especially do not score as well here. In contrast, Japan for example scores highest in life expectancy, but Spain and Switzerland also do well here. For women's employment the Scandinavian countries stand out, but China and Singapore are in the top group.

Result of the sub-indicator society



Focus

Focus SMEs: wide variety among the small ones

The role of small and medium-sized enterprises in the innovation system

Small and medium-sized enterprises count as the backbone of the economy. Nearly every second hidden champion is located in Germany. However, all in all, SMEs play a mostly insignificant part in the innovation system here.

Enterprises determine very much how innovation comes to pass in a country. They recognize the need for innovations in other companies and by consumers, they design innovative solutions, and they develop new products, processes and business models. The most important resource for this is a creative and competent staff – who in cooperation with the scientific community and business partners develops innovations. The ability of companies to effectively and efficiently shape such processes is often a decisive factor for the success of innovations.

Many companies contribute to the innovation performance of the economy – from large global corporations to small family-owned companies and startups. In the public perception the really big companies with products known worldwide usually are at the center. However, many innovations come from small and little-known companies. This year's focal topic of the Innovation Indicator examines the role of SMEs for the innovation performance of Germany.

The first part is concerned with the share small and medium-sized enterprises (see explanation next page) have in research and innovation. Part two deals with small and medium-sized enterprises that are innovative without internal research and development (R&D) activities. Many of the German small and medium-sized companies achieve innovation successes even without formal R&D. However, it is by no means a homogeneous group with identical recipes for success. Precisely these differences provide correcting variables for a targeted innovation and funding policy.

Small world market leaders

The third part is concerned with a group of small and medium-sized companies, characterized by being particularly successful on international markets. They claim the technology leadership in their field and can prevail the world over as a major supplier. These small world market leaders are also called hidden champions[4], since they are often not well known to the general public. Part four compares the situation in Germany to that in Japan, which has a similar economic structure and export orientation to Germany and is therefore a predestined country for comparison. Contributions of SMEs to the international success of the two countries differ significantly, however: a large number of SMEs from Germany with strong exports, face only very few Japanese SMEs with international activities. The section explains why.

SMEs are also important for the development and diffusion of new technologies. Their role in the innovation system is to be seen less in the creation of fundamentally new technologies, but rather in the use of new technologies for specialized applications. Market opportunities present themselves to them, especially when new applications for technologies initially promise only limited turnover, as these markets are less attractive for large companies.

Many innovations come from small and little-known companies.

4 The term "hidden champions" was coined by Hermann Simon in 1990 (H. Simon: Hidden Champions: Speerspitze der deutschen Wirtschaft, Zeitschrift für Betriebswirtschaft No. 60, volume 9, p. 875-890).

Part 1

Innovation performance of SMEs in international comparison

What are SMEs?

Small and medium-sized enterprises are defined by the EU as having fewer than 250 employees and less than 50 million euros in annual turnover, and are not owned by large companies to 25 percent or more. In Germany, a different definition is frequently used, which includes companies of up to 500 or even up to 1,000 employees. Finally, in Germany there is also the concept of the SME sector (*"mittelständische Wirtschaft"*), which also includes larger companies if they have typical organizational characteristics of smaller companies such as the company's management being in the hands of a family. In this part of the report, SMEs are generally defined following the EU definition. Since some statistics do not apply this definition, deviating differentiations must be used in parts.

One indicator of the relative importance SMEs have in the innovation system is their share of R&D expenditures in the economy. Here those countries whose economic structure is strongly influenced by small businesses and which do not have globally active, highly innovative companies have high values. The situation is different in the United States, Japan, Germany, Sweden and South Korea: they are home to a substantial number of very large, innovative companies. Therefore the share of SMEs in R&D expenditures turns out low in terms of figures.

In Germany, companies with fewer than 500 employees spent approximately EUR 8.3 billion for internal R&D in 2011. That is 16 percent of the total internal R&D expenditures in the German economy. SMEs with fewer than 250 employees even have a share of only 11 percent of these expenditures. Only Japan has a lower rate, with a share of 9 percent for businesses with fewer than 500 employees. In the US, companies with less than 500 employees contribute 19 percent of R&D expenditures, in Sweden, South Korea and Taiwan, the figure is around 27 percent.

Contribution of SMEs to R&D intensity

The contribution of SMEs to R&D intensity of an economy, which is the ratio between R&D spending and gross domestic product (GDP), indicates the overall economic importance of R&D activities of SMEs. Here Austria, Switzerland, Denmark, Finland, Singapore and South Korea[5] reach particularly high values. R&D expenditures of SMEs in these countries account for between 0.75 and 0.88 percent of GDP.

The share in some countries – South Korea, Austria, Switzerland and Singapore – is almost as high as the contribution of science to macroeconomic R&D intensity. In these countries, SMEs are thus an essential pillar of the innovation system. In Germany, the US and Japan, the situation is different, the R&D spending by SMEs is much lower: in the United States only 0.37 percent of GDP, in Germany 0.31 percent and 0.24 percent in Japan. In these economies, the dominance of large enterprises seems to affect the R&D activities of SMEs. Large companies have a better position in the labor market for highly skilled workers. Due to their higher level of name recognition (employer branding), more attractive career prospects and wider social benefits they have clear advantages in competing with SMEs for the most talented employees.

Patent applications show innovation output

The importance of SMEs for the results arising from R&D is shown among other things by their contribution to the patent applications of a country. A look at the applications in transnational patent offices (EPO and PCT procedures at the World Intellectual Property Organization) for most countries present slightly higher shares of SMEs compared to the SMEs' share of the R&D expenditure. This is primarily due to the different definitions of SMEs: in the R&D statistics, expenditures by SMEs, which are part of a group, is assigned to this corporate group. In the patent statistics on the other hand, the size of the respective enterprise filing is the basis.

But the higher proportion of SMEs in the patent applications also shows that SMEs generate more patents per euro of R&D expenditures. This higher "R&D productivity," on the one hand reflects the greater conversion efficiency in SMEs. Flexibility, quick decision-making and a focus on a few projects contribute significantly. But also the fact that R&D projects in SMEs are often short-term oriented and are less technologically sophisticated, plays a part.

5 South Korea is a special case, since most of the R&D activities in South Korean SMEs are tied up with large enterprises, whether through group integrations, or through supplier functions. So the patent performance of South Korean SMEs is rather low and only a few have brought about a strong international presence.

In Germany, approximately 24 percent of transnational patents[6] were registered by SMEs in 2010-2012. By comparison, the SME share of the R&D expenditures of the economy stood at 16 percent. In an international comparison, the contribution of SMEs to the patent activities is low: only Japan has a lower share value (9 percent). South Korea and France come to similar SME shares. In the US, however, the share of SMEs was 31 percent of all transnational patent applications in the country. The countries where SMEs register a high proportion of patents include Norway, Australia, Indonesia, Israel and Portugal. The value there is considerably more than 50 percent.

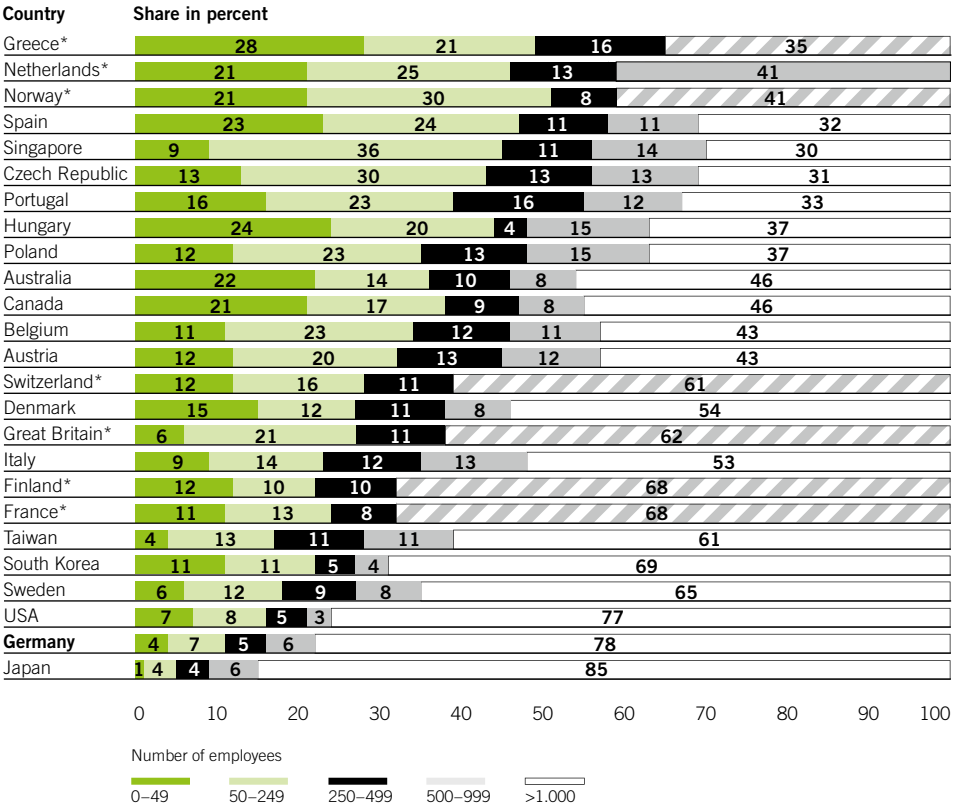
Emerging market countries strongly increase their SME patenting

In the majority of countries, the transnational patent applications by SMEs increased disproportionately over the past decade. The highest growth was in China and Turkey. However, the quality of patents from these countries is often not very high. Also in other emerging markets like Brazil, India, Indonesia and Mexico SMEs increased their internationally oriented patent activities strongly. Previously, the figure there was very low. Eastern and Southern European countries also show high growth rates. This indicates that an innovative sector of SMEs has emerged in recent years, contributing to the modernization of the countries and to strengthening their capacity for innovation.

In contrast, SMEs in most Asian countries, including Japan, Singapore, South Korea, India and Taiwan show below-average patent dynamics. The situation is similar in the US, Canada and some particularly innovation-intensive European countries like Sweden and Denmark. In Germany the number of patent applications by SMEs rose by 1.7 percent per year – higher than the average growth of 1.3 percent and above the growth of patent applications by large companies.

The low level of patent dynamic of SMEs in the highly developed industrial countries must be seen against the backdrop of an already very high level of patent activities. The patent intensity of SMEs, meaning the ratio between the number of transnational patent applications by SMEs and the inhabitants of a country – is highest in Switzerland with 20 patents per 100,000 inhabitants, followed by Israel with 15, Sweden with 14 and Finland with 13 patent applications per 100,000 inhabitants. The SMEs in Germany with a patent intensity of 8.7 are in eighth place in the ranking, behind SMEs from Denmark, Norway and Austria. Thus, this proves the impression gained of the R&D intensity: SMEs in Germany certainly are not at the top internationally, but rather rank in the midfield.

Distribution of R&D expenditures of the economy by enterprise size (2012)



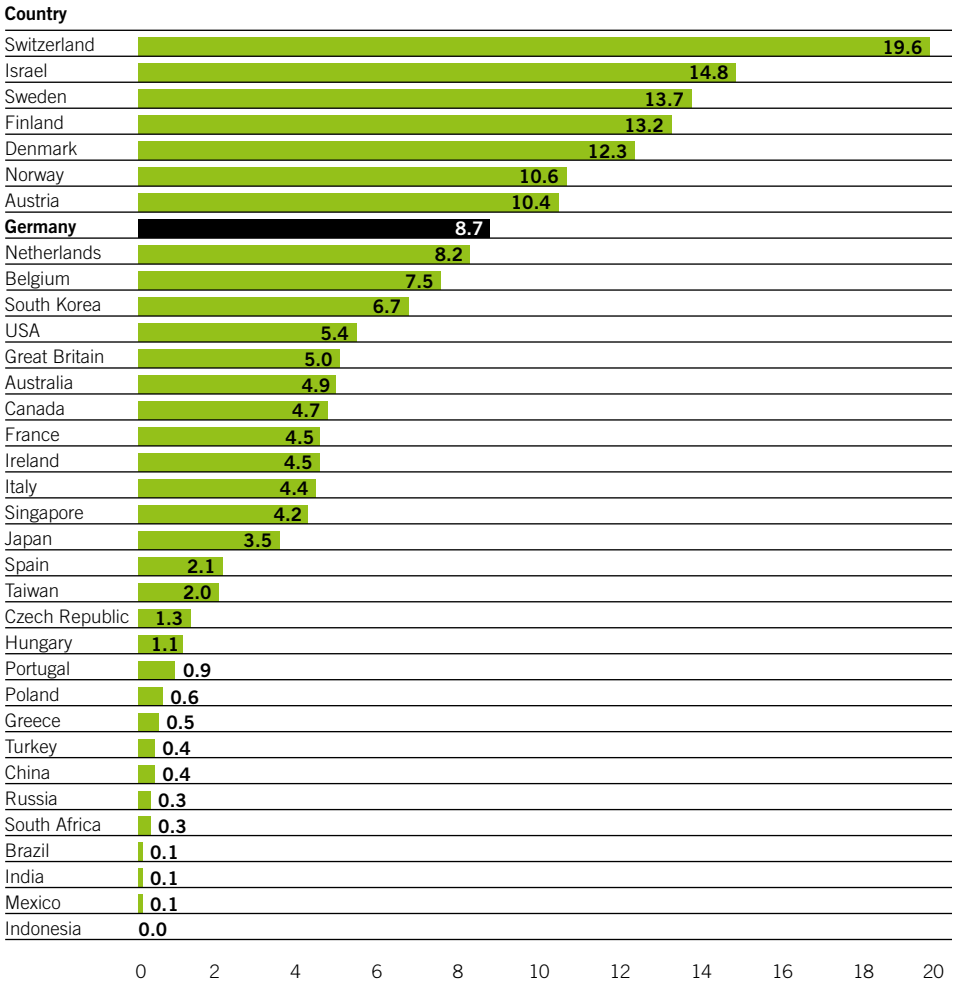
* FIN, FRA, GBR, GRE, NED, NOR, SUI: No separate information available for 500-999 employees and 1000+ employees.

AUS, AUT, BEL, DEN, GER, GRE, NED, SGP, SWE, USA: 2011; JPN, KOR, TWN: 2013.

Source: OECD: Research and Development Statistics. – ZEW calculations.

6 Transnational patents describe patents registered at the European Patent Office or with the World Intellectual Property Organization in Geneva.

Number of transnational patent applications of SMEs per 100,000 inhabitants (average 2010-2012)



Transnational patent applications: applications at the EPO and via the PCT procedure.
Source: EPA: Patstat. – Fraunhofer ISI calculations.

SMEs achieve higher yields per euro spent

Another aspect of the innovation capacity of SMEs is their contribution to product innovation. The turnover which companies achieve with new products are a major, direct output indicator of innovation activities of enterprises. The share of total new product turnover of enterprises with fewer than 250 employees in the German economy was on average 18 percent for the years 2008 to 2012. This percentage is higher than the share of SMEs in R&D expenditures, which stood at 11 percent. This higher percentage corresponds to SMEs' higher percentage of patent applications.

The two different values underline that SMEs tend to produce higher returns per euro spent on R&D than large companies. In regards to turnover with product innovations, this is because many SMEs put less emphasis on fundamental innovations. Innovations often represent incremental improvements and adaptations to specific customer requirements. Accordingly, the share of SMEs in total turnover of imitative innovation in Germany is higher with 19 percent than in the total turnover with market innovations (16 percent). This result appears not only for Germany but for most European countries.[7]

In an international comparison the SME share in the total new product turnover of the economy is rather low in Germany. Great Britain, Turkey and Italy, display high SME shares like some smaller, highly innovative countries. In most Southern and Eastern European countries SMEs contribute at a below average level to new product sales compared to their relatively high proportions of R&D spending in the economy. This suggests that they have difficulties in marketing their innovations.

Another output measure of the innovative strength of small and medium-sized enterprises is the share that product innovations make up of the total turnover of SMEs. This value was nearly 10 percent for SMEs in Germany in 2008 to 2012. By European standards, Germany is therefore in midfield. SMEs obtained the highest value, namely 17 percent, in Turkey. Great Britain and Italy follow. Poland, Greece, Norway and Hungary have the lowest values with between 5 and 7 percent. For Germany it is noticeable that the share of sales, which can be traced back to market innovations, is particularly low with 2 percent. However, the low rate is not necessarily a weakness of German SMEs. Instead, it points to their stronger global market orientation. Because in Germany market innovations of SMEs are often new prod-

7 Data on sales of new products are taken from the Community Innovation Surveys. Comparable figures for non-European countries are not available.

ucts for the world market. Whereas in many other countries, it is only a novelty for the regional or domestic market. And to achieve high revenue shares with innovations in the world market is far more difficult than in a regionally confined market.

Germany is well ahead in world market innovations

Considering only the sales share of world market innovations, suddenly a very different picture emerges: German SMEs are at the forefront. In 2012, 5.9 percent of all SMEs in Germany had a world market innovation in their product portfolio. Only SMEs from Norway and the Netherlands reach higher values. In Turkey, which leads on the share of sales generated with market innovations, only 0.5 percent of SMEs introduced a global market novelty. While in Germany almost every second SME with market innovations has introduced at least one world market innovation, this share lies between 20 and 35 percent in most other countries. The corresponding values in Hungary, Greece, Turkey and Poland are only a few percent. However, no information was available for this indicator for some countries, including Finland, Great Britain, Sweden and Switzerland.

Conclusion: some SMEs are top of the league, but many are only average

In summary, the innovation capacity of SMEs in Germany does not prove to be outstanding: both in R&D expenditures as well as in patents and new product sales they are in the midfield compared with SMEs from other countries. Although in Germany SMEs are better at the implementation than large companies, the higher efficiency is not a unique feature of German SMEs. Other countries are often much better in this regard. On the other hand, Germany has a group of internationally particularly successful innovative SMEs.

The patent intensity of SMEs is highest in Switzerland.

An automatic feeding system from Lely supplies cows in a barn. Small and medium-sized enterprises from the Netherlands are at the top as far as world market innovations are concerned. Many occur in the agricultural sector.

This is because German SMEs lie far ahead concerning their share of sales with world market innovations. In this respect one should not speak of "the SMEs". The group of SMEs is heterogeneous, and in addition to very high performing companies, there are also a lot of mediocre ones.

Part 2

Innovative SMEs without their own R&D

Whoever speaks of innovative SMEs mostly has the mental image of a small company, continuously with high R&D intensity, solving technological problems, researching new technologies, and using this to bring innovative products to the market. Without a doubt there are many SMEs that are innovative in this way. But they do not make up the majority.

Approximately 55 percent of all SMEs in Germany with product or process innovations in fact have no company internal R&D activities. These SMEs therefore innovate successfully without their own R&D. This part of the focal topic is devoted to the question of how these SMEs, despite not investing in R&D activities, can successfully bring forth innovations.

About half of German SMEs are innovative without their own R&D activities.

The share of innovative SMEs without their own R&D has remained largely stable over the past ten years. It varies, however, considerably by sector and size classes. It is very high in industries where generally little is spent on R&D. But even in the most research-intensive industries, about a quarter of innovators do not have their own R&D activities. In knowledge-intensive services approximately every second SME innovated without internal R&D. In the non-knowledge-intensive services only every fifth innovator innovates based on its own R&D. The percentage of companies that introduce innovations without own R&D, increases, the smaller the company is: for the group of companies with five to nine employees, it is 65 percent. This value falls continuously to a little over 20 percent for large companies with 1,000 or more employees.

Within industry, the share of innovators without their own R&D is lowest in the chemical and pharmaceutical industries. It is around ten percent. In other research-intensive industries, it is between about 20 percent, for example in areas such as the electronics industry as well as rail, shipbuilding and aircraft manufacturing. In the automotive industry a full third of companies innovated without their own R&D. In many non-research-intensive industries over 60 percent of innovators have introduced their innovations without their own R&D. Representatives of these sectors are the food, wood, leather and printing industries. Non-research-intensive small and medium-sized enterprises are thus found in relevant numbers in all manufacturing industries and successfully develop product and process innovations.

Innovation strength is based on different strategies

The empirical findings thus speak against a uniform innovative behavior of SMEs – as well as the findings of operational innovation research. The conventional wisdom today explains differences in competitiveness and innovation primarily from a resource-based view. Accordingly, the sustainable competitive advantage of a company lies in bundling strategically relevant resources. These include tangible resources such as technology and intangible resources such as knowledge and skills. Among them are also a company's routines. The strategic combination of these resources and action routines creates a competitive advantage. The complexity and organizational establishment in the company make it difficult for competitors to copy this advantage.

The many possible combinations of these various tangible and intangible resources – in terms of a "corporate DNA" – ideally lead to unique innovation strategies. Structural regularities within these innovation strategies can be compressed to "innovation patterns". Features that characterize such innovation patterns consist of external orientation

of a company, the relevance of different types of innovation knowledge, different customer requirements, the importance of advanced technologies in product development and production as well as the way of organizing production and work. Innovation patterns of SMEs therefore differ in the technical and non-technical innovation capabilities of companies, the use of modern manufacturing and production technologies, offering product-related services, the integration into networks and partnerships or the shape of the flexible and efficient design of internal processes.

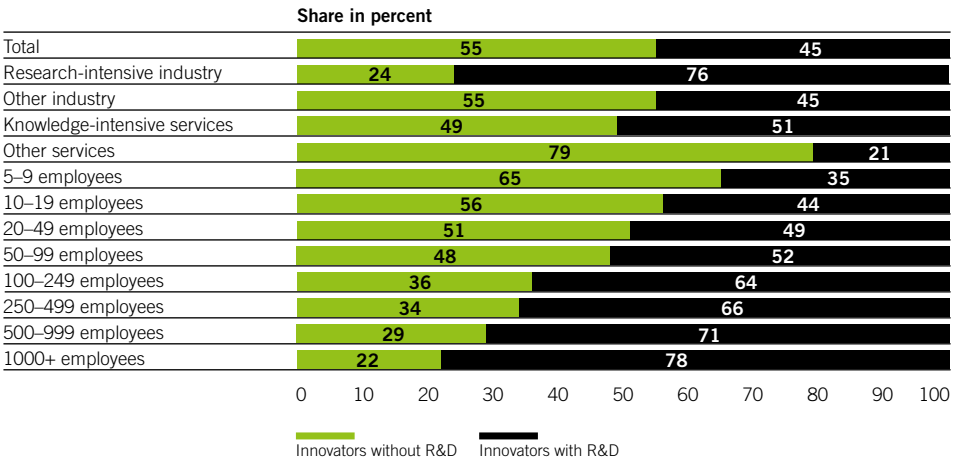
Five types of innovative SMEs without their own R&D

Based on representative operational data of about 1,500 SMEs from the German manufacturing sector five innovation patterns of non-research-active SMEs can be identified based on the different innovation resources and competences:

(1) Knowledge-intensive product innovator: the innovative behavior in this group is characterized by a high degree of knowledge intensity despite a lack of R&D. The focus is on the development of new products, which often contain high-tech components such as microelectronic components or new materials. Due to the high complexity of these products customers receive comprehensive, product-related services. The high knowledge intensity is reflected in a high proportion of workers with a university or college degree, in a high importance of internal and external knowledge and impulse sources for innovation as well as in frequent innovation collaborations with universities and other companies. The knowledge relevant for innovation is accordingly of a rather formalized and scientific nature. They achieve high revenue shares with product innovations, frequently including new products that they introduce as the first supplier in the market. SMEs belonging to this type, are often system suppliers in the fields of mechanical engineering, optics, measurement, and control technology.

(2) Customer-driven, technical process specialist: this pattern of innovation of SMEs is characterized by an above-average use of modern production technologies, such as high-performance machine tools, industrial robots and automation systems. For the mostly large OEM customers they develop and realize complex and highly sophisticated manufacturing processes. Innovation drivers are thus mainly customers. Innovation ideas are in many cases their own, but these are usually, due to the high customer dependency, not pursued on their own. An important internal success factor for this type of innovation are the company's internal processes and practical knowledge of employees in design, tooling or production, including semi-skilled and unskilled staff. If necessary, external knowledge from targeted cooperations with external partners in research and development acts complementarily. These include, for example, cooperations in the field of new production processes or materials. Product-related services in the field of technical documentation and project management round out the range of services. The small and medium-sized enterprises of this type

Share of innovators without own R&D in Germany (average of the years 2011–2013)



Source: (Mannheim Innovation Panel, ZEW)

achieve high delivery reliability and a high quality performance. In the value chain, these non-research-active SMEs are often parts and components suppliers. They are found mainly in the automotive industry and the manufacture of rubber and plastic products.

(3) **Consumer goods manufacturers with (occasional) product development:** the non-research-active SMEs in this group occasionally conduct product development. Their product complexity is rather low with regard to the number of "components". However, many products are based on quite complex recipes and diverse basic materials, for example in the food and beverage industry. The focus is on gradually improving products. Accordingly, product-related services mostly do not matter. The customization of products is also rather the exception. Mostly, a standardized basic program is produced, from which the customer can then choose different variants. Success factors for innovation are the expertise of their employees and the focus on non-technological innovation fields such as product design and marketing. Due to the often high level of automation or process goods manufacturing, only a few uses for innovative organizational concepts offer themselves. However, this SME type achieves short production lead times and a high total factor productivity. This innovation pattern is often found in the food, beverage and clothing industries, the furniture industry as well as with manufacturers of sports equipment and musical instruments.

(4) **Weakly-innovative, labor-intensive (contract) manufacturers:** this type of non-research-active SMEs mostly develops no own products and services, but serves its customers as an "extended workbench" for labor-intensive or costly production steps such as electroplating or welding. The proportion of staff in production and assembly is particularly high. Accord-

Rope production at Liros: the medium-sized company from Upper Franconia sells its products throughout Europe.

ing to the market positioning, customized production, often "build to print" frequently plays an important role. The innovation performance of these SMEs lies mainly in the customer-specific customization of products. The production of the rather less complex components usually takes place with standardized machinery and equipment. Only rarely are advanced production technologies or new forms of work and production organization used. Such companies are often contract manufacturers in industries such as metal production and processing, but also in the automotive industry.

(5) **Volume-flexible, specialized suppliers:** both the share of employees in production and assembly as well as the proportion of low-skilled and unskilled workers in this group are the highest by far. There is a high degree of customer orientation, which manifests itself particularly in an excellent price-performance ratio, as well as a large volume flexibility on the market. To achieve these goals, this SME-type is an above average user of innovative organizational concepts and management methods. The development of their own, new products rarely takes place and existing products have a rather medium degree of complexity. The range of product-related services, such as in packaging, logistics or distribution, however, are of great importance. Often they are part and component suppliers, which are equally to be found in research-intensive and non-research-intensive industries. They can be described therefore as the "backbone" of German industry.

Different paths to success

It is important to stress at this point that all the described patterns of innovation, despite – or perhaps because – of their different resource combinations may be economically successful. One can find companies with a strong turnover growth and a positive development in regards to employment for any type of SME. In all five types SMEs active in exports can be found, the average export ratio is, depending on type, 16-28 percent.

The exemplary depiction of these different innovation patterns of non-research-active SMEs in the manufacturing sector in Germany makes it clear that the statistical definition of SMEs frequently used is unable, solely on the basis of size, to reflect the variety of different strategies and behavior of SMEs. On the one hand, despite the lack of their own R&D activities, the different patterns of innovation of SMEs are quite innovative and competitive. Going without R&D thus represents an economically rational strategy for these companies. It avoids the high cost and risk of R&D. Technological excellence is replaced by an efficient and flexible internal organization, a high degree of process expertise, the transfer of existing technological solutions to new applications or a strong customer orientation.

Align support to development paths

On the other hand, the innovation patterns illustrated depict the strengths and weaknesses of the respective SMEs, which are reflected in different possible development paths. For the type "(contract) manufacturer", for example, two paths of development lend themselves: The first, technology-oriented, path would mean that these companies invest mainly in gaining expertise and process know-how for the use of modern production equipment. This would result in an ever stronger alignment towards a technical process specialist. The second, non-technology-oriented path, however, could focus on the flexibility and rationalization of work and production organization and processes. This would result in a development in the direction of a specialized supplier.

One can find companies with a strong turnover growth for any type of SME.

Many companies do not have the necessary processes in order to benefit from cooperations with scientific partners.

These development paths also have consequences for an SME-oriented innovation policy. A direct promotion of R&D collaboration with scientific partners would not do justice to the type (contract) manufacturer. On the one hand, there would be hardly any adaptability towards its pursued innovation strategy, since it usually does not carry out its own product development. On the other hand, the promotion would encounter non-existing competencies and skills in the enterprise. Many of these companies do not have the necessary processes, interfaces and human resources in order to benefit from cooperation with scientific partners. On the other hand, other types of SMEs, for example, product innovators and technical process specialists, could actually benefit from a cooperation promotion.

A future oriented and successful innovation and technology policy for SMEs should take the different innovation patterns into consideration and develop support offers for SMEs without their own R&D. This is because these SMEs also bear an innovation risk and are faced with various barriers to innovation. And their innovation patterns too expand knowledge, give other companies impetus for their own innovations and as a user contribute in a decisive role to the dissemination of new technologies. Support for innovation aligned to SMEs without own R&D should have mainly the following priorities:

- Securing a supply of skilled labor, which responds to the specific needs of these SMEs (high degree of process knowledge, ability to integrate different technologies, combination of technical and business knowledge). The training courses in typical professions and the curricula in universities of applied sciences could be developed accordingly.
- Providing support for the development and implementation of process innovations that do not require SMEs' own R&D activities. With regard to the funding of public co-financing models this could be developed similarly to the ERP Innovation Program in collaboration with the private and cooperative banking sector. To facilitate testing and successful implementation, non-discriminatory access to technical pilot plants, prototypes and demonstrators could help ensure that these SMEs can test fields of application of new technologies and the feasibility of new processes, without having to bear the necessary, often high, investment costs for this purpose in the first step.
- Strengthening of the exploitation ability for example through offering support for the establishment of new business models and for the development of new markets and new customer groups. In this way potential for growth – for example within the framework of Industrie 4.0 – can be developed and dependency on individual customers lessened. Exploitation aspects of this kind could be better integrated, for example as part of technological promotion schemes.

Part 3

Hidden champions: small and medium-sized world market leaders from Germany

A specialty of the German economy is that it has produced quite a lot of innovative SMEs, which are heavily geared to the world market and have gained a leading position in global markets. Hermann Simon[8] has described this phenomenon as early as 1990 under the name "hidden champions": small and medium-sized companies with high world market shares, which are among the technology and innovation leaders in their sector and significantly influence the development of their market. Because these traditional small- and medium-sized companies operate in niche markets or as suppliers and they often are family-run, non-listed companies, they lead a quasi-hidden existence away from the public eye.

A current compilation of Hermann Simon shows that nearly half of the world's more than 2,700 hidden champions come from Germany. The United States reached just over a quarter of the German number, Japan even only one-sixth. A relatively large number of hidden champions, however, can be found in Austria and Switzerland. Germany, Switzerland and Austria are also the three countries in which these companies are clearly most commonly encountered in comparison to the population. There are also high densities of hidden champions in the Scandinavian countries.

Good conditions in Germany

The large number of small global market leaders in Germany is derived from the combination of several particularities of the German economy:

- the high degree of orientation towards export,
- the large importance of industries producing intermediate products and technologies for other companies,
- the strong focus on innovation and high innovation intensity of companies,
- a domestic market demand with high demands for quality, technology and cost-efficiency,
- a domestic market, which is large enough to create sufficient demand for innovation, but too small to attract large companies purely oriented towards it.

Under these conditions, small and medium-sized companies can concentrate on industrial niche markets in which a precise knowledge of customer requirements is needed and where at the same time, customers have high innovation demands. The limited size of the market in Germany compared to the US, Japan or China means that these companies early on are geared towards export. It is not only when they have previously grown to large enterprises in their home market that they conquer foreign markets.

In order to work out the specific characteristics of small world market leaders and compare them with other companies, these players need to be identified based on certain characteristics. The data basis is the German Innovation Survey, the so-called Mannheim Innovation Panel of the Center for European Economic Research. The definition of hidden champions is based on that of Simon, but goes further in one regard. One criterion that is not adequately recognized in the usual discussion, is the company's growth. In addition to size, exports and market share, above-average growth, therefore, is a further criterion to define a champion. Based on the extrapolation of the innovation survey in Germany there are about 1,600 companies that meet these criteria (see info text to the right).

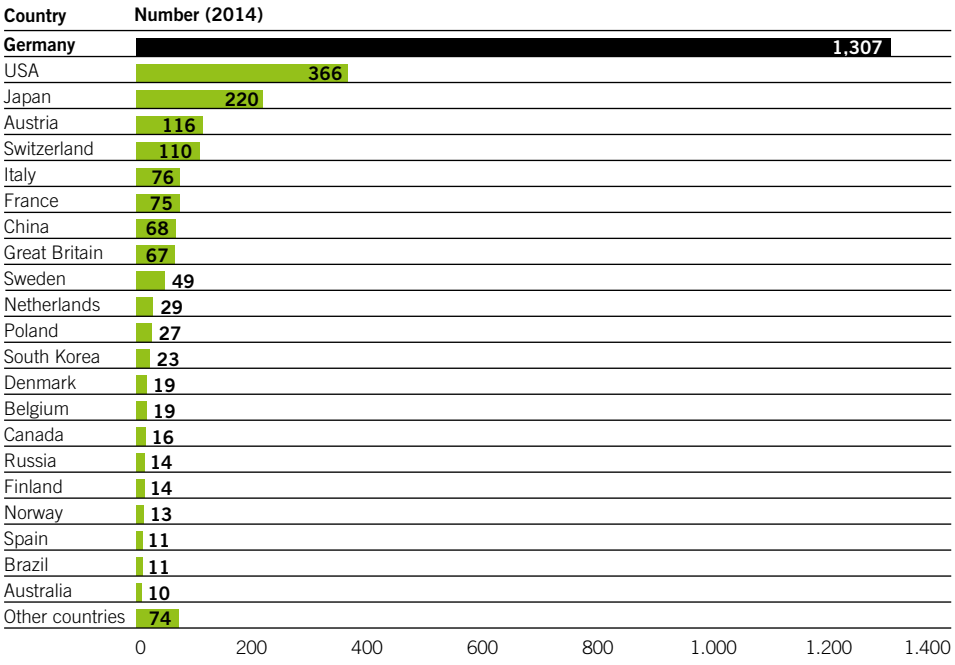
The companies identified here are relatively small. 21 percent have between 100 and 250 employees, with 20 percent having between 50 and 100 employees. Only about a quarter has more than 250 employees. The companies employ an average of 285 people and have an annual turnover of on average nearly 90 million euros. So they are noticeably smaller than the hidden champions in the compilation of Simon. This is due to the fact that in the evaluation employee and turnover figures are only concerned with Germany as a location and subsidiaries of corporations are included as independent companies. On the other hand,

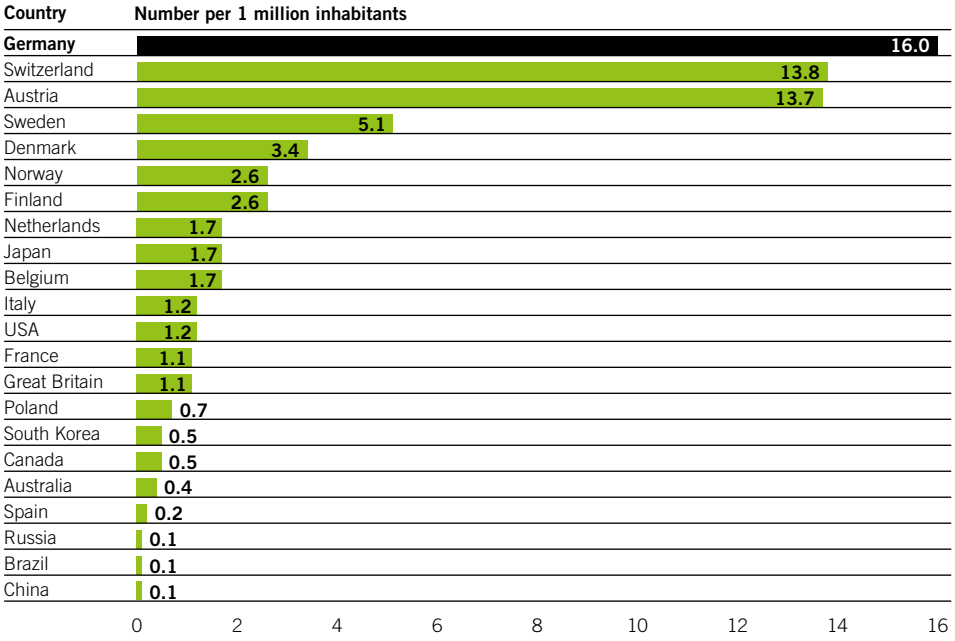
What distinguishes hidden champions?

Medium-sized world market leaders are companies with less than 10,000 employees worldwide, which are primarily active in international markets. In addition, they must have a large market share in their main market. The share in markets with a small market volume – less than 200 million euros per year – has to be at least 10 percent, in markets with 200 to 500 million euros at least 7. In markets with 0.5 to 1 billion euros the market share must be at least 3 percent and reach at least 1 percent in high-volume markets of more than 1 billion euros. In addition, the company must have had above-average growth in the past five years, benchmark is the average growth of the companies in its sector in Germany.

8 H. Simon (1990), Hidden Champions: Speerspitze der deutschen Wirtschaft, Zeitschrift für Betriebswirtschaft, 60(9), 875-890; H. Simon (1997), Die heimlichen Gewinner: Die Erfolgsstrategien unbekannter Weltmarktführer, Frankfurt; H. Simon (2012), Hidden Champions – Aufbruch nach Globalia, Frankfurt.

Hidden champions: number and relative importance





Source: Hermann Simon

dynamic, i.e. above-average growth companies, are often smaller than already long-established and barely growing global market leaders. Therefore, they are referred to hereinafter by the term medium-sized world market leaders.

The relatively small size of the companies with a high global market share means that most medium-sized world market leaders operate in markets with a rather low level of demand. For around three-quarters of medium-sized world market leaders the total annual turnover in their markets is under 200 million euros. For another 14 percent the market volume lies between 200 million and 1 billion euros. These markets are usually of little interest for large corporations, as they allow little opportunity for standardization of products and exploiting economies of scale in production.

The medium-sized world market leaders in 2012 employed a total of around 460,000 people and generated an annual turnover of a total of about 145 billion euros. More than 85 percent are engaged in industry. Around one quarter of which are from the mechanical engineering sector. 12 percent are in the metal industry, especially the production of specialized metal parts as supplier components. A further 11 percent are active in electrical engineering. 5 to 6 percent respectively come from the medical technology, the chemical industry and the automotive industry. A total of 62 percent of medium-sized world market leaders stem from high-level technology sectors, those industries in which the German economy has traditionally specialized in.

Little represented in some industries

Only 6 percent of medium-sized world market leaders are from the field of cutting-edge technologies. Of these almost 5 percent are active in the large area of electronics and measurement technology, among which, microelectronics, computer construction, telecommunications, consumer electronics, instrumentation and control engineering, optics and electro-medical equipment are counted among others. About 1 percent are from the pharmaceutical industry. However, there is

An example of a hidden champion from Germany is Qiagen from Hilden near Dusseldorf. The company is benefiting from the booming biotech market and sells tests and new devices that allow to easily detect diseases.

also a larger group, about 6 percent, of the world market leaders in the research and development sector. These are companies that are primarily focused on the development of new technologies and products and have not yet entered the marketing phase. The greater part of these companies have been active in cutting-edge technologies, for example in biotechnology, nanotechnology, optics and new IT applications.

Within the service sectors medium-sized world market leaders are found practically only in two sectors: in the software and Internet industry with 5 percent and in engineering offices where 1 percent is active. In many service industries it is legally very difficult for small businesses to be active worldwide and to achieve a significant market share in global service markets.

The importance of medium-sized global market leaders in the various industries varies greatly. The highest proportion is found in the sectors of research and development: here they comprise almost 6 percent of all businesses (excluding micro-enterprises with fewer than 5 employees). In electrical engineering, the pharmaceutical industry and the chemical industry the share is around 5 percent respectively. Mechanical engineering with 4 percent and vehicle manufacturing with 3 percent also include high shares of medium-sized world market leaders. In the most important cutting-edge technology sector, electronics and measurement technology, by comparison, just under 2 percent of the companies are world leaders.

Strong market position

The contribution of medium-sized world market leaders to the German innovation system is not to be underestimated despite the low absolute number of companies. Although they represent only 0.6 percent of all enterprises (excluding micro-enterprises and without consumption-oriented services). Their share of employment and turnover with around 3 percent each is already considerably larger. Their contribution to exports of the German economy with 6.3 percent is significant and reflects the high average export ratio of well over 60 percent.

Excursus

Typology of hidden champions

1. Champions in traditional niches

Many hidden champions operate in a small product niche within a fairly large product group and can become market leader there by means of specialization. Such special applications are often not economically attractive for large companies, because they are unable to reap the benefits of their size advantage, economies of scale in research and development (R&D) or distribution. At the same time, the national markets for these applications are so small that virtually no company can work efficiently and at the highest technical level without being present in the world market. As an example, the company ProMinent Dosiertechnik in Heidelberg produces dosing pumps which add the smallest amounts of liquid to a system with high precision. With 2,300 employees, the company is represented with more than 50 sales, production and service subsidiaries in the world market. For some products and services even the world market is small. With high technical requirements, very few companies or even only one can be active profitably in such small markets at the same time. Companies can only offer these products when the world market is consolidated. The buyer is frequently the driving factor of internationalization through his active worldwide search for suppliers. Examples of such narrow world markets are the engineering of cable cars, in which the Austrian company Doppelmayr operates or printing machines for banknotes, where the German company Giesecke & Devrient is active.

Some business groups have actually specialized in the global management of market niches. The Heitkamp & Thumann Group in Düsseldorf for example, has been acquiring small niche suppliers in metal forming and consolidating them into larger business units since 1978. Despite worldwide production and distribution companies, the group with approximately 2,000 employees in total, is still a medium-sized company. A similar case is the Austrian Andritz AG with 24,000 employees. Their subsidiaries are often world market leaders in their field, for example, in large-scale plant construction. An advantage of enterprise groups is that it is possible to share some resources for the foreign activities of each niche product within the group.

The Andritz AG from Austria is for example, specialized on niches. Its subsidiaries are often world leaders, e.g. in large-scale plant construction.

2. Champions in shrinking markets

Another group of hidden champions operate in a shrinking market. These markets have historically been relatively large and offered a variety of businesses space in national markets. They shrink mainly due to technical progress, by which specific materials and technical processes are replaced and limited to a few remaining applications. Champions in these markets are masters of survival. True global market leaders are initially rare, but develop over time through competitors leaving the business sector and the market consolidating world-wide. Among the remaining companies, those who actively invest in the global market, can transform a technical pre-eminence into a leading world market position.

These companies are usually very old, traditional companies. The products are technical masterpieces, increasingly perfected over the years. Examples are manufacturers of musical instruments like church organs, special glass or leather manufacturers. The advantage is based in some companies on traditional craftsmanship, which cannot be found any more in any school except in the vocational training workshop of the companies themselves. For other companies continuous process improvements are the decisive advantage, embedded in the experience of engineers and skilled workers. If the market turns into a small niche, it often requires no more technical advantage. Then long-term customer loyalty, availability of spare parts or global distribution alone can secure the market position.

3. Champions in dynamic markets

New hidden champions are more likely to be at home in fast-growing markets. But they are more of a short-term phenomenon. Because either they grow rapidly with the market to a large enterprise, other large companies acquire them thereby buying growth, or they fail. These companies are held in high regard mainly in the United States in corporate finance, politics and the general public because corporate growth is regarded as a performance criterion and sign of successful high-tech entrepreneurship. Fast-growing high-tech companies are often represented rapidly on the world market even without the establishment of foreign subsidiaries. They use innovative sales channels such as the Internet and foreign partners. A special kind of fast-growing companies are “born global” companies. They are present on the global market from the very beginning and do not have to tread the arduous path of setting up international sales companies.

Many of these companies arise in the United States. The aggressive growth orientation of these companies and the role of venture capital can let the name hidden champions seem unfitting, though. Because they often enjoy great attention on the capital market and by no means work in the shadows. Although there are German examples such as Jamba or Omikron, among hidden champions in Germany young, rapidly growing companies are rather the exception. One reason is the dynamic situation in fast-growing markets. Unlike the US, the term champion in Germany is more influenced by corporate stability, long-term and moderate growth and evolutionary internationalization.

In terms of innovation performance of the German economy, the importance of medium-sized world market leaders is even higher. They shoulder 7 percent of the total R&D expenditures in the German economy. In addition, they are responsible for nearly 6 percent of total innovation expenditures. Their contribution to sales with product innovations is more than 5 percent, making it almost twice as high as the share of total sales. Accordingly, the revenue share attributable to product innovations also exceeds the average of almost 13 percent in the German economy, being nearly double with just over 23 percent. For sales of the German economy with original new innovations, so-called market innovations, medium-sized world leaders contribute 6.6 percent. Considering only the turnover of those market innovations that represent a novelty for the world market, their proportion is nearly as high as 12 percent. On average world market innovations make up 5 percent of the turnover of a medium-sized world market leader.

The success factors of the champions

What lies behind the international success of the medium-sized world market leaders? A key success factor is clearly their strong focus on innovation. For the whole of German companies, except micro-enterprises and consumption-oriented services, every second one is active in innovation, i.e. it makes efforts for the development and introduction of new products or processes. Among the medium-sized world market leaders on the other hand, 90 percent are active in innovation. 55 percent engage in continuous research and development, compared to only 11 percent in the German economy as a whole. Four out of five medium-sized world market leaders have introduced new products recently. Over all companies, this proportion is less than one-third. For the share of enterprises with process innovations medium-sized world leaders reach a value of double that.

To answer the question of the success factors, a comparison will help between medium-sized world market leaders and other companies that are similar in size, active in the same sectors and innovate to the same extent.[9] Companies of the comparison group therefore differ only by having little orientation towards the world market, a lower (world) market share and less growth on average. Based on this comparative analysis, the following success factors arise:

(1) Global growth as a strategic corporate goal
The above-average growth of medium-sized world market leaders stems from the fact that growth is a key strategic objective and they think about it globally. Objectives such as improvement of the profit margin, revenue increase and cost reduction are of great importance for all medium-sized enterprises, but for hidden champions, the increase in market share is a particularly high priority. Opening up new overseas markets is an important measure to achieve the corporate goals. To attain this, hidden champions often establish subsidiaries outside of Europe.

(2) Innovative and active in research
More than 80 percent of medium-sized world market leaders have introduced product or process innovations in the past three years – ten percentage points more than in the comparison group. At the same time their innovation process is designed more efficiently. With similarly high expenditure on research and development and product launches, the hidden champions achieve higher sales revenues through innovations that they bring to the market first. These innovations include market novelties and radical innovations. The share of market innovations is significantly higher among medium-sized world market leaders than in the comparison group with nearly 53 percent. This value is associated with a heightened focus on continuous own research efforts. Three quarters of the companies continuously conduct research and development, in addition they also often subcontract to third parties in this area.

(3) Excellent process management
Medium-sized world market leaders transform ideas and knowledge into marketable services. 60 percent of companies have developed marketing and organizational innovations: they bank on new media, new design of products or online sales channels. They are constantly

A key success factor is the strong focus on innovation.

9 C. Rammer, A. Spielkamp (2015), Hidden Champions – Driven by Innovation. Empirische Befunde auf Basis des Mannheimer Innovationspanels, ZEW-Dokumentation 15-03, Mannheim.

The high level of investment in research and development is paying off for the world market leaders.

looking internally for improvements, detect new customer needs, incorporate almost all employees in the innovation process, and have the expertise to quickly implement new technical solutions according to customer needs. For this quality management tools, knowledge management and forms of work organization such as job rotation and teamwork are increasingly being used.

(4) Systematic knowledge management

Part of professional process management is the systematic internal and external search for knowledge. Basis for intra- and inter-organizational knowledge and technology transfer is the technically oriented knowledge within the company. Innovation impulses should therefore first and foremost come from all parts of your own house. In second place as drivers of innovation are clients from the private sector who are involved early on in the development cycle of products. Universities and colleges also act as a driving force and have a comparable status to trade shows, conferences and exhibitions for these companies.

(5) Research partnerships

60 percent of medium-sized world market leaders undertake cooperations on projects in research and development and innovation. Of importance here are university and non-university research institutions. National partners for collaborations in research and development are of great importance. However, regional proximity plays only a subordinate role. More often than in companies of the comparison group, hidden champions cooperate in research and innovation with European partners.

(6) Know-how protection through speed

Through a (temporal) lead medium-sized world market leaders hope for high effectiveness in securing know-how and thereby establishing a competitive advantage. By designing products and services hard to imitate, as well as secrecy, they erect more barriers to market entry for competitors. Of the legal protection measures they mainly use patents and trademark protection.

In summary – in addition to leadership qualities and strategic measures – innovation activities are an essential basis for the strong market position of the medium-sized world market leaders. An innovation management, which combines customer requirements and technological possibilities, is one secret of their success – another is the connecting of their own technical know-how with complementary knowledge of customers and science. These core competencies are difficult to imitate by competitors. The result is that medium-sized world market leaders are economically more successful than other medium-sized companies in their industries: They achieve a significantly higher market share, a higher revenue growth and a return on sales higher by around one percentage point. Hence the high level of investment in R&D and innovation projects pay off for the world market leaders.

The reason that there are so many and successful medium-sized world market leaders in Germany, is not only down to the management capabilities of the companies, but mainly to the economic structures. Therefore, securing a strong industrial base in the current specialization fields of the German economy (engineering, automotive, electrical, chemical, medical technology, measurement technology/optics, metalworking) is so important. For this the support of innovation efforts of SMEs, an adequate supply of skilled labor in both the academic as well as the vocational training areas, and a working knowledge and technology transfer between science and business are critically important.

Excursus

Cooperation between SMEs and science

Cooperations within the framework of R&D and innovation projects are of particular importance for SMEs for several reasons:

- First, SMEs often have limited internal knowledge resources. Due to the small number of employees, SMEs cannot develop and hold expertise in all technical fields relevant to them. Collaborations develop complementary sources of knowledge, and thus enhance their own ability to innovate.
- Second, collaborations allow to reduce the development cost and risk on the part of SMEs.
- Thirdly, cooperations can facilitate the exploitation of innovation results if, e.g. new business partnerships result from the integration of customers, suppliers or competitors or new sales channels can be tapped.

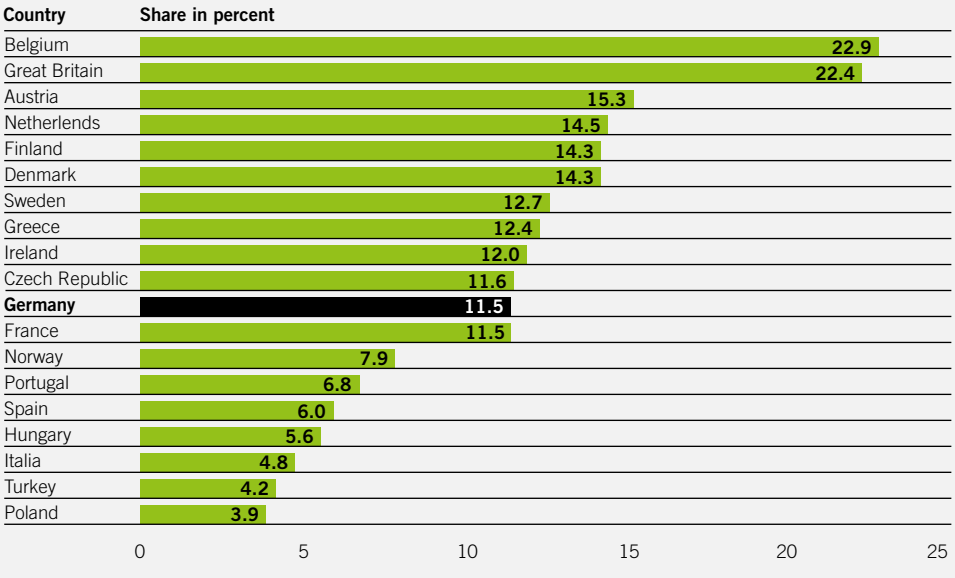
A major challenge in R&D and innovation projects of SMEs is an outflow of knowledge relevant to competitiveness. As cooperation projects are mostly about core strategic projects central for the company. Were innovation ideas to become known at an early stage and be acquired by other companies, it could not only make the concrete innovation project obsolete, but threaten the entire future competitiveness of an SME. Therefore the management of intellectual property and suitable protective measures play a decisive part.

In international comparison[10], SMEs from Germany show a small overall inclination towards cooperation. In the period from 2010 to 2012, 11.5 per cent of all SMEs in Germany worked with external partners on innovation projects. In other countries the inclination for cooperation is a lot higher. In Great Britain and Belgium for example, nearly a quarter of SMEs maintain innovation cooperations. The SMEs from Germany that cooperate, do this very frequently with science. 57 percent of cooperating SMEs from Germany have cooperations with universities, 40 percent work with non-university research institutions. Only SMEs from Finland have higher values. By contrast, the percentage of German SMEs that collaborate with clients from the private sector, is comparatively low with 34 percent.

The strong focus on science as a cooperation partner is connected to public support of such cooperations within the framework of various programs of the Länder (federal states), the Federal Government and the EU, among others. Many programs have a scientific cooperation either as a prerequisite or at least suggest such collaborations. Public promotion of cooperation between SMEs and research institutions in fact makes sense for a number of reasons:

- Without promotion, cooperation with SMEs often appears unattractive to science. The projects are often small, short-term and devoted to technical issues that rarely coincide directly with the current (basic) research activities of scientists.
- From the perspective of SMEs often high internal hurdles have to be overcome in scientific cooperations. To cooperate on an equal footing with scientists, appropriate technological and scientific expertise is required in the enterprise. Also, the two partners must converge in their own specific ways to access research questions: while scientists appreciate thoroughness and scientific rigor highly, the practical and cost-effective applicability and the rapid implementation of the outcome is of particular importance for SMEs.
- Through scientific collaborations SMEs can especially strengthen their basic technological competencies. Since such long-term investments are often expected to bear fruit only in the distant future, they are often quickly swept aside in the day-to-day business of SMEs. A promotion can provide a significant impulse, to nevertheless make such investments.

Share of SMEs in innovation cooperations



Source: Community Innovation Survey 2012

10 The international comparison figures stem from the European Community Innovation Survey (Community Innovation Survey) and refer to enterprises with 10 to 249 employees in industry and selected services.

Excursus

The role of startups in the innovation system

The importance of enterprise formations for a system of innovation is discussed quite controversially. In purely quantitative terms, and considered for an economy as a whole, startups play only a very subordinate role for R&D and innovations. ZEW estimates show that young companies in Germany – that is, companies that are no older than five years – spend about half a billion euros per year on R&D. By comparison, the largest German company, Volkswagen, has an R&D budget of over 14 billion euros. Seen purely from the output volume, startups can thus only have very limited impact in an innovation system.

A different picture emerges however, when looking at specific areas of technology. In bio- and nanotechnologies startups quantitatively played and play a relevant part. And in many areas of the IT industry startups are major players for new technological developments and innovative ideas.

The really important role of company foundings in an innovation system is a qualitative one though: especially technology-oriented startups again and again provide important impulses, by developing new technological solutions and opening completely new ideas and access routes. With the help of so-called disruptive innovations they break open completely new markets time and again. These are innovations that can completely displace existing technologies, an existing product or an existing service. An example would be platforms for providing driving services between individuals which challenge the conventional taxi industry, at least in some areas. Another example are platforms for renting private rooms to tourists, which challenge the classic business model of hotels. Especially in the IT field disruptive innovations are often introduced by startups.

Thus, for the contribution of startups to an innovation system, not the absolute number of enterprise formations are decisive, but those with really new ideas, who want to implement them via a growth-oriented business model. Such formations fuel innovation competition and those foundings also provide the fresh blood of innovative companies to replace older companies withdrawing from the market. This is particularly important in view of one of the strengths of the SME sector in Germany, the hidden champions. Because these

With a new lifebuoy, which is only slightly larger than a smartphone and then inflates within seconds, Markus Kunkis (left) and Christopher Fuhrhop of Restube managed to convince this year's jury of the German Founders Award. The reward: 1st place in the category startup.

companies are relatively old (on average 80 years) and move partly in markets that may become victims of disruptive innovations by startups.

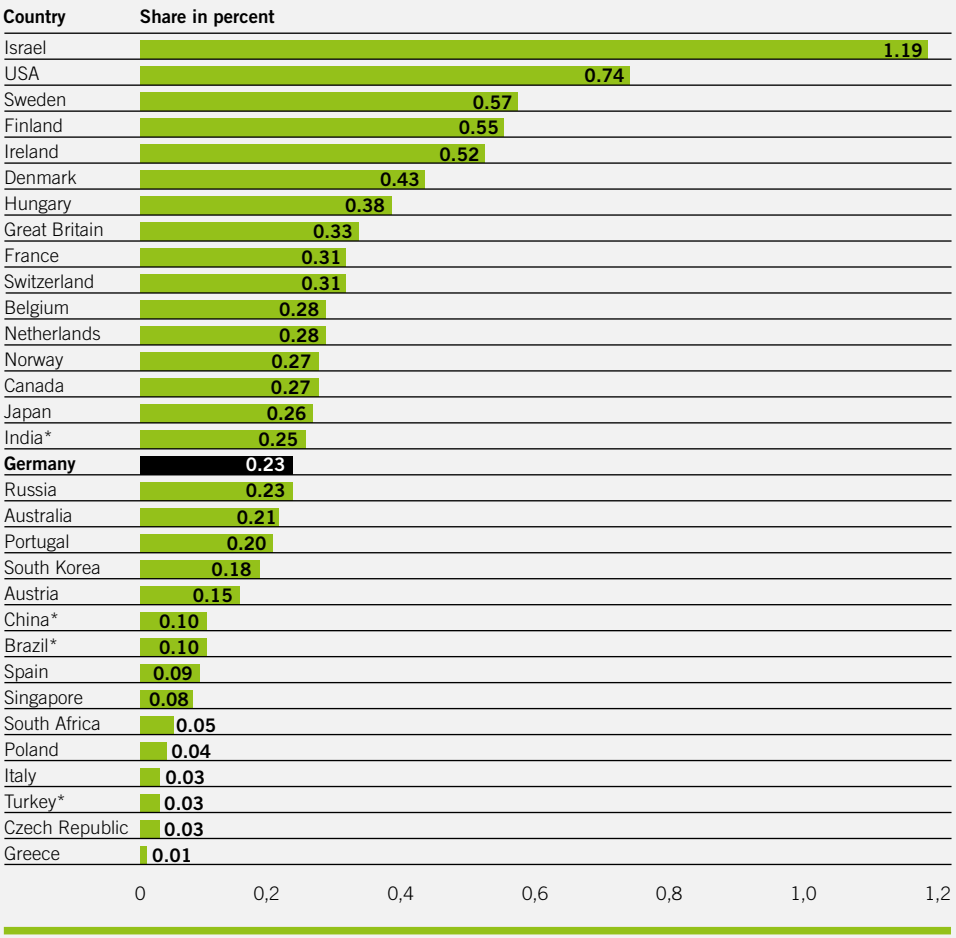
An important basic condition for innovative, growth-oriented startups is the availability of venture capital. This is because startups that are able to make a measurable contribution to innovation usually are characterized by four things: excellent ideas, great growth potential, significant risk of failure, and no money. And precisely here formal venture capital investors such as private venture capitalists (founding angels or business angels) come into play: they finance the implementation of ideas into marketable products and the marketing of these products. Due to the fact that they have a portfolio of investments in innovative startups, they can also bear the risk: one successful startup sometimes makes more money than nine unsuccessful projects have burned.

The venture capital market in Germany, however, is not nearly as strong as an innovation-oriented economy like Germany would need. On average in the years 2012 to 2014 approximately 650 million euros were invested in venture capital in the seed, startup and growth phase of enterprises in Germany. This is less than in Great Britain and France and only one-twelfth of the investment volume of the United States. In terms of GDP, venture capital investment in Germany lies behind almost all other innovation-driven economies. Even Japan, which has long had a poorly developed venture capital market, is now ahead of Germany.

There are several reasons for the low level of venture capital investment. Tax treatment of venture capital, e.g. concerning the treatment of losses carried forward, is less favorable than in other countries. Germany also lacks an important group of actors in the venture capital market, the pension funds. Finally, the exit options for venture capitalists are limited by the absence of a separate stock exchange segment for young companies.

In addition to a sufficient venture capital supply, other factors also play an important role for a stimulation of the startup activities: this includes the promotion of a risk-taking culture which encourages new starts and does not stigmatize failures of company foundings.

Share of venture capital investment in GDP (annual average from 2012 to 2014)



* Values refer to 2009.
Source: EVCA, NVCA, OECD.

Germany's startups need a stronger market for venture capital.

Part 4

Internationalization of SMEs in Germany and Japan

Both Germany and Japan have a high-performance, innovative medium-sized industry. In both countries, the industrial strength is based on high innovation competency paired with a strong focus on exports. A major difference is that Japanese medium-sized enterprises are far less present in the global market than German ones. Japanese SMEs are often the primary suppliers of Japanese (globally active) large corporations. Thus, only a very small share of Japanese SMEs export directly to customers abroad. Their share is less than 3 percent. The total number of exporting SMEs in Japan corresponds to only about 10 percent of the corresponding number in Germany.

This difference is striking, because the situation is very similar in both countries: technical excellence of SMEs and a similar industrial structure. While German companies use this base for an offensive internationalization, Japanese medium-sized industry displays an almost extreme reluctance to do business abroad. A comparison between Germany and Japan can thus also shed light on some of the reasons for the particularly good export performance of German SMEs.

In recent years, the discussion about hidden champions has also reached Japan. Traditionally, the interest of politicians and the public was very focused on large enterprises. For a long time the conventional wisdom in Japan was that export success and international competitiveness are based on national champions, i.e. large multinational companies based in Japan. This belief is influenced by the price competitiveness of Japanese large enterprises on the world market. In technologically sophisticated product areas these national champions could achieve a high quality of their products through economies of scale. In these product areas, such as cameras or watches, especially German companies often counted among the losers.

In Japan there are many family businesses that operate technically at the highest level and are highly innovative.

The international success of the Japanese economy is characterized by cost efficiency in mass production and less by customer proximity. The latter is the traditional strength of German companies. The Japanese industry is therefore at an advantage, where economies of scale in R&D and production exist and both a price and a quality competition take place. Nikon, the Japanese optics manufacturer, now a large corporation with nearly 25,000 employees, thus saw its competitive advantage in the mass market for high-quality miniature cameras, unlike the German traditional brand Leica. Through innovation, Nikon has achieved a strong global market position in this segment, which the company defends to this day.

Sleeping dragons

In Japan, a rethinking set in lately, though. After all, the Japanese medium-sized industry is similar to the German: there are many family businesses that operate technically at the highest level, are highly innovative and rely on a very strong customer loyalty – but only very few export directly.

For many of the German hidden champions a very similar Japanese company can be found, which is the market leader in Japan, but is only weakly present in the world market. Here a large, untapped export potential for Japan is seen and illustrated by the metaphor of the sleeping dragons. The Japanese Ministry of Commerce has thus, as part of a revitalization program, targeted the potential strength of medium-sized companies situated in areas outside the industrial agglomerations.

Hermann Simon has already pointed out that it in fact there are also hidden champions in Japan. However, their number is far lower than in Germany and these hidden champions are mainly engaged in the electronics and optics field. Of the few Japanese hidden champions some are technologically in an especially strong position. An example is the Japanese family-owned company Nichia, the world leader in LEDs. A former employee of Nichia, Shui Nakamura, received

the Nobel Prize for Physics in 2014, namely for the development of blue LED which he created in the company in 1993. Nichia with now just under 8,000 employees generates sales of 2.5 billion US dollars, with offices and production facilities around the world.

Obstacles to exports

But Nichia continues to be the exception. Most innovative Japanese small and medium-sized enterprises concentrate on the Japanese domestic market. They see their function mainly as a supplier to Japanese large corporations. Low exports are often not equated with low performance capability or competitiveness since Japanese large companies are very oriented towards exporting and thus the products of their suppliers are also represented to a large extent on the world market. Close, trusting supplier relations between Japanese companies, which include joint development projects and capital links, are a great advantage of Japanese industry.

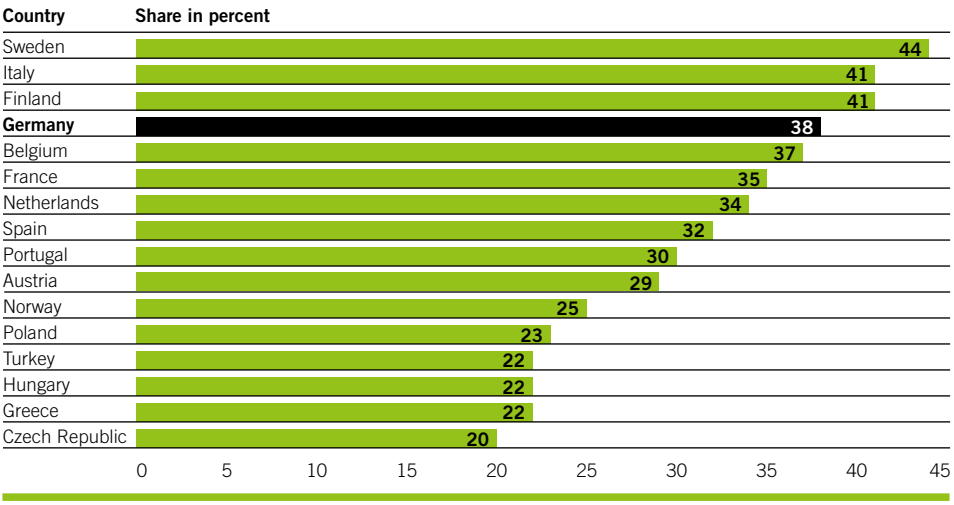
But they most likely also pose an obstacle to the export orientation of the small and medium-sized enterprises. This is because suppliers often see it as their duty to supply the domestic customer preferentially or to provide the latest technical developments first or exclusively to its customers in its home country. Thus, foreign companies even reported that it was difficult to convince small Japanese companies to export their latest technologies. This behavior can be advantageous for Japanese big industry, but it reduces the total export volume of Japan.

At any rate often a reluctance to conquering foreign markets on the part of Japanese SMEs can be seen, if this requires a high level of commitment by management. For Japanese companies, the first step into international markets is far more difficult than for German or European companies. The latter can also record intra-European trade as an export. German companies are certainly closer to their neighboring markets than Japanese companies.

From Japan entering the market in the East Asian neighboring countries is as major a challenge as stepping into the North American or European market. For Japanese companies, the first step into direct international business represents a fundamental decision that requires substantial resources and the development of new skills. For this purpose, first of all one needs an internationally oriented and experienced top management.

Another factor influencing the export ability of Japanese companies is the characteristic of the domestic demand. In many industries in which Japan today is a leading country in the world, the domestic demand takes on the part of a lead market in the world.

Share of SMEs in European countries with overseas exports



Source: Eurostat: Community Innovation Surveys. – ZEW calculations.

Production in Toyota City: the Japanese carmaker was established as a family business and matured into a global corporation.

In many other areas, however, a so-called idiosyncratic demand dominates: the needs and requirements of Japanese customers are hardly consistent with international preferences and trends. Products oriented towards Japanese customers are therefore hardly exportable.

High degree of success in internationalization

The success of German small and medium-sized companies on the international market consists of three essential components:

- a high degree of readiness of top management to export,
- the company's ability to operate in the world market and to be close to many customers around the world, and
- a long-term strategy of concentrating on a narrow product range and maintaining entrepreneurial independence.

The first component, the high export readiness of top management, is a frequently mentioned factor in the success of SMEs in Germany, where inter alia, the good English language skills and international experience of entrepreneurs and managers in Germany are referred to. Ultimately, however, the preparedness of companies to export is an individual characteristic of entrepreneurs. Some small and medium-sized companies simply show a particularly large desire to conquer the world market. The number of such companies in Germany can simply be quite large, as the number of small and medium-sized innovative companies as a whole is very large.

Compared to Japan not only the willingness to export is particularly high. Also the access to export markets is easier. Because the start into the export business and thus learning in foreign markets has become much easier for German as well as for companies in other European countries by the harmonization within the European Union.

The situation in the US and China in contrast is dominated by very large domestic markets. For a small US company covering the whole domestic market, from Alaska to Florida, already presents a major technical and logistical challenge. SMEs wishing to compete in the entire US market need to be much larger than SMEs in Germany wanting to cover the German market. Market leaders in the United States are therefore usually quite large when they take the first step into a foreign market.

Costly representations abroad

The second component of the ability of a small business to supply the world market, represents the biggest challenge. The description of hidden champions by Hermann Simon impressively demonstrated that small and medium-sized companies with the aim to supply the entire global market, often have a large number of representations abroad. Sometimes they number 50 or more, often in countries with rather marginal market volumes. The company ProMinent Dosiertechnik e.g. with 380 million euros in annual sales has representations in 48 countries, including Libya, Sudan, Armenia and Cuba.

A high number of representations abroad bring diverse challenges. These include setting up, management and organization of representations under very different legal and cultural conditions, high personnel costs compared to the total number of employees, a number of adjustments to local markets and a variety of feedback, suggestions for improvement and innovation impulses. SMEs which cope with these challenges, can gain a large competitive advantage.

It becomes apparent in international business, that not only the technical performance of a company is crucial, but also the ability to maintain and professionally manage a network of international offices, as the high resource expenditure is often offset only by small market volumes. With the exception of the US market, foreign markets are so small for niche companies that a subsidiary branch cannot finance itself alone. In addition, there is both a cost risk and a control risk: employees in foreign offices are more difficult to lead and to control than at the home location.

Germany's export model is rather the exception

The third special feature of the export-oriented German SMEs is the consistent focusing on a few core areas or individual products and services pursued long-term. Growth is achieved mainly by opening up foreign markets and less through diversification. Since internationalization is a long-term process that unfolds over many years and decades, the growth of export-oriented and specialized companies is usually lower than for companies for which growth is the primary goal.

Diversification is often avoided by small and medium-sized businesses, instead, the tireless safeguarding of competitiveness in the existing strengths is in the foreground. This is certainly one reason that Germany, compared to other countries, is characterized by a high number of very old, traditional and small world leaders.

The advanced age of hidden champions in Germany – on average over 80 years – is an indicator of the subordinate role of corporate growth. Many companies sacrifice a possible stronger growth for security in the niche.

From the US perspective this strategic direction is rather unusual. In fact, there are only a few examples of new hidden champions, let alone for major German companies that have emerged in the last two decades, from small and medium-sized companies. SAP is one of the few exceptions. The US

The hidden champions in Germany are on average more than 80 years old.

strategy of relying on fast-growing companies that are driven by high levels of venture capital investment, clearly stands against a German strategy of maintaining lasting values.

However, this also indicates that countries pursue different strategies and can be successful in their own way. The examples of Japan, South Korea and China show that the German model is rather the exception worldwide. In recent years in China large companies have emerged through aggressive diversification that are now pushing gradually into the world market.

Market niches are often not attractive enough for large companies.

For example in 2014 the Chinese construction machinery manufacturer Sany caused a stir by acquiring the medium-sized company Putzmeister in Germany. Putzmeister has been around since 1958. The company is the world leader in cement pumps. Sany also started with cement machinery in 1994. However, in the past twenty years since its formation it has pursued a dedicated growth strategy. In almost every year the turnover was doubled – with the result that today Sany is one of the world's largest construction equipment manufacturers.

The market niche on which Sany had concentrated at the beginning, only served to become established in an industry that is dominated by large companies. Although market niches are often not attractive enough for large companies, for the founders of Sany it was not enough to be the market leader in a certain small special machines segment. Sany gradually expanded its position in the Chinese market through entry into other areas of the construction machinery industry. It was only after the company had grown into a large enterprise that internationalization began. Today its size is the competitive strength, which the company plays on the global market and not specializing in technical core competencies.

Part 5
Summary conclusions

The role of SMEs for the German innovation system is as varied as the SME sector itself is diverse. The group of hidden champions assumes a special position in the international comparison. No other country is home to so many medium-sized world market leaders as Germany – and not only in absolute terms, but also counted per capita. Although these companies are less than 1 percent of German SMEs, they are a significant pillar of the German economy in terms of innovation and exports.

But hidden champions are not only success stories: Many of these small businesses are so strongly focused on niche and specialty applications that they do not in fact have any growth opportunities, since they already cover a large portion of global demand in their market.

A second, far larger and less noticed group are SMEs that produce innovations without their own R&D. This group is rarely in the focus of public debate when it comes to innovation by SMEs. Innovation policy disregards these companies. Because for most innovation-oriented promotion programs your own R&D activities are an eligibility condition. In fact SMEs with no R&D are the majority of innovative SMEs in Germany. And they are not weak companies, but pursue successful innovation-based competitive strategies. They just do not rely on technological leads, but high levels of expertise of their staff combined with flexibility, customer orientation and efficient internal processes.

Considering the totality of all SMEs in Germany, they are not more innovative than SMEs in other countries. Their R&D expenditure in relation to GDP even is far below average. The number of patent applications by SMEs is – considering the country's size – not particularly high in Germany. Because these findings also apply to the other

two major countries with highly innovative global champions, the USA and Japan, a presumption suggests itself that SMEs in fierce competition with major companies in their own country have greater difficulties in financing and implementation of investment projects.

One possible cause could be the access to highly qualified personnel. Large enterprises can make more attractive offers in terms of wages and career prospects to talented employees than an SME. Also the (innovation) competition in the domestic market is more intense. Finally, it may also be more difficult for SMEs to find suitable partners for their own projects, if, for example, science is primarily interested in working with large companies.

This means, especially because of the innovative strength of the German economy, that the innovation policy should offer special measures for SMEs, which compensate their size related disadvantages in competition for innovation. Even if SMEs shoulder a relatively small proportion of the total R&D and innovation activities in the economy: they form the reservoir for future, internationally successful large corporations. They are often innovative leaders when it comes to solutions in niche markets or for special customer requests.

In that respect they complement the technology portfolio in Germany in key positions and contribute to the strong export performance. The recommendations for action at the beginning of this report contain proposals on how the innovative power of SMEs can be strengthened.

The innovation competition in the domestic market is intense.

Hidden champions such as for example family-owned Kärcher are a significant pillar of the German economy.

Appendix

Making innovation measurable

How the Innovation Indicator works

The innovation capability of economies is a complex and multi-dimensional subject of investigation. You can neither survey nor measure it directly, but determine it only by a multitude of different values and indicators. The Innovation Indicator exclusively uses measures that have proven relevant in an empirical analysis based on a theory-based model. Together, these values give a single total – or – innovation indicator. This allows the complex interplay of all innovation factors in each country to be mapped.

The method used for the Innovation Indicator is called a composite indicator. It composes, in short, complex information simply and clearly. This method is now widely used in empirical research. Although it has not been without criticism, it has established itself in a systematic and robust application as a reliable form of representation. Moreover, it forms only the basis for a further discussion of the results in the relevant context and in conjunction with qualitative information. Composite indicators are the starting point of wider discussions and not their endpoint.

Despite the transparent methodology, the road to the final Innovation Indicator is a long one. Three individual steps are required: the selection of indicators and data collection, normalization of individual indicators and finally summarization via aggregated weights.

The indicators with the highest explanatory power were selected.

38 individual indicators form the basis

In order to take account of the different innovation structures in the countries, the Innovation Indicator compiles 38 individual indicators for sub-systems of innovation systems. These sub-systems are industry, science, education, government and society. The information contained is finally consolidated by the Indicator into a single measure.

In developing the Innovation Indicator, the 38 individual indicators are selected on the basis of an empirical model. The model identifies those indicators that have the highest explanatory power for the innovative capacity of economies. It was important that the overlap between the indicators is as low as possible, so that each indicator makes an additional contribution or illuminates an additional dimension. Originally, there were more than 100 indicators to choose from. Significant, however, were the ones that have a statistically significant influence on the success indicators downstream with regard to content of innovation systems (“output indicators”). One example: the number of researchers in science is related to the number of scientific publications in the following years. The output indicators in turn had to qualify on the basis of a direct or indirect contribution to overall economic prosperity (GDP per capita).

The US, Japan, Germany, Great Britain, France, Italy, and Switzerland: on the basis of a fixed set of reference countries, an interval with values from 0 to 100 scales the individual indicators in order to make them comparable. The overall indicator can then be calculated as the average of the equally weighted individual values. Equal weighting occurs because only those indicators are taken into account which actually make an independent explanatory contribution. In addition, a sensitivity analysis takes place, which analyzes the effects of the choice of different weights on the overall result.

In addition to the overall indicator, the results are reported separately for the sub-systems industry, education, science, government and society. Thus fields for innovation policy action can be better identified. The methodology for the calculation of the sub-systems is identical to that for the overall indicator. The individual indicators are aggregated within the sub-systems weighted equally. It should be noted that the sub-indicators cannot be simply added to reach the overall indicator, as some indicators are attributed to several sub-systems.

A strength of the Innovation Indicator is that it combines data from different sources in investigating the innovative capacity of economies. But because of the diversity of data sources, the indicators contained in it have different periodic-

ities with respect to the publication dates. While some indicators are available annually, and up to the current values, others are only available once every two or even every four years. These partly long periods between data updates would diminish the relevance of the Innovation Indicator. All data on which the Innovation Indicator is based refer to the reference year 2014. This way, the timeliness is assured and the comparability of the values for individual countries guaranteed. For indicators and countries whose data status is not sufficiently available up to 2014, forecasting methods of time series econometrics are applied in order to update the values up to the present.

Sensitivity analyses

Robustness is of great importance in composite indicators, because the results and rankings depend not only on the metrics and indicators used, but also on the chosen aggregation weights. Indicator systems such as the Innovation Indicator therefore have to make the extent to which the results of the concrete weights depend transparent. To this end, a sensitivity analysis is carried out, with randomized weights and no equal weighting takes place. This results in random weight constellations that lead to a correspondingly specific ranking of countries. This procedure must be repeated many times to achieve the full results. The various rankings that result from the specific random weights eventually form simulated variation intervals for the rankings of the individual countries. These make it possible to examine the robustness of the results.

This results in three main groups of countries: top contenders, midfield and stragglers. Within a major group of rank positions for countries in general is not very robust to changes in weights. Belonging to a main group in turn is quite robust to changes in the weighting. This means that the actual position of a country in the ranking may be changed by a slightly different weighting, but not to which one of the three groups it belongs. For example, it cannot be said with certainty for Germany that it is better with its fifth place than Norway at no. 14 and South Korea ranked 13th. One can though very clearly state that Germany is behind Switzerland. Even in the ideal case of a weighting of individual indicators especially favorable for Germany, it would achieve no better than third place, but no worse than eighth place.

A detailed report, an overview of the individual indicators used as well as graphics regarding the methodology of the Innovation Indicator can be found on the German-language website: www.innovationsindikator.de

Project partners

The Innovation Indicator is a cooperation of acatech – National Academy of Science and Engineering and the Federation of German Industries (BDI). Co-initiator of the study is the German Telekom Foundation. A consortium of two institutions developed the Innovation Indicator: Leadership of the project lies with the Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI). It is supported by the Centre for European Economic Research (ZEW).

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acatech represents German engineering sciences domestically and abroad in a self-determined and independent way for the good of society. As a working academy, acatech advises politics and society in engineering science and technology policy issues of the future. Moreover, acatech has set itself the goal to support the transfer of knowledge between science and industry and to support young scientists and engineers. Outstanding scientists from universities, research institutions and companies are among the members of the academy.

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The BDI is the umbrella organization in the field of industrial enterprises and industry-related service providers. As representative of the interests of industry, the BDI contributes to the opinion-forming and decision-making of its members. It provides information on all areas of economic policy. The BDI thus supports enterprises in the fierce competition that comes with globalization.

www.bdi.eu

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The Fraunhofer Institute for Systems and Innovation Research analyzes the origin and impact of innovations. It explores the short- and long-term developments of innovation processes and the societal impacts of new technologies and services. On this basis, the institute provides its clients from industry, politics and science with policy recommendations and perspectives for key decisions.

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The Centre for European Economic Research (ZEW) is a non-profit economic research institute. It was founded in 1990 on the initiative of the Baden-Württemberg state government, the federal state's business community and the University of Mannheim and started work in April 1991. Since then, the ZEW has established itself as one of the leading German economic research institutes with a high European reputation.

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