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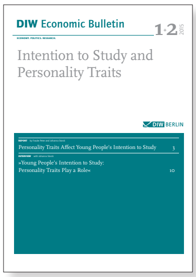

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Incentives for the long-term integration of renewable energies: a plea for a market value model

By Karsten Neuhoff, Nils May, and Jörn Richstein

Due to increasing shares of renewable energies in electricity production, the cost-effective system integration of these installations is becoming more and more important. Technologies and locations are viewed as system-friendly when they are more cost-efficient and easier to integrate because they, unlike other installations, produce at times when electricity is more valuable.

This report shows that project developers of renewable energies in Germany have had limited incentives to invest in system-friendly installations. A market value model is derived based on five criteria for the further development of support instruments. This model creates appropriate incentives for investments in system-friendly installation while simultaneously avoiding additional financial risks for project developers. With such an approach based on a market value factor, the support costs for renewable energies as well as for levies in the overall electricity system and for the energy transition in general can be minimized over the long-term.

Germany wants to raise the percentage of renewable energy in its gross electricity consumption from currently slightly less than one-third—19 percent wind and solar energy and 12 percent other renewable energies[1]—to 55 to 60 percent in 2035 and up to at least 80 percent in 2050.[2] Since growth is primarily coming from wind turbines and solar panels, it will become increasingly important that these installations are well integrated into the power market. The more system-friendly the installations are, the more easily they can be integrated. System-friendly installations generate electricity when it is particularly valuable. This can be achieved, for example, by building installations that generate electricity more consistently than others even though they might produce less overall. One example are wind turbines, which can be designed to produce more electricity during times of lower wind speeds.

There are two challenges here. First, the power market does not yet reflect all the advantages of system-friendly installations, for example because of low CO_2 prices or lack of a location-specific price signal. Second, installations built today will operate for around 30 years.[3] However, project developers[4] do not adequately consider such

1 AG Energiebilanzen (2017): Stromerzeugung nach Energieträgern 1990–2016 (available online, accessed October 5, 2017. This applies to all other online sources in this article unless indicated otherwise).

2 German Parliament (2016): Gesetz zur Einführung von Ausschreibungen für Strom aus erneuerbaren Energien und zu weiteren Änderungen des Rechts der erneuerbaren Energien (Erneuerbaren-Energien-Gesetz-EEG 2016) (available online) *as well as* Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2016): Climate Action Plan 2050—Principles and goals of the German government's climate policy (available online).

3 Analyses of early wind turbines and solar panels show that in many cases, life spans longer than the originally planned 20 years are possible (Juan Lopez-Garcia, Alberto Pozza, Tony Sample (2015): Analysis of crystalline silicon PV modules after 30 years of outdoor exposure. 31st European Photovoltaic Solar Energy Conference; Ann-Kathrin Wallasch, Silke Lüers, Knud Rehfeldt (2016): Weiterbetrieb von Windanlagen nach 2020, Studie der Deutschen WindGuard GmbH). The first photovoltaic manufacturers offer product guarantees for a 30-year life span, and wind turbine manufacturers design their products to run for 30 years. Wind turbines and solar panels built in the next few years will therefore have expected life spans of up to and over 30 years, respectively.

4 This article uses the term "project developers" to also mean "operators."

long-term perspectives because of high discount rates applied to uncertain revenues.

Support instruments for renewable energies can also be used as incentives to invest in system-friendly installations. By further developing the current support system into a *market value model*, installations' long-term system-friendliness can be taken into consideration when making investment decisions.

The market value model functions independent of whether the remuneration level is determined in a call for tenders or is set by the regulatory authorities.[5] It is possible in both cases to offer project developers incentives for system-friendly installations with a market value model. In the case of tenders, for example, the bids are adjusted according to the installations' expected market value with a *market value factor*.[6]

Long-term perspectives are important for transforming the electricity system

Public investments in areas such as education or transport infrastructure are evaluated using low discount rates.[7] For example, when conducting an economic assessment of transport infrastructure investments, the expected future benefits need to bear interest at a social discount rate of 1.7 percent.[8] In the case of renewable energy, a large amount of the benefits of system-friendly installations now being built will only materialize with a larger share of renewables in the overall system. At a low discount rate of 1.7 percent, the benefits occurring in the eleventh to thirtieth year of operation would dominate the overall project evaluation with a weight of 61 percent.

However, project developers are exposed to uncertainties regarding the political and regulatory framework conditions for the further expansion of renewable energies and the commercial benefit of system-friendly installations. It is unclear whether or not the advantages of system-friendly installations will be reflected in the market design and lead to additional revenues in the future for individual project developers, even though such installations are associated with higher investment costs per megawatt hour than conventional ones. Therefore, it can be assumed that lenders require significantly higher return expectations, around ten percent, when assessing investment projects.[9] At such a discount rate, revenues in years 11 to 30 would only be included in the investment decision for system-friendly installations at 35 percent. From a public perspective, it would be preferable to properly assess the long-term benefits of system-friendly installations. This can be done by continuing to develop support policies for renewable energies.

Design support instruments so that investors consider the long-term market value

The declining technology costs of renewable energies mean that the importance of support policies for covering incremental costs is declining.[10] Instead, the importance of support policies is increasing in terms of reducing regulatory risks and enabling hedging against market risks. This way, financing costs can be minimized and cost increases which otherwise would have occurred can be avoided.[11] Furthermore, support instruments can be used to internalize negative environmental externalities, such as emissions avoided by electricity from renewable sources. This is an important aspect as long as the negative climate impacts of electricity from coal and gas power plants are insufficiently reflected in European emissions trading.[12] Therefore, it can be assumed that support policies will continue to be used.

Currently, new wind turbines and solar installations from 750 kilowatts and upwards are being subsidized by a sliding market premium. The premium is calculated using the difference between the weighted average of the hourly electricity prices of the respective month and a reference price determined by competition of project developers in a tender.[13] This way, uncertainties about the long-term development of the electricity price level are hedged and financing costs are reduced.

5 The market value model is applicable to wind farms and larger solar panels whose implementation has been subject to tenders since 2017 and 2015, respectively, as well as to smaller installations with a fixed feed-in tariff.

6 The authors would like to thank Thorsten Beckers, Robert Brückmann, Albert Hoffrichter, Ralf Ott, and Bernhard Strohmayer for their helpful comments and discussions as well as financial support by way of a grant from the Federal Ministry of Economics and Energy under funding number 03MAP316 (SEEE).

7 Discount rates indicate how much you prefer today's revenues compared to future revenues. A low rate places higher weight on the future.

8 Federal Ministry of Transport and Digital Infrastructure (2016): Bundesverkehrswegeplan 2030, Entwurf März 2016 (in German) (available online).

9 Support policies currently hedge many regulatory uncertainties and thus allow the extensive use of debt capital (loans, bonds). This leads to low financing costs for non-system-friendly installations. Since the additional revenues from system-friendly installations are uncertain, the additional investment costs must be backed up by equity and meet the correspondingly high expected returns.

10 Such extra costs historically existed due to technology costs of renewable energies and because the climate-damaging emissions from fossil-fuel power plants are not priced properly.

11 Nils May, Ingmar Jürgens, and Karsten Neuhoff (2017): Renewable Energy: Risk Hedging Is Taking Center-Stage. *DIW Economic Bulletin* 39/40 (available online).

12 For details, see Paul Lehmann and Erik Gawel (2013): Why should support schemes for renewable electricity complement the EU emissions trading scheme? *Energy Policy* 52, 597–607.

13 Cf. German Parliament (2016): l.c.

Criteria for further developing support instruments

The continued development of the sliding market premium must fulfill a set of criteria.

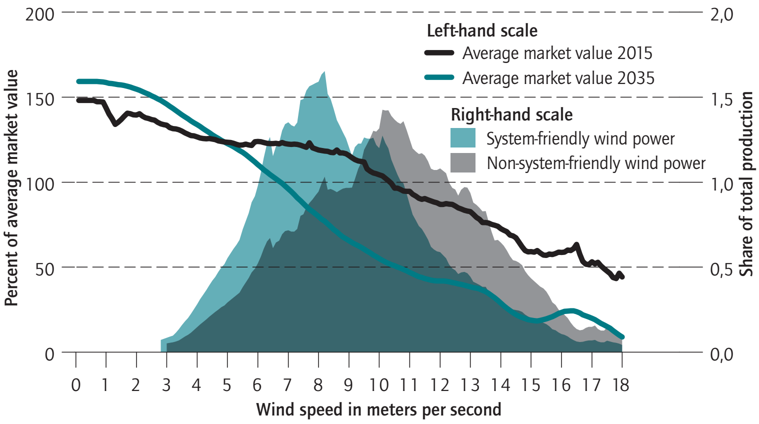
It must *reflect the market value of electricity*, including system aspects that may not yet be reflected in the price of electricity, such as insufficiently priced CO_2 externalities or redispatch costs.[14]

Furthermore, the support must *take the future development of the market value into consideration*; *reflect positive externalities* such as innovation or learning effects in supply chains; and *minimize financing costs*, for example by reducing regulatory risks or taking opportunities to hedge market risks that are not hedged bilaterally over the long term due to institutional frameworks. Finally, support instruments should *avoid excessive rents*.

These criteria must be fulfilled in terms of the four elements which make up system-friendly installations: the design, choice of location, choice of technology, and operation of the installation.

Figure 1

Share of production of two wind turbines per wind speed and market value in percent of average market value



Source: Authors' own calculations based on Nils May (2017): The impact of wind power support schemes on technology choices. Energy Economics 65, 343–354.

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System-friendly wind turbines generate a bigger share of electricity at times of low wind speeds, which especially in the long term has a higher value than generation at times of strong winds.

Incentives for system-friendly designs

System-friendly installations are easier to integrate into the energy system. System-friendly wind turbines are one example; they generate more electricity during hours of lower wind speeds as opposed to regular wind turbines. Three technical parameters determine how to achieve system-friendly production: the rotor blade length, the hub height, and the generator's nominal capacity. A longer rotor blade exposes the turbine to increased wind energy and can thus generate electricity for more hours. A higher hub experiences higher wind speeds, which has the same effect. Finally, a generator with a low nominal capacity increases the full-load hours and also lowers costs, which can be used to increase the other two parameters (see Figure 1).[15]

Another example for a system-friendly design are solar panels facing east or west, causing them to generate electricity earlier in the morning and later in the afternoon when it is usually most needed. However, these photovoltaic systems generate less electricity overall compared to south-facing panels (Figure 2).[16] A comparable effect occurs with bi-facial photovoltaic panels[17] and with larger module surface areas in relation to the inverter capacity.

The current support system does not fulfill the criteria for system-friendly installations

Consider the market value of the electricity: In the case of sliding market premiums, the incentives depend on the reference period in particular, that is whether the premium is determined hourly, monthly, or annually. The premium is calculated based on the average production value of all other installations within these periods. All incentives for system-friendly investment decisions resulting from the electricity price profile within one year are maintained if the premium is determined annually, such as in the Netherlands.[18]

However, if an installation deviates from this average annual production profile and tends to run at times of higher market prices, project developers will profit from the correspondingly higher revenues. Incentives for designing installations that maximize their production in months with higher electricity prices are lost when the premium is determined monthly, as in Ger-

14 Redispatch costs are incurred when network bottlenecks force network operators to shut down certain power plants and other plants must operate in their place.

15 Fraunhofer IWES (2013): Entwicklung der Windenergie in Deutschland. Commissioned by Agora Energiewende (in German) (available online).

16 Fraunhofer-Institut für Solare Energiesysteme ISE (2014): Effekte regional verteilter sowie Ost-/West-ausgerichteter Solarstromanlagen. Commissioned by Agora Energiewende (in German) (available online).

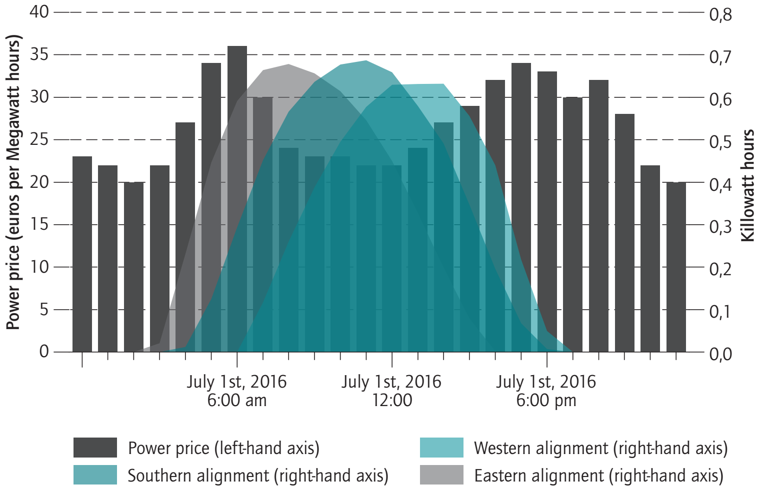
17 Bi-facial panels capture solar radiation from both orientation and transform it into electricity, see *Photon* 06/2017.

18 Dutch Ministry of Economic Affairs (2015): Besluit stimulering duurzame energieproductie (in Dutch) (available online, accessed October 10, 2017).

Figure 2

Exemplary share of production of a photovoltaic panel on July 1st 2016 and normalized power prices

Power price in euros per megawatt hour (left-hand axis), kilowatt hours (right-hand axis)



Quelle: Authors' calculations based on data by renewables.nina (available online) and Open Power System Data. 2017. Data Package Time series. Version 2017-07-09.

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Photovoltaic panels facing east or west produce more system-friendly in the morning or in the evening.

many. Incentives remain for designing system-friendly installations corresponding to the electricity price profile within a period of one month. When the premium is determined hourly, like in the United Kingdom,[19] there are no incentives for system-friendly investment decisions. In every case, incentives for system-friendly installations can only arise when these benefits are built into the design of the electricity market—as regionally differentiated electricity prices, for example.

In order for *the future development of the market value* to be able to contribute to system-friendly decisions, the above-listed criteria for the design of the premium and the electricity market first must be fulfilled. However, even with an efficient electricity price signal, it can be assumed that project developers will only partially incorporate these developments into their investment because of strong discounting of uncertain future revenues.

Financing costs can be minimized by facilitating the hedging of electricity price risks between installations and end customers with the definition of an hourly market premium, like in the United Kingdom. Risks for project developers arise when the reference period is extended to a month or even a year. End customers are safeguarded to a lesser extent and the financial costs increase.[20]

Market value model offers incentives for system-friendly designs

The market value model capitalizes on the benefits of a sliding market premium—and minimizes financing costs with an hourly reference period.[21] Comprehensive incentives for an installation with a system-friendly design are created by a market value factor that reflects the system-friendliness of an installation's location and technology (see Box 1). In a call for tenders, project developers win by having the lowest bid price, which is adjusted by the market value factor.[22] As a result, the tendering process and therefore also project developers take the expected market value of electricity into account.

In doing so, benefits of a system-friendly installation which aren't yet reflected in the electricity market design, such as regional aspects, can also be considered. The market value factor reflects the expected development of the market value and thus allows this development to be appropriately weighted when selecting system-friendly installations.

Incentives for choosing a system-friendly location

The choice of location determines how much support the installation requires and how easy it will be to integrate large shares of renewable energy. One example of a beneficial choice of location is wind-generated electricity placed near load centers with few network requirements or wind production in southern Germany, where electricity may also be generated when the wind isn't blowing in the north. A system-friendly choice of location should weigh these factors and take them into consideration. However, there is currently a lack of incentives to do so.[23]

19 Department of Energy and Climate Change (2013): CFD Contract Terms and Conditions (available online, accessed October 10, 2017).

20 At a fixed premium, where project developers receive a fixed premium in addition to electricity revenues, or in the absence of any support, project developers are much more exposed to electricity price risk, increasing financing costs and making incentives stronger.

21 An alternative support scheme proposed by the Öko-Institut under the name "EEG 3.0" aims at more system-friendly installations yet increases the financing risks and related costs as it is based on fully exposing project developers to the price of electricity. For details, see Öko-Institut (2014): Erneuerbare-Energien-Gesetz 3.0 (Langfassung). Commissioned by Agora Energiewende (in German) (available online, accessed October 9, 2017).

22 Procedurally similar to the existing reference yield model that adjusts bids on wind power tenders according to the expected yield. For more details, see German Parliament (2016): l.c.

23 Oliver Grothe and Felix Müsgens (2013): The influence of spatial effects on wind power revenues under direct marketing rules. *Energy Policy* 58, 237–247.

In addition, as the current electricity price signal does not reflect the redispatch costs, *the market value is not reflected*. In principle, these are more likely to occur in locations affected by network bottlenecks. Thus, project developers don't have any incentives to choose system-friendly locations that lead to low redispatch costs.[24]

Here, too, the future development of the market value is taken into account only to a limited extent because project developers ascribe less importance to long-term developments and there are uncertainties about mapping the regional components in the electricity price signal.

A market value model would lead to appropriate incentives for a system-friendly choice of location, including from a long-term perspective. This would take not only location-dependent redispatch costs and network bottlenecks into consideration, but also the simultaneity with the production of other installations and demand. In some countries, such as Mexico, similar approaches to selecting locations have been implemented with some success (see Box 2).

Scarcity rents at locations with better resources are reduced under the market value model because the market value factor is calculated for a long-term horizon and with the assumption of a further increase in renewable energies. At market equilibrium, investments in renewable energy are spread across sites so that the value of electricity generated at each site is equal to their cost. This leads to the market value factor offsetting location-specific cost differences and thus reducing windfall profits.

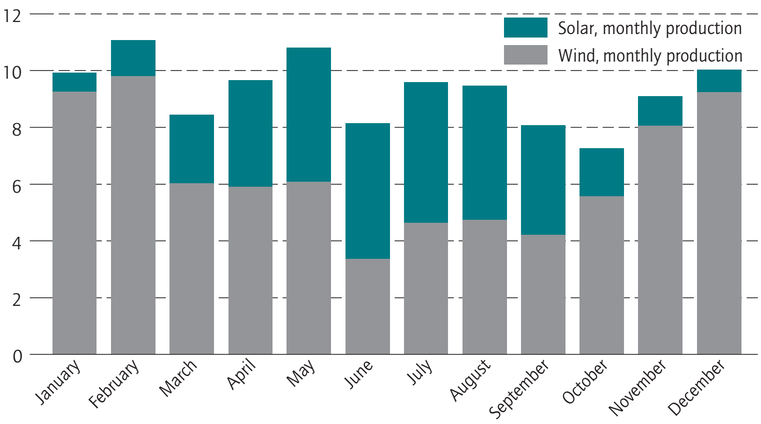
However, revenues in one region can exceed costs, for example when there is a scarcity of locations. Such additional revenues lead to landowners earning higher rents on their land and can at the same time encourage them to make more land available. If there are fears of large windfall profits, then regionally differentiated tenders could be carried out, similar as to how they already exist through a limit on the volume of bids accepted from within a North German grid expansion area.[25]

Financing costs are minimized under the market value model by not exposing project developers to the uncertainties about developments in the electricity market design or grid expansion.

Figure 3

Production of wind and solar power in 2016 in Germany

Monthly production in million megawatt hours



Source: Authors' own calculations based on Open Power System Data. 2017. Data Package Time series. Version 2017-07-09. (available online; primary data from various sources, for a complete list see URL).

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Wind and solar power production complement each other in a portfolio over the course of a year.

Incentives for choosing system-friendly technology

Wind turbines and solar panels often generate electricity at different times, both in terms of seasonal production and day/night cycles (Figure 3). A portfolio comprising multiple technologies can better cover the electricity demand throughout the year and thus achieve a higher value.[26]

The market value of different technologies is insufficiently reflected by a monthly sliding market premium alone. However, the different values of technologies in one portfolio would be reflected well with a transition to a market value model so that principally, joint tendering for all technologies would be possible.

However, positive externalities arise with the growing experience and innovation (learning effect) that occurs by installing technologies.[27] For example, the cost of large solar panels in Germany fell by 85 percent between 2007 and 2017. This enables cheaper investments in the future.

24 Furthermore, a sliding market premium with monthly adjustment offers no incentives to choose a location with larger shares of electricity production in months of high electricity prices, cf. Nils May (2017): The impact of wind power support schemes on technology choices. Energy Economics 65, 343–354 and Johannes Schmidt et al. (2013): Where the wind blows: Assessing the effect of fixed and premium based feed-in tariffs on the spatial diversification of wind turbines. Energy Economics 40, 269–276.

25 Only a limited proportion of the bids submitted for wind energy tenders may be attributed to the northern German grid development area; the rest must go to southern and central Germany. For more details, see Federal Network Agency (2017): Entwurf einer Verordnung zur Änderung der Erneuerbare-Energien-Ausführungsverordnung (available online).

26 Lion Hirth (2013): The market value of variable renewables: The effect of solar wind power variability on their relative price. *Energy Economincs,* 38, 218–236 (available online).

27 Pablo Del Río (2012): The dynamic efficiency of feed-in tariffs: The impact of different design elements. *Energy Policy,* 41, 139–151.

Furthermore, a stable demand for a technology allows value chains—from production to distribution and installation and maintenance—to establish and develop.

On the other hand, significant rents can come about if the need for renewable energy expansion cannot be covered by only one technology. In this case, a second, more expensive technology would set the price. Project developers with the cheapest technology would then offer the highest price and make a profit.

Separate tenders for different technologies like wind or solar should be maintained in the market value model as well so that positive externalities can develop and rents can be avoided. However, it is important to avoid differentiation between include too many technologies in order to ensure the competition in the tenders is not weakened.

Incentives for market-oriented operation

A goal of integrating renewable energies into the system is to create incentives for early and precise forecasts of wind turbine and solar panel generation as well as an efficient integration into the energy system. For example, 24 hours prior to actual electricity generation, a majority of conventional power plants and, in the future, flexible loads, can offset a projected reduction (or increase) in production. The closer it gets to the time of actual electricity generation, the less power plants or flexible loads can compensate for an installation's reduced electricity generation and the higher the costs and prices of an adjustment are (see Figure 4).

Project developers have incentives to make good forecasts and to compensate for expected deviations of production in the market with a sliding market premium. In Germany, the sliding market premium is calculated relatively to the prices of the day ahead auction in the power market. At that time, however, wind and solar forecasts are still unsure. If there are deviations from subsequent, better forecasts, they are adjusted on the market with other market actors. Although the costs for these deviations can be reduced by improving the quality of the forecasts, the price risk, which depends on developments in the electricity market, supply (flexibility options, for example), and demand, remains with the project developers.[28]

28 Although this uncertainty is generally passed on to third parties in yearly marketing contracts, the uncertainty regarding future years remains and is reflected in an uncertainty about the prices at which marketing contracts will be closed in the future.
For further details, see Albert Hoffrichter and Thorsten Becker (2016): Perspektiven für die Bereitstellung und Refinanzierung von Windkraft- und PV-Anlagen – Eine Analyse von Weiterentwicklungsoptionen des institutionellen Rahmens unter Einbezug institutionenökonomischer Erkenntnisse. Technische Universität Berlin, Arbeitspapier (in German) (available online, accessed October 9, 2017).

Box 1

The market value model

The goal of the market value model is to create incentives for project developers of wind turbines and solar panels to build system-friendly installations.[1] These incentives should, first, reflect the value of the electricity generated in a functioning market and, second, result in appropriate weight being given to longer-term development of the electricity system. The market value model is conceived as a further development of the market premium with the adjustment through a *market value factor*.

A model of the electricity sector, hosted, for example, by the national regulatory agency (in Germany, the Federal Network Agency, *Bundesnetzagentur*), is used to project hourly, location-specific electricity prices for a reference year (such as 2035). It would be comprised of endogenous investments in renewable energy technologies in terms of technology selection, design, and location based on renewable expansion targets.

Every project developer as well as regulatory body can calculate the location-specific energy production of an installation using the available data about wind speeds or solar radiation for a reference year. Together with the published hourly price projections, this results in the average realized electricity price. The difference between the average realized price and the calculated average price of all installations forms the market value factor. This reflects the system friendliness of an installation. Each project developer can calculate this factor and thus incorporate it in their design and location choice.

In the case of a tender, project developers continue to offer a reference price. In the clearing algorithm of the tender, the bids are adjusted for the market value factor. The bids with the lowest reference price minus the market value factor win.

In an example calculation for a location in northern Germany (Boltenhagen in the federal state of Mecklenburg-Western Pomerania), the market value model leads to system-friendlier installations being selected. Under the current sliding market premium, project developers decide on turbines with a rotor blade length of 52.8 meters and a rotor sweep of 8,756 square meters. Using the market value model, the design changes to a system-friendlier turbine

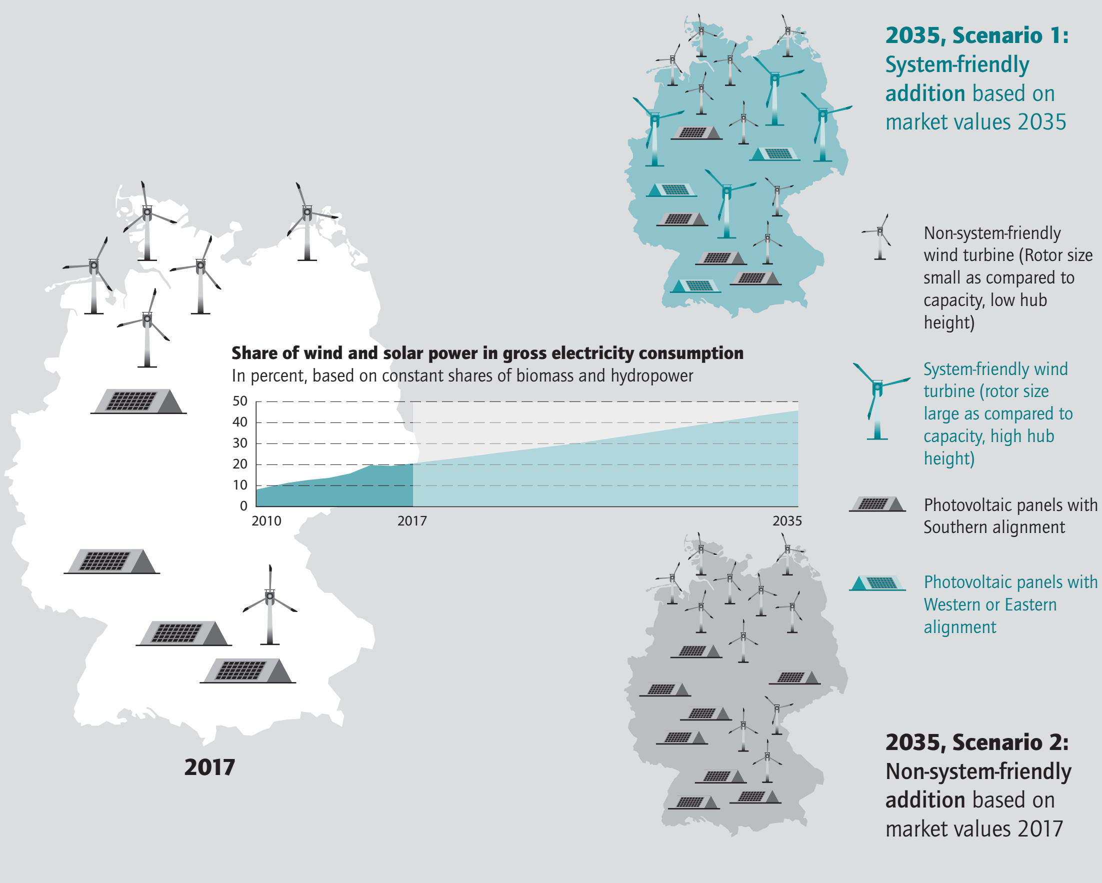
1 The suggested market value model is based on earlier suggestions for wind turbine design, cf. Nils May, Karsten Neuhoff, and Frieder Borggrefe (2015): Market Incentives for System-Friendly Designs of Wind Turbines. *DIW Economic Bulletin* 24/2015 (available online).

with a rotor blade length of 54.7 meters and a rotor sweep of 9,386 square meters. The capacity falls from 2.7 megawatts to 2.4 megawatts and the hub height increases from 118 meters to 128 meters. This system-friendlier design increases the amount of full-load hours by 11 percent while keeping the amount during strong winds (more than ten meters per second) the same. The number of full-load hours increases during frequent moderate wind speeds by 19 percent and by 26 percent during low wind speeds (less than five meters per second). The electricity market value is principally higher during these hours.[2]

2 For details on the calculation and alternative design options, cf. Nils May (2017): l.c.

Figure

Two scenarios for the addition of renewables in comparison



Source: Authors' own depiction.

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If the long-term perspective is taken into account for investment decisions today, more system-friendly installations will be built.

Box 2

The example of Mexico

In 2015, Mexico launched tenders for renewable energy with bids adjusted according to expected system friendliness. To do this, the Secretariat of Energy (Secretaria de Energia) first calculates what value the electricity will have in different regions during the installations' lifetime using an energy market model. The bidding order rewards projects in regions of higher value with a bonus, and projects in regions with lower expected value receive a penalty. This gives project developers incentives to build projects in specific regions according the market value in these regions without being exposed to additional (price) risks.[1]

Furthermore, if installations produce in hours of higher or lower value, then they receive additional bonuses and penalties, respectively. This creates (so far, weak) incentives for system-friendlier installation designs, as in principle, these produce during more valuable hours.[2]

The underlying electricity market model is updated in each bidding round to reflect new developments for the next set of bids without exposing investors in earlier projects to uncertainties from these new developments. While surprisingly strong regional differences were still recorded in 2015 during the first round of calls (with a maximum difference of 42.69 US dollars per megawatt hour), the anticipated grid expansion was subsequently taken into account. Thus, the longer-term price differentials paid for electricity from renewable energies converge with the regional differences. In the second tender round in 2016, there was a maximum difference of 30.67 US dollars, while in the third round in 2017, there was only a maximum difference of 13.53 US dollars.[3]

1 Nera (2015): Manual de subastas de largo plazo para el Mercado electrico mayorista. Report created by the Secretaria de Energia (Sener) (in Spanish) (available online, accessed October 10, 2017).

2 Nera (2015): l.c.

3 Cenace (2017): Subastas de Largo Plazo (in Spanish) (available online).

In the medium term, the real time price could be used as a reference price for the sliding market premium instead of the price in the day ahead auction in the power market.[29] This could also avoid the price risk that cannot be influenced by project developers in order to prevent additional financing cost surcharges for renewables. Incentives for good forecasts and adjusting the sale early would be preserved because more favorable prices can be achieved at earlier auctions. As is currently, this marketing could be organized in a decentralized manner, but alternatively could also be organized through public tenders for wind and photovoltaic marketing.

How the sliding market premium is determined also has a limited influence on the timing of maintenance activities. When maintenance can be planned flexibly, it may be considered that less energy production is lost during times of low wind speeds or little sunlight. It should be performed at times when the electricity value is low. Incentives to consider these factors in the timing of maintenance activities can result from the reference period of the sliding market premium (either hourly, monthly, or annually). In principle, longer periods give incentives for planning maintenance in a value-maximizing manner. Generally, however, the exact time of the maintenance work is less important than for conventional power plants because the individual installations of a wind or solar park can be maintained independently and thus with very limited impact on overall production capacity and volume while a conventional power plant often has to be completely shut down for maintenance.

The market value model can create incentives for system-friendly installations while simultaneously minimizing risks and financing costs

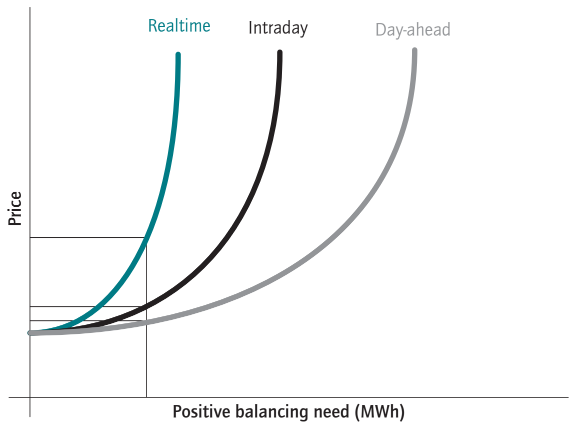
There are conflicting goals surrounding the sliding market premium currently used in Germany for most renewable energy installations. The conflict is between stronger incentives for system-friendly installations and better mitigation of financing risks, which can be achieved with an annual reference period and a shorter or hourly period of reference (see table), respectively. However, both goals can also be achieved together. This requires complementing a sliding market premium with an hourly reference period in the market value model with an ex-ante determined market value factor. The market value factor adjusts the remuneration amount for the anticipated market value of a system-friendly investment. The use of

29 Due to continuous trading, the German intraday market does not have a precisely definable reference price. This could change with the introduction of cross-border intraday electricity auctions.

Figure 4

Prices for balancing forecasting errors based on the time of adjustment

In euros per megawatt hour, megawatt hours



Source: Authors' own depiction.

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The more short-term deviations from forecasts occur, the more expensive it is to balance them.

Table

Selected production mechanisms in comparison

	Sliding feed-in premium				No support; higher CO_2-price only
	Annualy	Monthly (Status Quo)	Hourly	Market value model	
Market value	+	0	–	++	+
Development of market value	+	0	–	++	+
Positive externalities	0	0	0	0	– –
Financing costs	–	0	+	+	– –
Windfall profits	0	0	0	0	– –

Source: Authors' own depiction.

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long-term scenarios enables the expected market value development to be fully considered.

Phasing out support instruments and instead using a higher electricity price from significantly higher CO_2 prices would not ensure incentives for cost-efficient investments in system-friendly installations. While the short-term market value leads to somewhat system-friendlier installations without accounting for local price components, long-term developments in the electricity market would continue to be too highly discounted to support system-friendly investment decisions. Furthermore, without support instruments, financing costs would rise, resulting in approximately a 30 percent increase of the total cost.[30] In addition, the positive learning externalities of supporting a portfolio of different technologies are not reflected, and significant rents arise if the electricity price is higher than the costs of the most favorably priced renewable energy installations.

In order to meet the objective of internalizing learning effects and avoiding rents, separate tenders and differentiated pay ranges for different technologies should continue to be used.

Conclusion: The market value model enables the long-term integration of renewable energies

Selecting system-friendly locations, technologies, and installation designs for the use of renewable energies is important for the economic implementation of the energy transition. To do this, project developers must have the right incentives. Since it is expected that many installations will have a technological lifespan of around 30 years, the future development of the market value should already be taken into account today.

However, project developers cannot appropriately take the long-term benefits of system-friendly installations into consideration. System-friendly installations require higher investment costs per megawatt hour of generated electricity, while their long-term benefits are uncertain for individual project developers. Therefore, the additional investment cost of system-friendly installations needs to be backed by equity and deliver a high rate of return. As a result, the benefits of system-friendly installations are strongly discounted and receive limited weight.

The market value model remedies this situation. It builds upon existing support mechanisms, which continue to be necessary even with falling wind and solar energy costs to avoid regulatory risks and enable the hedging of market risks. This prevents risk premiums from leading to high financing costs and thus creating additional burdens for end customers. Moreover, such support systems enable the factoring in of negative environmental externalities that are so far otherwise insufficiently priced.

The market value model can be combined with tenders as well as regulatory set feed-in tariffs. Incentives for system-friendly investment decisions arise from a *market value factor* that reflects the system-friendliness of an

30 See Nils May, Ingmar Jürgens, and Karsten Neuhoff (2017): l.c.

installation in terms of its location and design. For example, in the clearance algorithm for tenders, the bid price is adjusted by the market value factor for the identification of the projects with lowest bid price. Thus the tendering process and project developers take the expected market value of electricity into consideration.

In doing so, benefits of a system-friendly installation which aren't yet reflected in the electricity market design are taken into account, and the expected longer-term development of the market value receives appropriate weighting by project developers in the design and location of a technology.

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JEL: L94, L98, Q42, Q48, D47

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Companies with R&D abroad make Germany a strong research location

By Heike Belitz

In recent years, German companies have invested more in research and development (R&D) abroad. After a prolonged plateau period, the proportion of investment abroad rose to around 35 percent; concurrently R&D expenditure in Germany has continued to rise sharply. Growth abroad did not occur at the expense of domestic research. Foreign companies in Germany have also invested more in R&D recently but have not yet topped the 2011 record high. Measured by stocks of foreign direct investment, they should still have some potential for higher expenditure in R&D. In international comparison, the growth in private R&D investment in Germany in recent years was high. This was mainly driven by German companies with R&D abroad.

The globalization of research and development (R&D) has made rapid progress in the top R&D investing multinational corporations. They are headquartered in a few industrialized countries, among them Germany. The target regions for their international R&D activities are: the US, Western Europe, Japan, and increasingly China.[1] Research locations can benefit from globalization if they are connected via knowledge transfer to research units of multinational corporations in foreign countries, such that the knowledge also benefits local companies.[2] The scope and growth of the R&D activities of foreign companies are often used as an indicator of the attractiveness of the research conditions in the country.

In conjunction with foreign owners' takeover of corporations conducting research, however, there is also the fear of foreign countries draining Germany of its technological knowledge and hollowing out the domestic research location.[3] In the home countries of multinational corporations, R&D investments in foreign countries are often interpreted as outsourcing capacity that is then lost to the domestic location. However, the key motives for globalization are market- and technology-based, not cost driven. Multinational corporations have to develop their products and processes further in their target markets and/or adapt them to local conditions and customer requirements. Establishing in-house research laboratories abroad is also a means of acquiring new technological knowledge from competitors, universities, and research institutes. After all, the use of qualified research personnel in the host country is a key motive for conduct-

1 In 2013, the R&D expenditure of foreign corporation in the US was estimated at just under 40 billion euros; in the EU (ignoring inter-European globalization) the estimate was around 28 billion euros; and in China it was around 4.3 billion euros. See Eric Iverson et al., "Internationalisation of business investments in research and development and analysis of their economic impact (BERD Flows)," European Commission, Brussels, 2017 (online available).

2 See Heike Belitz and Florian Mölders, "International Knowledge Spillovers Through High-Tech Imports and R&D of Foreign-Owned Firms," *The Journal of International Trade & Economic Development* 25 (4) (2016): 590–613.

3 For example, the public expressed concern that key technological know-how could drain to China when Midea, a Chinese corporation, took over Kuka, the German robot manufacturer.

Box 1

Data on the globalization of private R&D

Since the mid-1990s, the science statistics company at *Stifterverband*, an association of companies and foundations with an interest in civil society, has collected and evaluated the R&D data of companies according to the ownership principle for Germany every two years. The results of its special evaluations have been published in Stifterverband's own publications[1] and made available to international organizations such as the OECD as well as academia, science, and politics since 2003.[2]

Stifterverband determines the R&D expenditure of German companies abroad by subtracting their expenditure in Germany from the total global R&D expenditure of the 100 companies most highly active in research (including the money invested in Germany).

The extent of foreign companies' R&D expenditure in Germany is determined as part of the national R&D survey of responding companies that conduct research. With the assistance of an external database, it is allocated to the ultimate owner.

The database for measuring the globalization of R&D in companies is poorly developed in many countries.[3] Information is woefully lacking on R&D expenditure abroad. The OECD (AMNE—Activity of Multinational Enterprises database) and Eurostat (FATS—Foreign AffiliaTes Statistics) compile the available data from national sources for international comparison.

1 Most recently in Verena Eckl et al., "a:rən'di: Zahlenwerk 2017 und Entwicklung in der Wirtschaft," SV Gesellschaft für Wissenschaftsstatistik mbH, Essen, 2015 (online available).

2 They are also prepared for studies on the German innovation system for the German government's independent Commission of Experts for Research and Innovation (*Expertenkommission Forschung und Innovation*), most recently in Heike Belitz, "Internationalisierung privater Forschung und Entwicklung im Ländervergleich," *Studien zum deutschen Innovationssystem* 12-2017 (online available).

3 OECD, *Science, Technology and Industry Scoreboard.* Paris: OECD Publishing, 2015 (online available).

ing R&D abroad. Based on current data (Box 1), in this section we examine the globalization of German companies' R&D efforts abroad as well as those of foreign companies in Germany and compare Germany to other industrialized countries.

German companies' R&D abroad

At 24 billion euros, the R&D expenditures of German companies abroad reached a record high in 2015.[4] The foreign share was 35 percent, the same as it was in 2001. After 2001 it fell but turned around starting in 2007 (Table 1).

Between 2003 and 2015, the annual global R&D expenditure of international German companies active in research grew from 36 billion euros to around 69 billion euros. Nominally, it almost doubled. In comparison to 2003, 60 percent of the 32.5 billion euros in growth was attributable to locations in Germany and 40 percent to those abroad. Domestically, motor vehicles fueled the dynamic, as the sector received 80 percent of multinational corporations' R&D expenditures. The share abroad was 42 percent. The pharmaceutical industry also expanded abroad substantially and was responsible for a further 32 percent of the growth in German companies' R&D expenditure abroad after 2003. But German pharmaceutical companies also expanded their domestic R&D (Figure 1). In sum, the majority of R&D abroad flowed into motor vehicles and the pharmaceutical industry. Pharmaceutical companies invested more than half of their R&D expenditure abroad. German finance and insurance service providers had an even higher share abroad: at 1.5 billion euros, they invested 88 percent of their worldwide R&D expenditure abroad. But the proportion of foreign R&D has not increased in all sectors recently (Table 2). For example, it remained fairly constant in the computer and electrical engineering sectors and even fell in the chemicals sector.

The growth of R&D expenditure at home and abroad was broadly parallel in these sectors. Domestic rises or declines in R&D often went hand in hand with similar changes abroad (Figure 2). The expansion in German companies' R&D activities abroad was primarily driven by companies that also expanded their R&D at home (car manufacturers and pharmaceutical companies). In German computer and electrical engineering companies, as well as in the chemicals sector, the R&D expenditure plateaued both at home and abroad or even declined. Only

4 See Verena Eckl et al., "a:rən'di: Zahlenwerk 2017 – Forschung und Entwicklung in der Wirtschaft," SV Gesellschaft für Wissenschaftsstatistik mbH, Essen, 2015 (online available).

the mechanical engineering companies expanded their R&D abroad and, as of 2009, spent less at home.

R&D abroad in international comparison

An analysis of companies' investment in R&D abroad must take place within the context of investment in the domestic location. However, data on R&D expenditure at home and abroad are only available for German, US, and Swedish companies. In the companies from these three countries, expenditures have moved in parallel in the period since 1997 (Figure 3). For Swiss companies highly active in international research, information is only available for investment abroad. Their expenditure abroad is higher than the total domestic expenditure for companies in Switzerland,[5] but between 1992 and 2012 it did not grow faster than the latter.

The growth in the R&D expenditures of domestic companies at home and abroad can also be estimated approximately using patent data (Box 2).[6] We did this for Germany and seven other industrialized countries in which a particularly large number of top R&D investing companies are headquartered (France, Great Britain, Japan, Sweden, Switzerland, South Korea, and the US).

The proportions of patent applications submitted by domestic applicants with inventions made abroad varied considerably from country to country (Figure 4). Switzerland and Sweden had high proportions of inventors abroad, indicating extensive foreign R&D activity. In relatively small countries, their multinational corporations must conduct more of their research abroad because capacity at home is limited. Companies from France, Great Britain, Germany, and the US had intermediate globalization levels of research. The lowest proportions of inventors abroad were in South Korea and Japan. In most countries, the degree of corporate globalization rose between 2000 and 2014, but in South Korea and Japan it declined slightly. The number of patent applications by domestic applicants with inventors at domestic and foreign research locations varied largely in a parallel manner (Figure 5). The expansion and contraction of the number of patents at domestic locations led to similarly aligned changes abroad. This indicates that as a rule, companies view research abroad as a supplement to their domestic activity and not as a replacement for it.

Table 1

Global R&D expenditure of German companies 1995–2015

	1995	2001	2003	2007	2013	2015
	In billion euros					
Global	22.1	34.4	36.3	38.6	55.3	68.9
Thereunder abroad	5.1	11.9	10.9	9.4	17.3	24.0
	In percent					
Share	23	35	30	24	31	35

Sources: SV-Wissenschaftsstatistik; authors' own calculations.

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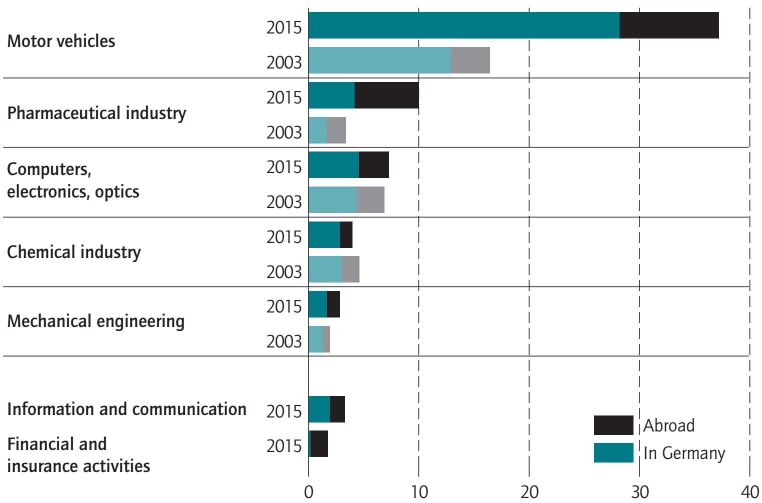
The foreign proportion of R&D expenditure was 35 percent in both 2015 and 2001.

Figure 1

R&D Expenditure of German companies of selected industries at home and abroad, 2003 and 2015

In billion euros



Sources: SV-Wissenschaftsstatistik; authors' own calculations.

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R&D abroad grew most rapidly among motor vehicles and pharmaceutical companies, which also increased their domestic investment.

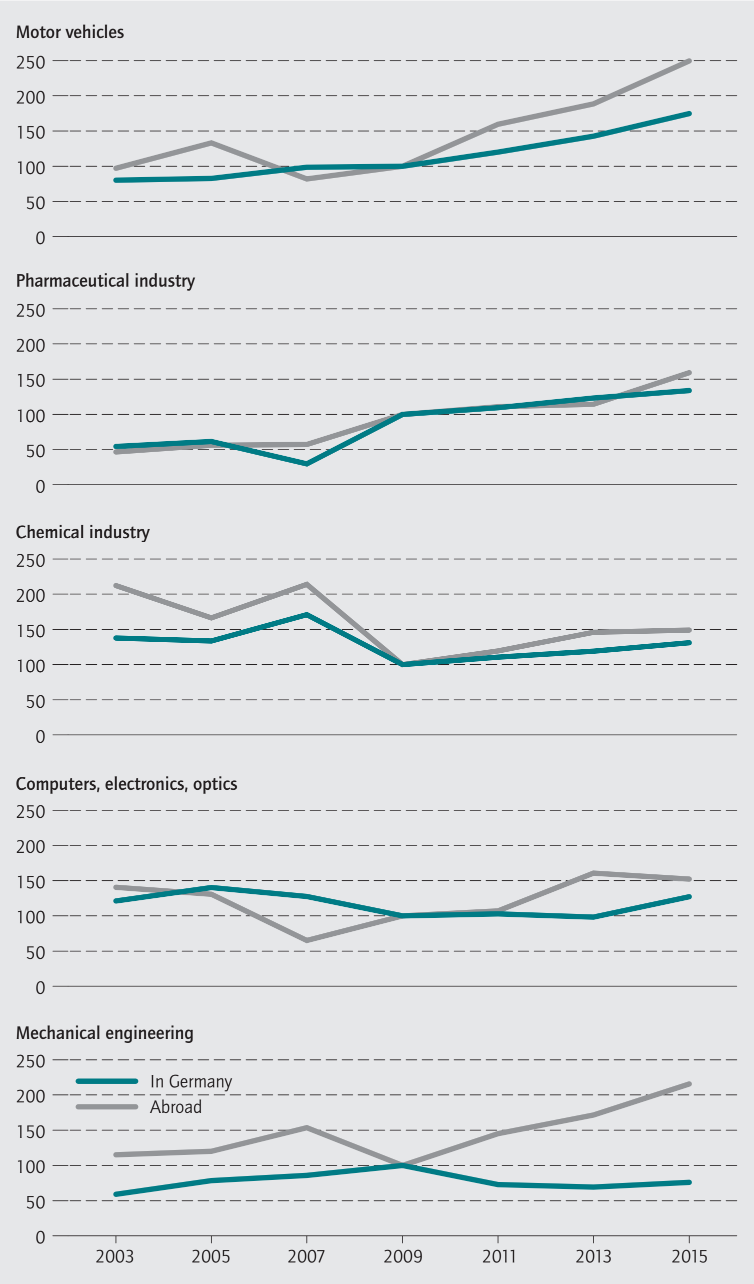
5 In addition to Swiss majority-owned companies with R&D abroad, the group also included foreign and Swiss companies that do not conduct international research.

6 In research in this field, the number of patent applications is often used as a measure of R&D investment. But it must be accepted that R&D with non-patentable results is not included and is contingent upon deviations in both indicators as a result of different propensities to patent in various sectors.

Figure 2

R&D expenditure of German companies at home and abroad, 2003–2015

Index 2009=100



Sources: SV-Wissenschaftsstatistik; authors' own calculations.

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In almost all sectors, the R&D expenditure of German companies experienced parallel growth at home and abroad.

Table 2

Share of R&D expenditure of German companies abroad in selected industries, 2003 and 2015

In percent

	2003	2015
Chemical industry	34	28
Pharmaceutical industry	50	58
Mechanical engineering	32	41
Computers, electronics, optics	37	37
Motor vehicles	21	24
Information and communication	–	40
Financial and insurance activities	–	88

Sources: SV-Wissenschaftsstatistik; authors' own calculations.

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German financial service providers and pharmaceutical companies invest in more R&D abroad than in Germany.

Foreign companies' R&D investment in Germany

According to information from the *Stifterverband*, all foreign companies in Germany had a total internal R&D expenditure of 13.1 billion euros in 2015.[7] They spent more than they did in 2013 (11.9 billion euros) but could not match the record high of 13.2 billion euros in 2011. Measured by full-time equivalents, around 90,000 persons were employed in R&D in foreign companies in 2015 just as in 2011. At 22 percent, the proportion of R&D personnel in foreign companies was at its lowest since 2001 (Table 3). However, it recently declined in most sectors of the economy. There were only slight increases in mechanical engineering, metal production and processing, and in research and development services, which together accounted for less than one-fifth of R&D employees in foreign companies (Table 4).

Foreign companies also had particularly high proportions of R&D personnel in aerospace engineering (78 percent) and the pharmaceutical industry (36 percent). Foreign companies are more highly committed to these and other cutting-edge industrial technology sectors that are highly promising for future technological development.[8] These fields were the recipients of 39 percent of the total R&D expenditure, while in German companies the total is only 17 percent. However, companies in other European countries invested more than half of their R&D

7 See Verena Eckl et al., "a:rən'di: Zahlenwerk 2017."

8 Per definition, the cutting-edge industrial technology sectors have R&D expenditures of more than nine percent in relation to revenue. In the high-quality technology sectors, the figure is three to nine percent. See Verena Eckl et al., "a:rən'di: Zahlenwerk 2017."

in Germany in its cutting-edge technology sectors. At 23 percent, US companies are less active in this field (Table 5). German companies' low level of commitment to cutting-edge technologies is, however, also a result of their strength in the field of high- technology, including motor vehicles, which is responsible for 39 percent of their total intramural R&D expenditure alone. Further, at 14 percent, the overall share of German companies' R&D expenditure invested in research-intensive services was twice that of foreign companies.

R&D investment in international comparison

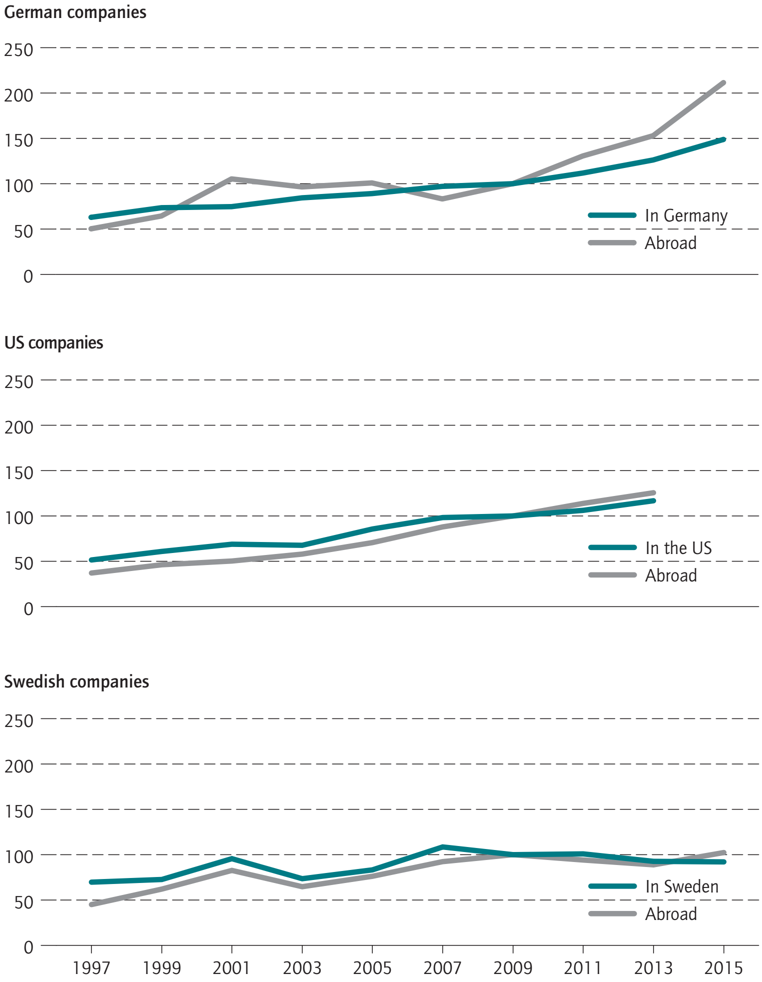
In Belgium, Ireland, the Czech Republic, Great Britain, Austria, and Poland foreign companies recently invest around 50 percent or more of the private R&D expenditure. (Table 6). Among the industrialized countries that are highly active in R&D, at six percent Japan had the lowest proportion of foreigners in private R&D expenditure, followed by Finland with just below 15 percent, and the US at 16 percent. At 22 percent, the proportion in Germany is only slightly higher, approaching the values of Italy, France, and Switzerland. In recent years, the contribution of foreign companies to R&D rose significantly in some countries, including: Poland, the Czech Republic, Spain, Norway, and Belgium. In ten of the 17 countries for which we had data as of 2003, it only rose slightly or even declined, for example in Ireland, Germany, Sweden, Italy, and France. Hence the speed of globalization in private R&D in the industrialized countries was only moderate in recent years.

Foreign companies are responsible for a comparatively low share of R&D expenditure among all companies in Germany, which at two percent is, however, high in relation to the German GDP (Figure 6). France had significantly lower R&D intensity with a similar contribution from foreign companies, and Great Britain's lower R&D intensity was accompanied by a significantly higher contribution of foreign companies. Alongside Germany, Austria, Japan, and the US recorded strong growth in private R&D intensity. In Germany, Japan, and the US, domestic companies drove all or most of the R&D intensification in the economy. Foreign and domestic companies both contributed to R&D intensification to the same extent. Our international comparison shows that the higher share of foreign companies in R&D investment did not parallel higher R&D intensity and is, therefore, not necessarily proof that a country has attractive research conditions.

It is obvious that the shares of foreign companies in R&D relate to their proportions of production and employment. Since relevant data are not available for many countries, we used the stocks of foreign direct investment in relation to GDP as an indicator of the signifi-

Figure 3

R&D expenditure of German, US and Swedish companies at home and abroad, 1997–2015
Index 2009=100



Sources: SV-Wissenschaftsstatistik; Bureau of Economic Analysis (BEA) / U.S. Department of Commerce; Swedish Agency for Growth Policy Analysis; authors' own calculations.

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The R&D of German, US, and Swedish companies grew at virtually the same rate at home and abroad.

Box 2

Measurement of corporate research globalization with patent data on applicants' and inventors' place of residence

The OECD provides data on applications for international patents (including those of PCT patents, see below) in which at least one inventor abroad participated. The relevant indicator, "domestic ownership of inventions made abroad," reflects the extent to which the companies in a country control inventions based on R&D in subsidiaries in another respective country. Evaluations of the data on patent applications are based on the assumption that the vast majority of the international patents used are from companies, and only a small portion of them are applied for by research institutes or the inventors themselves. The proportion of patent applications from domestic applicants (companies) with foreign inventors is therefore approximately equal to the proportion of inventors abroad. The indicator supplements the R&D data for the subsidiaries of domestic companies abroad.[1]

In contrast, from the viewpoint of the target countries the globalization of R&D can be measured by the number of patent applications from foreign applicants with domestic inventors (foreign ownership of domestic inventions).

Based on these data, it is possible to estimate the patent applications of domestic companies in their homelands by subtracting the patents of foreign applicants with inventors in the relevant country from the total number of patents. To smooth the fluctuation in the annual application numbers in small countries, the sum of the patent applications of the current and previous year was used to calculate all indicators.

PCT patents

In order to receive patent protection abroad, applicants must submit a separate application to each national patent office. Since the procedure is complex and expensive, the international Patent Cooperation Treaty (PCT)[2] was created to provide the option of submitting a single (international) application to replace individual national applications in all signatory nations.[3] After submitting an application, applicants have up to 18 months to decide whether or not to pursue the patent application in other countries. An international treaty among more than 150 countries, the PCT is managed by the World Intellectual Property Organization (WIPO). However, national or regional patent offices are still responsible for the grant of the patent proper during the national phase of the process.

Due to the international orientation of the procedure and the high quality of the research on the patentability of an invention, PCT applications are more likely to reflect equivalent inventions than the patents of the various national patent offices.

1 Pluvia Zuniga, Dominique Guellec et al., *OECD Patent Statistics Manual.* Paris: OECD Publishing, 2009 (online available).

2 Available online.

3 Also see information on PCT applications (available online).

cance of foreign companies. As expected, we found a positive relationship between the proportions of foreign-controlled companies in R&D and production. Yet it is rather weak (Figure 7). In Israel, Belgium, the Czech Republic, Great Britain, Austria, and Poland, considerably higher R&D expenditures attract foreign companies more than the stocksof foreign direct investment there would lead one to expect. Conversely, in Switzerland, the US, and Japan—and to a lesser extent in Finland, the Netherlands, Germany, and France—the R&D shares of foreign companies are rather low in relation to the stocks of foreign direct investment (Figure 7). These countries also home countries of many multinational corporations that are highly active in R&D. In these countries in particular, measured by the stocks of foreign direct investment, there is additional potential for foreign companies to commit to R&D. It could be more difficult for them to gain footholds in countries with R&D in which they would encounter established competitors. Domestic companies employ the majority of R&D personnel there and maintain mature cooperative partnerships with each other, state research facilities, and universities. Further, they are probably also the primary beneficiaries of government R&D commissions and the most important funding recipients. However, there is a lack of sufficient information on the possible existence of access barriers to the research landscape for foreign companies in Germany and other countries.

Conclusions

After an extended period of stagnation German companies R&D abroad gained momentum in 2009. By the year 2015, the annual total R&D expenditure of German companies with international R&D activity at home rose by just below 50 percent and more than doubled abroad. At 14.7 billion euros at home in contrast to 12.7 billion euros abroad, domestic growth in R&D expenditure was higher. During the same period, foreign companies increased their R&D investment in Germany by only around ten percent (1.5 billion euros). This puts Germany among the countries with the lowest growth in R&D among foreign companies in recent years. However, the R&D expenditure of all companies in Germany rose to two percent of GDP, putting it at the same level as the US and significantly higher than that of France and Great Britain, for example. German multinational corporations with international R&D activity drove this positive development.

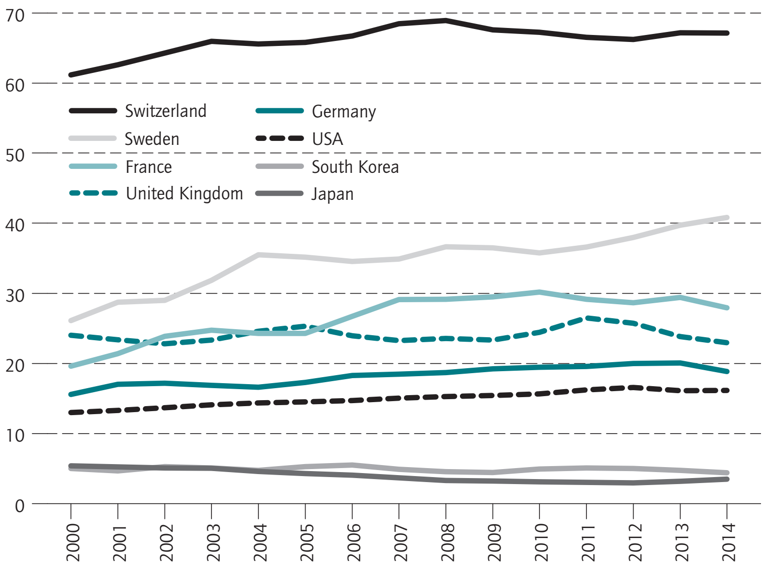
In those companies and their most important global competitors, the majority of investment in R&D at home and abroad developed in parallel. The companies that expanded their domestic investment were primarily the ones that invested abroad. This contradicts the assumption that R&D investment takes place abroad at the cost of domestic investment.

Alongside Japan, the US, and Switzerland, Germany is one of the countries in which the R&D activity of foreign companies is lower than expected based on the stocks of foreign direct investment. These countries have many of their own multinational corporations with strong research departments that traditionally conduct R&D at their home location. Because they employ most of the domestic pool of skilled personnel and take full advantage of the research landscape and funding opportunities, this may make it difficult for new foreign investors to gain access to the research location. Research policy makers should confirm whether or not there are barriers to accessing the research landscape for foreign companies in general or in specific sectors. In the field of cutting-edge technology, where foreign companies are particularly active, and beyond, eliminating them could contribute to intensifying the global transfer of knowledge.

Figure 4

Share of patent applications with inventors abroad, 2000–2014[1]

In percent



1 Calculated with PCT applications of the current and the previous year.

Sources: OECD; authors' own calculations.

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There was moderate growth in the proportions of inventors in companies abroad.

Table 3

Foreign companies' share of R&D in Germany 1995–2015

In percent

	1995	2001	2007	2013	2015
Industry total					
R&D personnel	15.7	24.2	25.8	22.8	22.4
Internal R&D expenditure	16.1	24.8	27.3	22.6	21.5
Manufacturing industry					
R&D personnel	15.9	25.2	26.8	23.8	24.5
Internal R&D expenditure	16.4	25.6	27.6	23.1	22.7

Sources: SV-Wissenschaftsstatistik; authors' own calculations.

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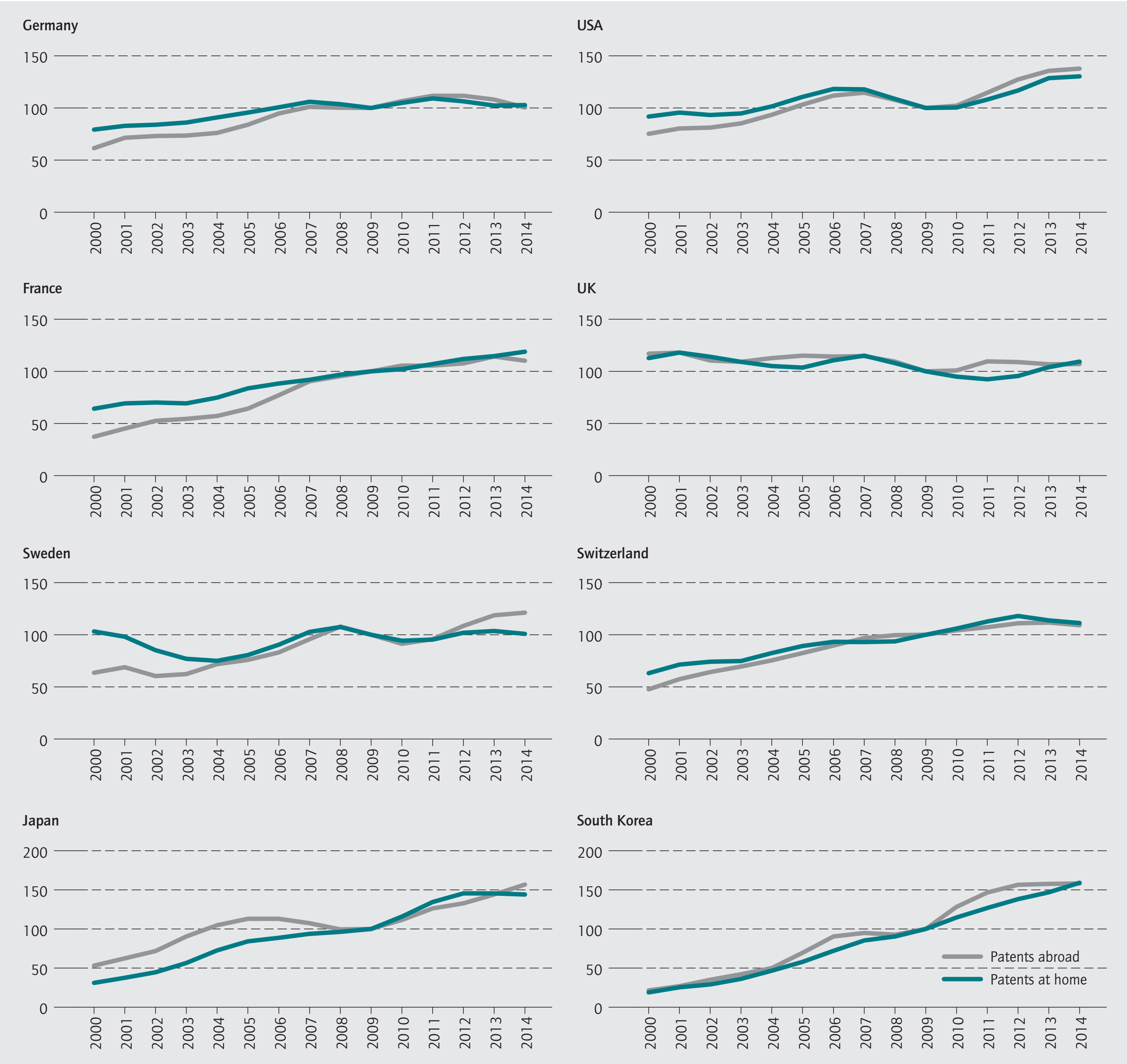
In 2015, the proportion of R&D in foreign companies in Germany was at its lowest level since 2001.

Figure 5

Patent applications of selected countries with inventors at home and abroad

Index 2009=100[1]



1 Calculated with PCT applications of the current and the previous year.

Sources: OECD; authors' own calculations.

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Parallel change in the number of inventors at home and abroad.

Table 4

Share of R&D Personnel in Foreign companies, 2009 and 2015
In percent

	2009	2015
Manufacturing industry	26.8	24.5
Chemical industry	17.5	15.0
Pharmaceutical industry	44.0	35.7
Rubber, plastics, non-metallic mineral products	34.3	26.7
Metal production and processing, and manufacture of metallic products	21.0	28.2
Mechanical engineering	20.8	23.6
Computers, electronics, optics	29.5	27.5
Electrical equipment	26.6	21.0
Motor vehicles	19.2	17.1
Aerospace engineering	87.4	78.4
Information and communication	22.6	11.8
Financial and insurance activities	16.2	2.7
Professional, scientific and technical activities	6.8	4.6
Architectural and engineering activities and related technical consultancy	16.7	19.0
Scientific research and development		
Total	24.3	22.4

Sources: SV-Wissenschaftsstatistik; authors' own calculations.

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The proportion of foreign companies with R&D personnel decreased in most sectors.

Table 5

Share of R&D-intensive industries in R&D expenditure of foreign and indigenous companies in Germany, 2013 and 2015
In percent

	Indigenous companies		Foreign companies		Thereunder from			
					Europe		USA	
	2013	2015	2013	2015	2013	2015	2013	2015
R&D-intensive industries	75.6	74.7	76.6	78.1	74.8	78.5	79.9	80.4
Cutting-edge technologies	20.8	17.4	37.2	39.2	46.1	51.1	23.8	22.9
Cutting-edge technologies	54.8	57.3	39.3	38.8	28.7	27.4	56.1	57.5
R&D-intensive services	11.4	13.7	5.5	5.7	5.4	5.2	5.2	5.7
Miscellaneous	13.0	11.6	18.0	16.2	19.8	16.3	14.9	13.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Sources: SV-Wissenschaftsstatistik; authors' own calculations.

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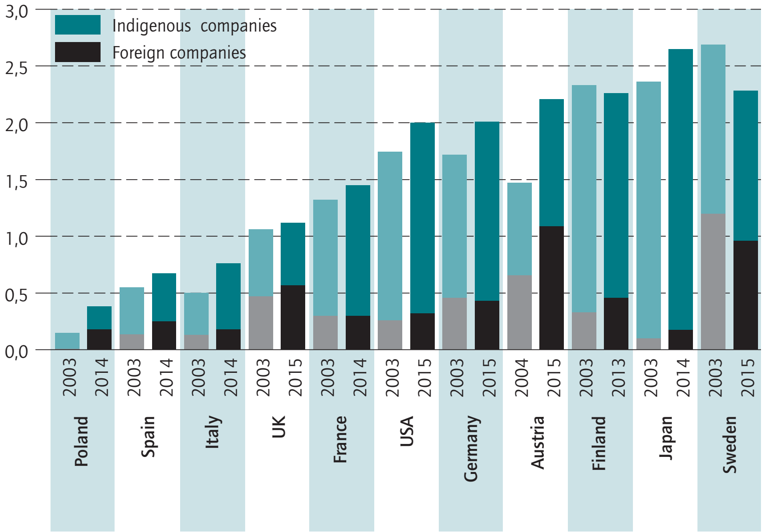
Foreign companies are more likely to concentrate their R&D in cutting-edge industrial technology sectors.

Figure 6

R&D expenditure of indigenous and foreign companies in percent of GDP 2003/04 and 2014/15

In percent



Sources: OECD and national data; authors' own calculations.

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Higher contributions of foreign companies to R&D do not go hand in hand with higher R&D intensity.

Table 6

Share of R&D expenditure in foreign companies in selected countries, 2003 and 2015

	2003	Last available year	change	Last available year
	In percent		*In percentage points*	
Belgium	57.1	66.0	8.9	2011
Ireland	70.2	65.2	−5.0	2013
Czech Republic	46.6	62.8	16.1	2013
United Kingdom	43.9	50.9	6.9	2015
Austria	47.7	49.4	1.6	2015
Poland	9.3	47.0	37.7	2013
Sweden	45.2	42.1	−3.1	2015
Spain	26.2	37.0	10.8	2013
Canada	31.8	35.5	3.8	2013
The Netherlands	25.4	33.5	8.1	2014
Norvay	20.9	31.6	10.7	2012
Italy	26.3	23.9	−2.4	2014
Germany	25.2	21.5	−3.7	2015
France	22.6	21.0	−1.6	2014
USA	14.8	15.8	0.9	2015
Finland	14.0	14.8	0.8	2013
Japan	4.3	6.6	2.4	2013

Sources: OECD, national data; authors' own calculations.

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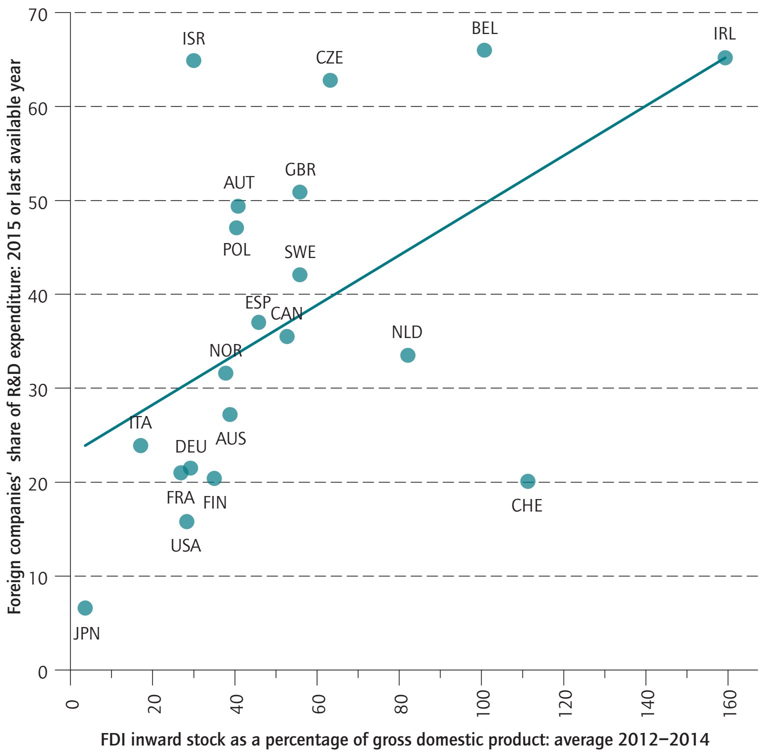
In ten out of 17 countries, the proportion of foreign companies involved in R&D rose slightly or even fell.

Figure 7

FDI inward stock and foreign companies' share in R&D in selected countries



Simplified the relation between foreign companies share of R&D (y) and the FDI inward stock as percentage of GDP (x) can be represented as a linear function: y= 0,2563x + 23,59, R2=0,2635.

Sources: OECD; UNCTAD; authors' own calculations.

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Measured by their foreign direct investment stocks, foreign companies have a low share of R&D in Germany.

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