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Research and Development 4.0

The mutual benefits of digitization and R+D

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About the authors

Dr. Nils Naujok, Dr. Gerhard Nowak, Dr. Christian Foltz, Dr. Alexander Timmer, Dr. Thomas Wolf and **Timo Johnson** are leading members of the Strategy& EMEA Innovation and Development Excellence Community of Practice. The community was established to foster intellectual exchange, share knowledge and discuss the ideas of innovation practitioners at Strategy& and throughout the PwC Network. The community also serves as the origin of prominent publications in the areas of innovation, research and development.

Foreword

Dear readers,

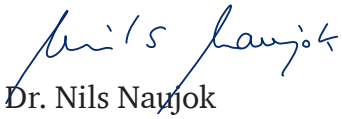
Excessive costs. Significant risks. Lack of capital and specialized personnel. These are the reasons enterprises mention most often for not investing in innovation or research and development (R+D). The trend toward digitization of the value chain and Industry 4.0 can be considered as a game changer for the future in this respect. Digitized R+D after all makes major contributions improving efficiency (through cost-saving modeling and simulations) as well as minimizing risk (by validating real-time data) and improving engineering capabilities (fast prototyping). Altogether, this could significantly reduce cycle and development times.

Before this can happen, both available and emerging Industry 4.0 solutions must be leveraged much more along the entire innovation and development process. In addition to the technical application of Big Data Analytics, additive production methods (3D printing), Cloud Computing and horizontal as well as vertical networking, the proper understanding of the benefits as well as the limits of technology is decisive. In this context, enterprises must make the strategic decision as to what role they wish to play in digitilized value chains.

Overall, our analysis has revealed that innovations must be considered that go beyond purely technical new developments. R+D can decisively influence whether in addition to products, an enterprise's processes, services and even its business model are ready for Industry 4.0 and the requirements of a digital market. In this paper, we discuss which measures and steps need to be taken to combine Industry 4.0 on the one hand and R+D on the other hand to create R+D 4.0.

We hope you'll find the current report informative and illuminating. We look forward to discussing this further with you.

Frankfurt a. M., May 2016



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Not enough R+D in the digital future fields

The digital crash?

"Germany is on the brink of a digital crash"[1] was the title of an article in the Frankfurter Allgemeine Zeitung early in 2016 in the wake of an analysis of the official report of a commission of experts on research, innovation and technical performance in Germany 2016. The annual experts' report gave Germany average reviews in a European comparison. According to the experts, the German economy did not exhibit any major strengths in classic information communications technology (ICT) nor in the Internet-based segments.[2] The commission determined that the level of intensity and the funds dedicated to innovation are much lower in German small and medium-sized enterprises (SMEs) than in France, Sweden and Great Britain for example. The committee found another complicating factor in the stagnation of spending on innovation among German SMEs since 2009; the level of spending among newly founded SMEs appears to have declined in recent years. In contrast, France, Sweden and Great Britain have spent twice to two and a half times as much on innovation. In an international comparison, German companies also lag behind on the output side. In looking at innovation success, the experts calculate that German SMEs indeed occupy the middle ground on transnational patent registrations and may even lead when it comes to product or process innovations, but they were less capable of turning these advantages into sales revenues than companies in other European countries such as Great Britain, France or Italy (*see Exhibit 1, next page*).

"Digitization" has indeed arrived at German SMEs, but the picture is much more heterogeneous on the use of Cloud Computing, Big Data, or Industry 4.0 applications. Three out of ten of the enterprises surveyed in this context consider their firms to be (exceedingly) digitized.[3] Another 30 percent assess their level of digitization as (very) low. Overall, German industry would put itself in the middle of the digitization scale, while it was obvious that 43% of the enterprises complain of the lack of a strategic anchoring of the digitization process.

43% of enterprises complain of the lack of a strategic anchoring of the digitization process.

Exhibit 1

Patent activities and innovation successes of SMEs 2010 to 2012

Patents		Innovations		Turnover	
Transnational patent applications of SMEs (< 500 employees) per 1 million inhabitants		Percentage of SMEs (10 to 249 employees) with product or process innovations		Percentage of sales with product innovations of SMEs (10 to 249 employees)	
Sweden	137	**Germany**	**42%**	Great Britain	18%
Finland	132	The Netherlands	41%	France	8%
Austria	104	Finland	40%	Italy	8%
Germany	**87**	Sweden	40%	The Netherlands	7%
The Netherlands	82	Italy	39%	**Germany**	**6%**
Great Britain	50	Austria	36%	The Netherlands	6%
France	45	France	32%	Finland	5%
Italy	44	Great Britain	28%	Sweden	5%

Source: EPA, Patstat, Eurostat: Community Innovation Surveys. Berechnungen des Fraunhofer ISI sowie des ZEW in Rammer et al. (2016)

Already during this "early phase" of the fourth industrial revolution, the focus would seem to be on digitization – particularly the areas of selling and procurement are already relatively strong on digitization today. One in three enterprises already has a (very) high degree of digitization inthese areas. However, only one in five appears to have digitized manufacturing capabilities.

It is not surprising therefore that the majority of the companies surveyed see the greatest benefits of digitization in the simplification of work processes (83.4%). Less than half of those surveyed believe that value is added by digitization in the area of product and process innovations. Even fewer see any positive impact on business model innovations (*see Exhibit 2, next page*).

The leveraging of digitization in production is linked to earlier automation trends and has apparently been known for quite some time; that there is considerable untapped potential in functions such as R+D and the business model is not so well known.

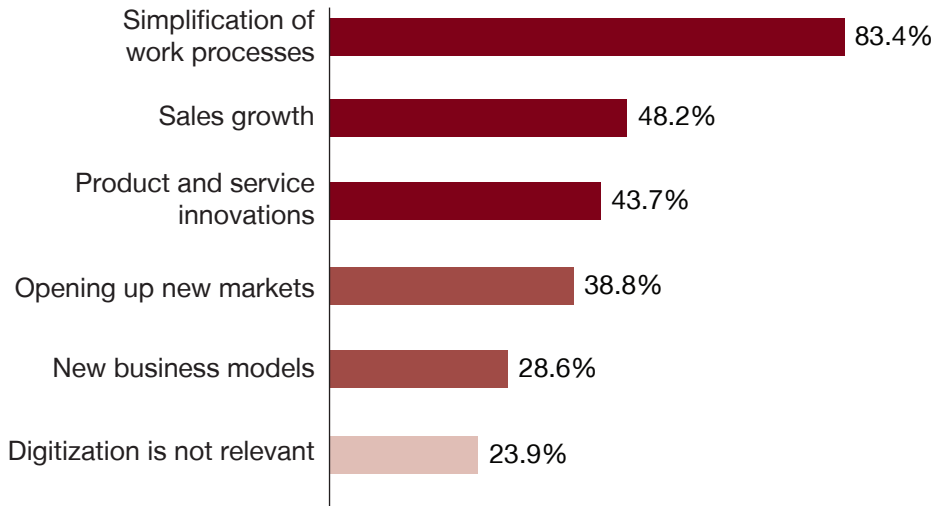
German enterprises invest 14 percent of their research budget in digital technologies.

No innovation without investment

There is no doubt that German industry is willing to make investments in Industry 4.0. In a survey of 513 German companies within the manufacturing industry as well as the information and communications industry, we were able to determine that German enterprises plan on investing around EUR 31bn in Industry 4.0 solutions as of 2020.[4] However, only a fraction of that amount will be dedicated to innovation processes. Ultimately, an average of 4.3% of the total investment volume of SMEs is put toward digitization.[5] German enterprises also only invest 14 percent of their annual research budget in the industrial application of digital technologies.[6] In the USA, the comparable figure is twice as high. These numbers make it clear that the budget for digital innovations leaves significant improvement potential. The mutual benefits of R+D and digitization, as a R+D 4.0, seem very apparent.

Exhibit 2
The benefits of digitization

Digitization helps optimize business processes
Extrapolated values, n=648 (1,574 responses)
Multiple responses allowed



Source: BDI/Pwc, SME Panel 2015

Reciprocal effects of R+D and Industry 4.0

In our view, digitization and Industry 4.0 will revolutionize how research and development will be done in the future. To date the changes introduced by Industry 4.0 are frequently primarily affected in connection with processes and automation options in the production process (e.g. Smart Factory) or in sales and marketing (e.g. web shops, e-commerce). All these developments remain highly relevant, but they don't aim high enough. The actual target is to extend digitization activities to create an integrated product and service development process to fully exploit the potential of Industry 4.0 solutions (e.g. the use or processing of real-time data).

On the other hand, R+D must do its part to digitize the value chain, the service and product portfolio and even the digital business model. This reciprocal effect has mutual benefits. Just as R+D can be integrated in a holistic development cycle along the entire value chain with the help of digital networking, digitization – within the framework of an innovation strategy – can contribute significantly to making R+D more efficient, more affordable and at minimal risk.

Industry 4.0 ultimately offers various industries impressive ways to develop new business models for products and services. The technology trends associated with Industry 4.0 have a major impact on this development. Automation technology is a good example. Our studies have identified seven technology trends, ranging from modularization to networking to mechatronics as well as engineering and simulation (*see Exhibit 3, next page*).

The specific effects on the product portfolio can thus be identified and must be implemented in modular and scalable automation components which also support a horizontal and vertical networking with the corresponding exchange of information. The new product portfolio must also offer appropriate solutions to incorporate and specifically evaluate data to improve the performance of the total system. Another requirement which R+D must meet in the engineering process is the integration of these systems in efficient engineering and simulation tools.

More than just innovative processes are needed to provide the range of services required to develop a new digitized product portfolio. R+D process participants must also take a different approach.

To date the changes introduced by Industry 4.0 don't aim high enough.

Exhibit 3
Technology Trends, e.g. Automation Technology

Technology trend	Impact on product portfolio
Modularization	Modular control and drive program
Scalable performance	Scalable program re. functions and performance
Integrated platforms	Horizontal and vertical exchange of information on all levels of the automation pyramid
Networking	Networking and international standards
Internet	Connectivity for internet-based services
Mechatronics	Convergence of mechanics, electronics, software
Engineering and simulation	Efficient engineering and simulation tools

Source: Strategy& analysis

Enterprises can develop the requisite capacities and qualifications on their own or cooperate in innovation networks on a case by case basis. In regard to the overall goal of shortening time-to-market cycles, the second option is preferable in many cases. Involving external specialists is also an effective way of dealing with disruptive trends early on that could affect the enterprise's own product and services portfolio. The typical inside-out view is often too narrow and obscures the ability to recognize dramatic changes at all, or causes them to be recognized too late or only with a limited understanding of the consequences.

The example of automation above can be applied to other applications and industries with similar results. The changes introduced by Industry 4.0 reveal that enterprises, and specifically R+D, can expect massive changes due to the technological trends in their respective industries. A necessary step to be prepared is the early adapting of processes and skills that also incorporate external capacities and qualifications – for example, through innovation networks.

In addition to the effects of the methods and resources available in Industry 4.0, R+D must meet other requirements to satisfy the needs of Industry 4.0 vis-á-vis the product and service offerings to be developed. It can be assumed that this will include following highly integrative areas:

- Adjustments to the product and service portfolio
- Shorter time-to-market cycles
- Improved digital capabilities

Involving external specialists is also an effective way of dealing with disruptive trends.

Using sensor systems and actuator technology, development processes in manufacturing are simplified and are being structured more clearly. Just think about what it would mean to have the option of extracting data from the raw material to the individual process steps in R+D to the prototype phase available and capable of being analyzed immediately. This dramatically shortens the drawn-out and cost-intensive trial-and-error process, and the evaluation of historic, at best current data. The prerequisite, however, is the intelligent linking of the processes with a Big Data analysis.

The argument used in respect to cost is not just the optimizing of the reliability of machines and machine elements, but also that existing approaches are used. R+D of integrated and networked solutions basically rely on a functioning basis and do not necessarily have to be drawn up from scratch. Additional advantages can be generated in early quality control, the enabling of product modularization and standardization on the road to batch size 1 and identifying the metrics

for predictive maintenance. R+D 4.0 also stimulates the development and expansion of a digitized service segments, the latter being one of the growth segments in Manufacturing and Engineering.

Overall, it can be stated that R+D can make a major contribution to preparing an enterprise's products and services for Industry 4.0 and the challenges of a digitally revolutionized market. Then again, the digitization of R+D must be supported by a strategy that is a good fit to the enterprise's capabilities. Or to put it another way, the skills and core competence in the enterprise's R+D function must be reflected in the digital strategy.[7]

Digitization of R+D must be supported by a strategy that is a good fit to the enterprise's DNA.

Practical applications

1. **Big Data and IT Security in Pharma / Chemicals**
   The capabilities for the development of intelligent tools for medication and diagnosis are a key component of a digitized process in pharmaceutical research. In this context, the available data potential must be put to optimum use. This is the case when there are no restrictions on how research partners communicate in networks and if they are allowed to share their results transparently. Ideally, other external real-time data (patient data, test results, guidelines, feedback from production, logistics and from users) are also incorporated in the results. In this way, it is possible to detect side effects early, for example, or to integrate the specific drug treatment of certain patient groups in the individual development stages. Results of this integrated approach include, for example digital engineering (e.g. 3D printing) or new products such as Smart Plastics or polymer electronics. The availability of data and data mining are also linked, however, to the security of the IT infrastructure. Ultimately, confidence in the available security is the deciding basis for the inclusion of external stakeholders in the process. In this way, the characteristics that are essential to shape a digital end-to-end view of the entire value chain are developed during R+D.

2. **Connected Cars and Vehicle Diagnostics**
   In the context of automotive manufacturing, digitization supports a revolutionary form of vehicle diagnostics. Traditionally, OEMs are provided with information either by the suppliers of certain components within the framework of joint development and manufacturing or by analyzing data at a certain point in time (usually retrospectively and historically, such as crash tests or the reading of control units). This process is undergoing a fundamental change thanks to digitization. It is not just that real-time data about vehicle performance is available around the clock thanks to satellite technology. The storage capacity in clouds also simplifies both the input, ability to retrieve and analyze vast amounts of data. A number of previously ignored factors can thus be incorporated e.g. in co-creation and trigger new products and services. Just which factors this additional knowledge can determine are indicated by the following list of sensor elements found in state-of-the-art vehicles: Adaptive Cruise Control, Collision Avoidance, Traffic Sign Recognition, Cross Traffic Alert, Park Assist, Blind Spot Detection, and Surround View.

Roadmap: Four strategies for R+D alignment

Enterprises can basically apply four strategies to successfully lead their R&D functions into the Digital Age. Every business must determine which of the following strategies below to adopt.

Enhancers – Providers of, or dealers in data, information and services based on the Internet of Things (IoT), but not necessarily their owner

Engagers – Producers of networked products and IoT services

Embedders – Users of IoT in own operations, manufacturing processes, value chains, services and own sales

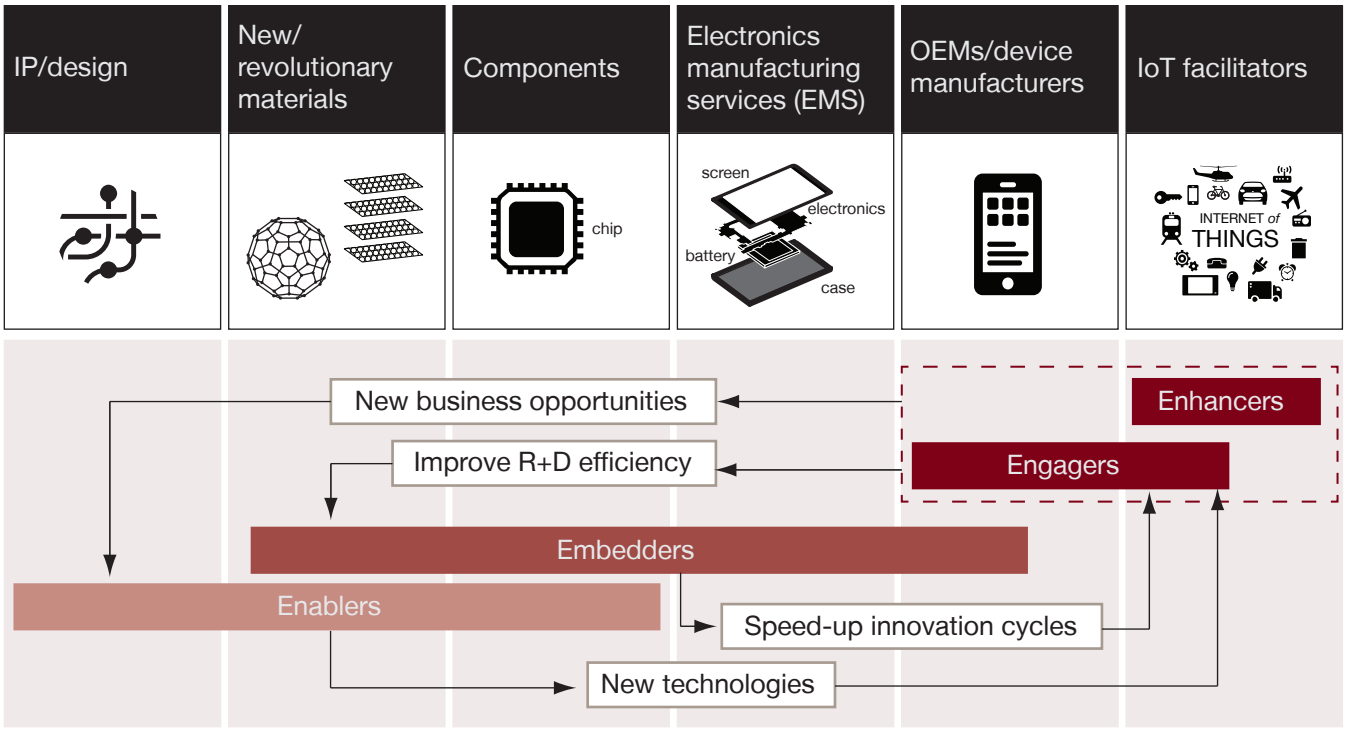
Enablers – Technology providers of IoT (sensor systems, actuator technology) and platforms (Clouds) to produce/deliver networked services and products

We studied specific business behaviors and classified them using these four strategies. What we realized was that these strategies are distinct and ambiguous at the same time. What this actually means is that enterprises that decide to go with one strategy can still also assume different roles across the other remaining strategies. Suppliers in particular in the automotive industry can act both as *Enhancers* as well as *Engagers* within the framework of one technology, and operate as *Embedders* with other technologies – in each case depending on their respective service level (*see Exhibit 4, next page*).

Every business must determine their strategy to adopt: Enhancers, Engagers, Embedders or Enablers.

Exhibit 4

Enterprise strategies within the Electronics Manufacturing Ecosystem



Source: Strategy& analysis

Do the right thing in R+D – and do R+D right in Industry 4.0

On the way to becoming a digital champion?

The questions an enterprise has to ask on the subject of successful innovation management in Industry 4.0 vary in regard to the four strategies (from user behavior in social networks to fundamental scientific research within the framework of interdisciplinary industry clusters). To increase clarity within these four basic strategies, we recommend to answer the following questions:

For Enhancers

- Which customers does the networked information target?
- What value does the data have for customers?
- What are potential and practical applications in industries that are not (yet) open to Industry 4.0?
- What developments in related areas are relevant for Industry 4.0?

For Engagers

- What data are relevant enough to continue to use them?
- What interfaces, protocols, and standards need to be taken into account?
- What technical limits are there in regard to data processing and transmission (e.g. bit rates, bandwidth, etc.)?
- What key developments are there in general in business and society? What can they trigger in science and technology?

For Embedders

- What are potential applications in Industry 4.0?
- What processes can the digital technology support?
- What limits are there in the terms of use (IT architecture, etc.)?
- What value is promised for Embedders and customers?

For Enablers

- What developments are other Industry 4.0 solution providers offering?
- Is there any possibility of R+D cooperation?
- What kind of scientific-technical progress has been made? Which developments have disruptive potential?

Do the right thing in R+D

Industry 4.0 is a continuous development, a movement away from traditional business models and processes towards digital processes, products and business models. To realign R+D to achieve a top position in Industry 4.0, planning must be staggered to include the following four dimensions of the Digital Economy:

1. Data analysis and Big Data
2. Digital products and services
3. Digital value chains
4. Digital business models

An example from the area of data analysis illustrates the evolutionary course of development. Initially, based on the available data, enterprises can incorporate their customers' digital maintenance data and plant manuals as well as industry-specific measurement data and other sales data in R+D processes within a short window of time (<1 year). From a medium-term perspective (1-3 years), it is possible to use data in a structured manner specifically to optimize the use of raw materials and resources as well as for production innovations. It is, however, in the long term (>3 years) that real-time data and horizontal networking

Initially enterprises can incorporate their customers' digital maintenance data and plant manuals in R+D processes.

with customers, suppliers and academia flow into new products (e.g. smart series) or new services (e.g. in the area of predictive maintenance).

Overall, we anticipate digitization to proceed in two waves, in which case the second wave is based on the principles and findings of the first. In a first wave, the push is for process automation and the optimization of maintenance. The subsequent second wave consists of the supply chain integration, including consistent tracking as well as the linking of quality management and R+D processes. In the long term and as a continuous process, corresponding analysis and process control capabilities are developed and the continuous development and tracking of the business case are monitored.

Doing R+D right in Industry 4.0

Innovation costs and economic risks are significant and companies cannot afford to fail on the creative side of the business.[8] Yet specifically when it comes to the right connection of R+D with Industry 4.0, precisely these obstacles can be overcome. Or to put it bluntly, doing the right kind of R+D in Industry 4.0 can leverage enormous savings potentials within the innovation process. The only thing that has to be done is to properly utilize the new possibilities digitization presents.

Doing the right kind of R+D in Industry 4.0 can leverage enormous savings potentials within the innovation process.

Developing products in an appropriate period of time, with the right features and at a minimal cost structure and still stay within the development budget is an important task of R+D in any business. What will change in these processes are the available resources and methods. They will largely have an impact on the following requirements:

- Improvement in R+D efficiency through cost-saving modeling and simulations
- Minimization of the risks in R+D, e.g. by means of the validation of real-time data
- Improvement in engineering capabilities, e.g. rapid prototype production by means of 3D printing or additive production technologies

The cycle times and thus the available development times must be reduced considerably in Industry 4.0 in order to meet the demands of changing customer requirements. Different approaches are taken in this effort. A decisive contribution can be made by development in open innovation networks. Acceleration is possible if different system partners pursue parallel research and development. Including customers, suppliers and

other cooperation partners along the entire value chain puts R+D on a new and different level and increases its importance in relation to other group functions.

In addition to costs and risks, enterprises frequently cite the lack of specialized personnel as impeding innovation. In actual fact, the manufacturing industry can expect a change in the activities and thus also in the abilities and skills of their employees within the context of the Digital Revolution. In order to not only find and acquire employees with the right qualifications, but also to be able to tie them to the company for the long term and provide continuing education and further qualification, the right course must be set today in education. New content and new qualifications based on this learned content should now determine core curriculum. The classic engineering program, for example, must be modified in such a way as to be multi-disciplinary so that the Digital Engineer of the future not only possesses fundamental knowledge of technology and the natural sciences, but also skills and abilities in data analytics, product management, (multi) project management as well as IT architecture and security. This educational reform is imperative. The Digital Engineer will ultimately be expected to answer different, more complex questions in the future than engineers do today in regard to the availability and usability of information and its actual benefits. These questions are outlined by the four dimensions of digitization:

1. *Digitization and integration of vertical and horizontal value chains*

   What are the advantages of greater transparency in the value add?

   Can we respond earlier than in the past to changing requirements and customer requests?

2. *Digitization in the product and service portfolio*

   What digital development of my products and services actually produces an added value for customers and users?

3. *Innovative digital business model*

   Who profits from the available information – and who is willing to pay for it? Is there a benefit that no one else offers yet?

4. *Data and Analytics as core competence*

   What conclusions can I draw from the data?
   What methods and algorithms support the analysis?

The Digital Engineer will ultimately be expected to answer different, more complex questions in the future in regard to the availability and usability of information and its actual benefits.

Enterprises will have to prepare to face these new questions and challenges in order to not jeopardize their own competitiveness. The time-to-market cycles will be given even greater importance under Industry 4.0, and this will require the use of adequate resources within the R+D process. Enterprises that recognize these new requirements make and take decisive steps to optimize development processes will have a unique competitive advantage.

Endnotes

[1] Frankfurter Allgemeine Zeitung dated 18 Feb. 2016.

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[8] Centre for European Economic Research ZEW, Innovation Behavior in the German Economy. Indicator Report on the Innovation Assessment in 2015, 2016.

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