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The Impact of the Covid-19 Crisis on Innovation: First In-sights from the German Business Sector

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Executive Summary

- In 2020, firms expected their innovation expenditures to decrease by about 2% in 2020 compared to 2019. This decline is much smaller than that in 2009 following the financial crisis, when innovation expenditures fell by 11%. However, smaller firms with 5 to 99 employees planned to cut their innovation expenditures by 7% to 17 % in 2020. For 2021, firms planned a slight increase in innovation expenditure by 1%.
- The number of employees in short-time work in Germany peaked at 2.9 million in April 2020, corresponding to a share of 8.7% of all employees. The situation relaxed by October 2020, when the share of short-time workers fell to 2.3%. The most R&D-insensitive industries showed the highest share of short-time work in April 2020 (16.6%), but the lowest in October 2020 (2.0%), indicating that the impact of the crisis on R&D intensive industries weakened in the second half of 2020. This development was strongly driven by the drop of short-time workers in the automobile industry. The recovery of some export-intensive industries, such as the automobile industry, also reflects that firms are starting to adopt and overcome the initially severe disturbances and challenges Covid-19 imposed on international value chains.
- The global R&D expenditures of large R&D performing German firms declined on average by 1% between 2019 and 2020. However, there are major differences between individual industries. The pharmaceutical and ICT service industries significantly increased their global R&D expenditures, whereas mechanical engineering experienced the sharpest decline in 2020. Firms' average R&D intensity increased in most industries, except for the electronics/instruments industry and ICT services.
- Firms with R&D or other innovation activities prior to the crisis more often reported negative impacts of the Covid-19 crisis on their general business activities than firms that do not conduct any R&D or innovation activities. This result may be linked to the fact that the crisis had a more severe impact on firms with a more complex internal organisation and more international activities, both of which are typical for R&D and innovation performing firms.
- The most common strategic responses of firms to the Covid-19 crisis were i) to enhance the digitalisation of their internal processes and ii) to extend their digital offers and sales channels. Both responses were mostly of permanent nature. Reorganising sales towards domestic customers and removing products or services from their portfolio were less common responses.
- The most frequent crisis-related changes in firms' innovation activities include i) the extension of innovation projects and ii) a reduction in the number of innovation projects due to a lack of impulses for innovation. Reducing collaborations and withdrawing from all innovation activities were less frequent changes.

1. Previous economic crises and their impact on innovation

Innovation is essential for economic growth (Bravo-Biosca et al. 2013) and a critical element for the management of, and recovery from the Covid-19 crisis (Ebersberger and Kuckertz 2021; Roper and Turner 2020). However, the Covid-19 crisis itself affects the conditions for innovation in various ways and poses both asymmetric threats and opportunities for innovators (e.g. Bloom et al. 2020; Paunov and Planes-Satorra 2021). Previous research on the impact of economic crises on the innovation activities of firms identified three broad factors affecting innovation: i) financial liquidity, ii) market uncertainty and iii) opportunity costs. The financial liquidity of firms decreases during an economic crisis, hampering their ability to invest in innovation (e.g. Aghion et al. 2012, Paunov et al. 2012). For example, bank lending becomes more restrictive (Ivashina and Scharfstein 2010), cash flows shrink (Rafferty and Funk 2008), and venture capital investments decrease (Howell et al. 2020). During a crisis, market uncertainty rises, as demand becomes harder to predict, and supply chains become less reliable. As a result, firms delay their research and development (R&D) investment decisions (Bloom 2007) or the introduction of new products (Rafferty and Funk 2004), for instance, in anticipation of less uncertain economic times. They also rely more on public subsidies for financing innovation (Hud and Hussinger 2015). The opportunity costs of innovation activities decrease during economic crises (Hud and Rammer 2015). Firms have fewer opportunities for short-term profit during crises, thus making investment in innovation with potential future profits more attractive (Aghion and Saint-Paul 1998, Saint-Paul 1993).

Most empirical evidence finds a negative net impact of economic crises on the innovation activities of firms (Pellens et al. 2020). The impact of crises on individual firms, however, depends on the structure of the crisis and firms' starting positions. Campello et al. (2010) and Kabukcuoglu (2019) find, for example, that the innovation activities of particularly small firms were impacted during the financial crisis in 2008 and 2009. Aghion et al. (2012), on the other hand, show that firms without credit constraints invest more in R&D during recessions. Economic crises can therefore widen the gap between firms with high cash and low cash holdings and between smaller and larger firms (Joseph et al. 2020; Schmitz 2014). The literature about the impact of economic crises on innovation, in general, revealed a large heterogeneity with regard to innovation strategies (Archibugi et al. 2013). Rammer (2012) shows for the case of Germany that around 34% of firms increased their innovation activities as a response to the financial crisis in 2008 and 2009, whereas at the same time, 33% reduced their activities due to financial constraints, increased uncertainty or unfavourable economic prospects.

2. Existing empirical evidence on the impact of the Covid-19 crisis on innovation

The Covid-19 crisis is particularly damaging to industries that rely on social contact, as governments largely restricted interpersonal communication to combat the pandemic (Bloom et al. 2021b). Kinne et al. (2020) show, for instance, that German firms in the areas of entertainment, hospitality, education, agriculture and personal services, in particular, most frequently reported problems resulting from Covid-19 on their websites. As aggregate investment in innovation in these industries is relatively low, the negative impact of the Covid-19 crisis on private sector innovation is likely to be negligible (Paunov and Planes-Satorra 2021). However, international companies, especially those that rely on global value chains, are also negatively affected by the crisis. Wohlrabe (2021) shows that 45% of manufacturing firms in Germany faced a significant shortage of intermediate products in 2020. Based on data from Italian firms, Brancati and Brancati (2020) find that international firms expected a sharper decline in sales and

were more likely to cancel future R&D plans than firms only operating in the domestic market. This finding is also reflected in a significant reduction of revenues and R&D spending in certain multinational corporations in the automotive, aerospace, and defence industry between mid-2019 and mid-2020. This was observed in companies such as Boeing, Daimler and Volkswagen, for instance (OECD 2021). In line with this, a survey conducted by the Federation of German Industries in May 2020 among R&D performing German firms finds that 38% of all firms surveyed had cancelled or reduced their R&D activities. In the automotive industry, the share was as high as 78% (Wehmeyer 2020). Nevertheless, more recent empirical findings, such as those of the ifo Business Survey (Sauer and Wohlrabe 2021) suggest that, in 2020, the share of R&D personnel in firms' total employment and the share of R&D expenditures in firms' sales was only slightly below the average of the last few years. They further show that the number of manufacturing firms performing R&D increased by 2%-points from 2019 to 2020. This increase is, however, predominantly driven by large firms with more than 500 employees as the share of small and medium-sized firms (SMEs) undertaking R&D fell slightly from 2019 to 2020 (Sauer and Wohlrabe 2021).

Similar to previous crises, Covid-19 may also reduce firms' financial liquidity. Bloom et al. (2021b) find that Covid-19 had a negative impact on the sales of small US businesses. Paunov and Planes-Satorra (2021) demonstrate a significant decrease in overall cash flows during the first months of the crisis. They identify this as a threat for the innovation activities of SMEs and technology-driven start-ups in particular. Venture capital investments slowed down during the first months of Covid-19 too, but sped up again during the second half of 2020. That said, although the overall amount of investments increased over time, venture capital investments concentrated on a smaller number of deals and on later stages (Paunov and Planes-Satorra 2021). The increase in venture capital investment therefore does not ease the financial situation for start-ups. Dörr et al. (2021) identify a backlog of insolvencies in Germany, particularly among financially weak and small firms. This is consistent with other empirical findings that point to i) massive government Covid-19 support schemes and ii) the suspension of the obligation to file for insolvency as an explanation for the drop in insolvency rates during 2020 (Gourinchas et al. 2020; Eurostat 2021). More importantly, the former is also argued to explain the small decrease in firm closures despite the significant sales drop in 2020.

One of the differences between the Covid-19 crisis and other economic crises is the introduction of government-enforced working from home during lockdowns (Waizenegger et al. 2020). Brynjolfsoson et al. (2020) found that 35% of US employees switched to working from home in April and May 2020. This differs significantly across industries, however. Work from home is more frequent in industries with better-educated workers because knowledge-intensive work can often be performed electronically, whereas work in, for instance, factories, supermarkets and hospitals, cannot (Bartik et al. 2020). Even if some tasks in knowledge-intensive work can be performed at home, lockdowns are nevertheless likely to affect the innovation activities of firms. Research facilities closed, as did laboratories and science parks, which is directly impacting firms' research progress, product development and commercialisation activities (Paunov and Planes-Satorra 2021). Moreover, the restrictions on in-person meetings reduce knowledge flows between people and organisations, which may complicate the execution of innovation projects and reduce the inflow of new ideas for innovation (Paunov and Planes-Satorra 2021; Xiao et al. 2021). This issue is also highlighted in a survey of innovative German firms, undertaken in April 2020 by the Federal Ministry for Economic Affairs and Energy (BMWi 2020). The majority of firms surveyed report a number of obstacles for their R&D activities, including a lack of in-person meetings (58%; e.g. due to staff working from home), limited availability of employees (54%; e.g. due to childcare), a lack of demand (52%) and financial constraints (45%). However, historical evidence from the lockdown during the 1918 influenza pandemic suggests no negative impact on patenting activities in the US (Berkes et al. 2020). These inconsistent findings hint at different impacts of lockdowns on basic research and experimental development. Recent qualitative interviews of the Stifterverband with German firms strengthen

this hypothesis (Schmitt et al. 2021). Several firms surveyed stated that mainly projects with a stronger focus on basic research were suspended during the crisis. Applied R&D projects, on the other hand, were reduced less often. They probably withdrew from basic research not only due to limited resources and increased competition but also because of severe disadvantages that rest on work from home. Several firms that took part in the interviews highlighted that the absence of in-person meetings harmed their creativity, which is in their view essential to create innovation impulses. Taken together, this underlines the hypothesis that in-person interactions foster creativity, which is important for basic research, but are less relevant for routinized testing and experimental development, which are applied research tasks that are frequent precursors of patenting.

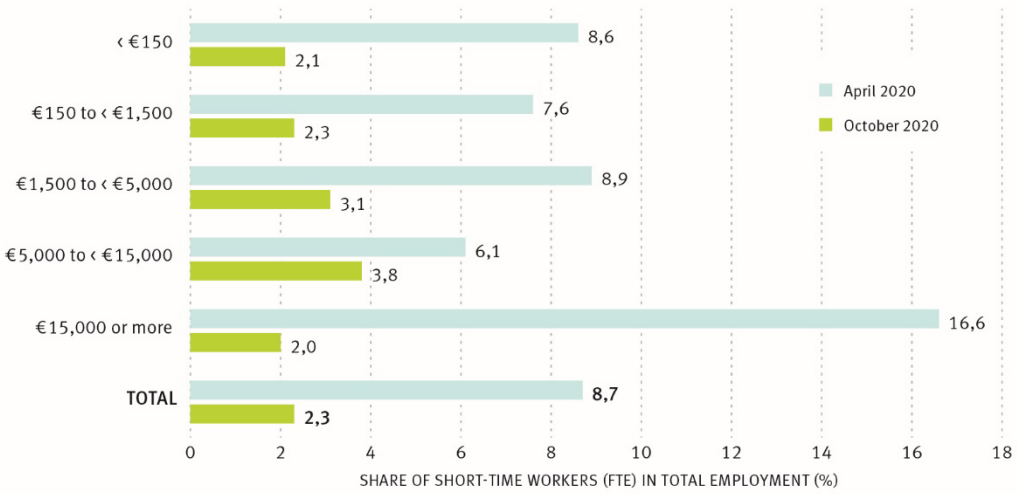
Given the distinctive characteristics of the Covid-19 pandemic, certain industries experienced positive impacts on innovation and demand – including pharmaceuticals, the healthcare industry as well as industries related to digital services and products. Firms with digital offers have generally thrived since the start of the Covid-19 crisis (Paunov and Planes-Satorra 2021). Facebook, Apple and Microsoft, for example, significantly increased R&D expenditures by mid-2020 compared to the previous year (OECD 2021). The need for firms to introduce work from home arrangements sparked the development and diffusion of digital technologies. The share of new patent applications for work-from-home technologies received by the United States Patent and Trade Mark Office (USPTO) more than doubled from January to September 2020 (Bloom et al. 2021a) and firms with previously low work-from-home feasibility attempted to catch up with their competitors by increasing their software investment (Bai et al. 2021). At the same time, health-related industries, in particular, increased their innovation activities with the aim of better tackling the pandemic and its challenges. A survey conducted by the Federation of German Industries in May 2020 among R&D performing firms showed that 38% were involved in finding solutions for overcoming the Covid-19 pandemic, e.g. through developing medical devices, vaccines, therapeutics or protective equipment (Wehmeyer 2020). However, only biotechnology and pharmaceuticals saw above-average increases in R&D through Covid-19. Some pharmaceutical firms, such as Gilead Sciences, Pfizer and AstraZeneca increased R&D expenditure by 10 to 20% in 2020 (OECD 2021). In Germany, BioNTech almost tripled R&D expenditures in 2020.

3. Differences in the economic effects of Covid-19 by R&D intensity of industries

To assess the consequences of the Covid-19 crisis for innovation in the German business sector, we first examine the impact of the crisis on different industries. We particularly consider differences in industries' R&D intensities. A suitable measure for the vulnerability of an industry to Covid-19 is its share of short-time workers. Short-time work is a government scheme that allows firms to reduce the working hours and payment of their employees substantially, while the government compensates most of the employees' lost wages.

In April 2020, short-time work in Germany peaked at 2.9 million employees, which corresponded to 8.7% of the employee population (see Figure 1). When further differentiating by the R&D intensity of an industry, industries with a high R&D intensity of more than €15,000 annual in-house R&D expenditures per employee showed the highest share of short-time work (16.6%). However, this result is driven by the automobile industry, in which 27.8% of employees were in short-time work in April 2020 (see Figure 2). In contrast, other industries with high R&D intensities had either low shares of short-time work (pharmaceuticals: 1%, R&D services: 2%), or at least a below-average share (electronics: 6%).

FIGURE 1: SHARE OF SHORT-TIME WORKERS IN GERMANY IN APRIL AND OCTOBER 2020, BY R&D INTENSITY OF INDUSTRIES

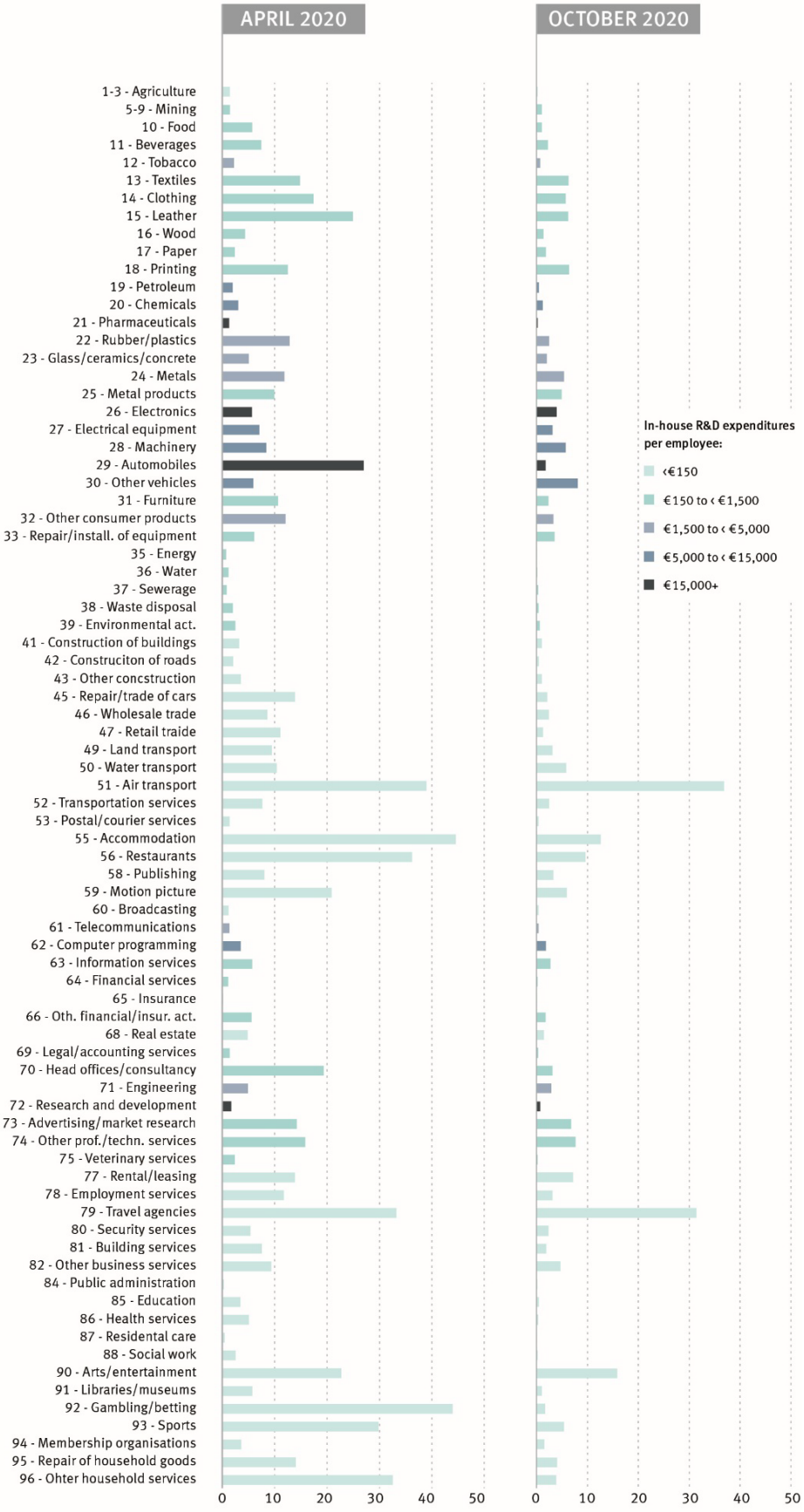


R&D intensity: Average in-house R&D expenditures per employee. Share of short-time workers: Short-time workers measured in full-time equivalents (FTE) as a percentage of total employment in the previous month. Reading example: In April 2020, 16.6% of all employees in industries with an R&D intensity of €15,000 or more were in short-time work. Source: Federal Employment Agency; Eurostat (R&D statistics); ZEW calculations.

The situation had eased by October 2020, when only 2.3% of German employees were in short-time work (see Figure 1).[1] The automobile industry, in particular, reduced their share of short-time work significantly (see Figure 2) and the overall share of industries with high R&D intensities above €15,000 per year, per employee fell to 2.0% (see Figure 1). Industries with an R&D intensity of between €5,000 and €15,000 per year, per employee reported the highest short-time work share of 3.8%. This is due to the machinery and electrical equipment industries, as well as the other vehicles sector, which covers, for instance, aircraft, train and ship manufacturing. In these industries, high levels of short-time work of between 4 and 8.1% remained (see Figure 2), reflecting a fall in the demand for their products and services: i) industrial investment in new machinery and equipment declined globally and ii) air and ship passenger transport plummeted.

[1] The latest data available on the number of people in short-time work measured as full-time equivalents at the time of writing this report (May 2021) is for October 2020. More recent data on the number of people firms had registered for the scheme show an increase in December 2020 and January 2021, followed by a strong decline until April 2021. The number of people registered for January 2021 (975,000) was only 12% of the corresponding number for April 2020 (8.02 million), suggesting that most of the immediate effects of Covid-19 on German industry were felt during the first lockdown (March–May 2020).

FIGURE 2: SHARE OF SHORT-TIME WORKERS IN GERMANY BY R&D INTENSITY OF INDUSTRIES AND NACE CLASSIFICATION

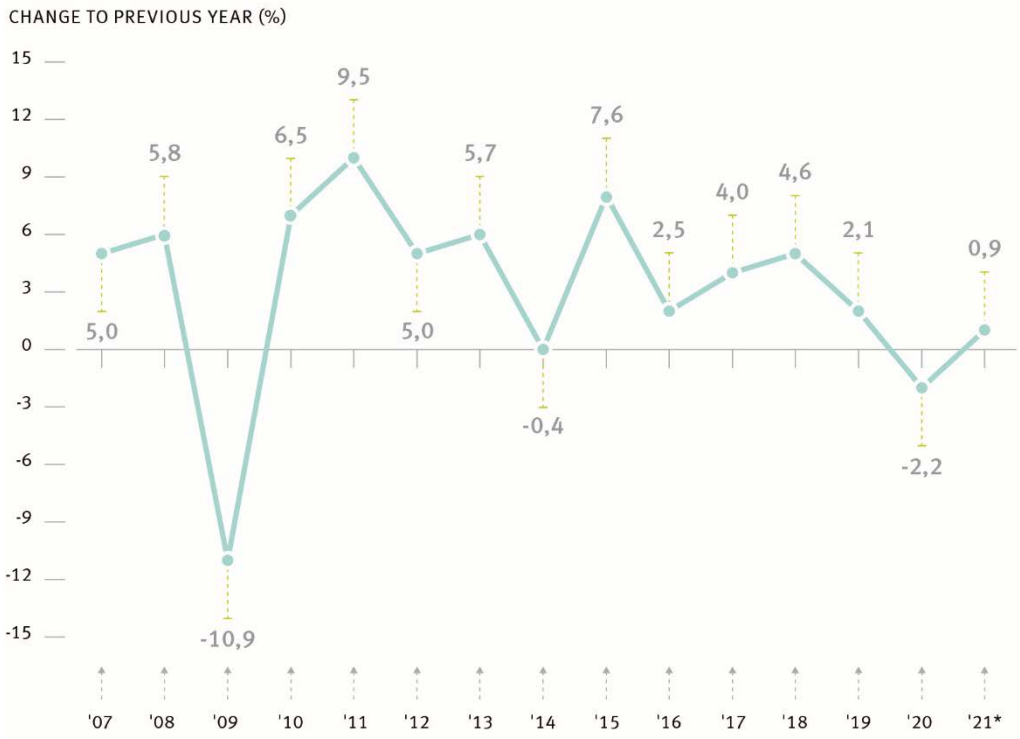


R&D intensity: Average in-house R&D expenditures per employee. Share of short-time workers: Short-time workers measured as full-time equivalents (FTE) as a percentage of total employment in the previous month.
Source: Federal Employment Agency; Eurostat (R&D statistics); ZEW calculations.

4. Planned innovation expenditures in 2020

The innovation survey conducted in 2020 provides insights into the planned innovation activities of the German business sector. The survey asked firms to provide an estimate of their planned innovation expenditures in 2020, along with their actual innovation expenditures in 2019.[2] The answers were provided between March and July 2020.[3] The results show a small decrease in planned innovation expenditures for 2020 of about 2% compared to 2019 levels. This is significantly smaller than the drop of 11% reported for 2009 after the financial crisis (see Figure 3). In addition, firms were asked to estimate their innovation expenditure in 2021. The results suggest a modest increase of 1% as compared to 2020, though the uncertainty surrounding this figure is particularly high.

FIGURE 3: DYNAMICS OF INNOVATION EXPENDITURES OF THE GERMAN BUSINESS SECTOR, 2007–2021



* Plans as of spring/summer 2020.

Source: ZEW, Mannheim Innovation Panel.

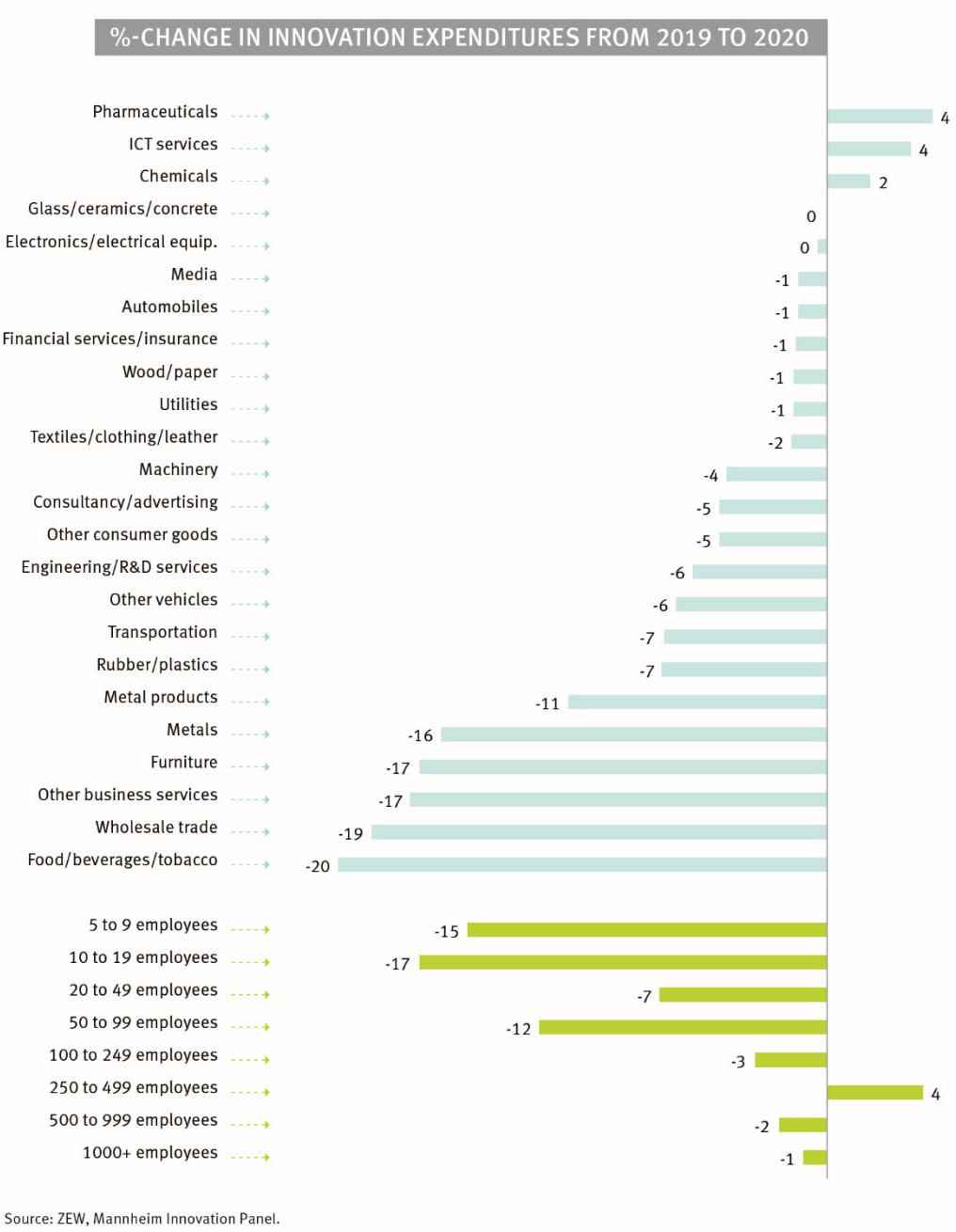
Figure 4 shows the percentage change in planned innovation expenditures in 2020 as compared to 2019 by industry and size class. It demonstrates that the negligible overall decrease of innovation expenditure in 2020 is mainly driven by R&D intensive industries: i) Pharmaceuticals and ICT services, which include software programming, plan to increase their innovation expenditures in 2020, while ii) other industries with high innovation expenditures, such as chemical, automobile, and electronics/electrical equipment, report planned expenditures for 2020 which are more stable. Among these industries with high innovation expenditures, only machinery (-4%), engineering/R&D services (-6%) and other vehicles (-6%) report more substantial reductions in their innovation budgets. The strongest cuts are planned in

[2] Innovation expenditures include in-house and external R&D expenditures, expenditure for machinery, equipment, software and external knowledge, as well as marketing, training, design and other expenditures for the development and introduction of product or process innovations.
[3] For firms that did not provide an estimate of their planned innovation expenditures in 2020, the amounts were imputed based on i) the information the firm provided regarding the expected change in their innovation expenditures (increase, stay about the same, decrease), and ii) the aggregate development of innovation expenditures in the firm's industry and size class.

industries with a limited significance for the aggregate innovation activities of the German business sector.

Broken down by size class, small and medium-sized firms with 5 to 249 employees plan to reduce their innovation expenditure in 2020 (see Figure 4). The planned innovation expenditures of very small firms with less than 20 employees, in particular, declined by between 15.2% and 16.5%. Interestingly, medium-large firms with 250 to 499 employees show a planned increase of 4%. Only a slight reduction of 2% is planned by firms with 500 to 999 employees and a 1% cut by firms with 1,000 or more employees.

FIGURE 4: PLANNED CHANGE IN INNOVATION EXPENDITURES FROM 2019 TO 2020 IN GERMANY BY INDUSTRY AND SIZE CLASS



Source: ZEW, Mannheim Innovation Panel.

5. Change in R&D expenditures in 2020 among the largest R&D performing German firms

The figures in the previous subsection show firms' plans and projections shortly before, during, or shortly after the first lockdown in spring 2020. These figures might deviate from the actual development of innovation activities for the whole of 2020, particularly if firms were too optimistic or pessimistic about the development of the Covid-19 crisis. A more recent indication of the innovation activities of the German business sector can be derived from annual reports of large R&D performing corporations. Their annual reports for the financial year 2020 are usually published by April 2021. This is much earlier than data releases from official surveys on R&D and innovation. As a key indicator of the effect of Covid-19 on innovation, we use the change in the firms' R&D expenditures from 2019 to 2020. This indicator deviates from the innovation expenditures presented in the previous subsection. First, data from annual reports are only available for very large corporations and thus do not take the dynamics in the SME sector into account. Second, R&D expenditures only cover a part of all innovation expenditures and do not include most capital expenditure for innovation, which may behave differently during an economic crisis. Third, R&D information from annual reports refers to firms' global activities, whereas innovation expenditures, as reported above, refer to activities in Germany.

Based on the Mannheim Innovation Panel, we established a list of firms with headquarters in Germany and high R&D expenditure in 2019. The list comprises 137 firms with a total of €89.8 billion in global R&D expenditure in 2019. For comparison, total in-house and external R&D expenditures of the German enterprise sector in 2019 were €95 billion (Schmitt 2021). We were able to obtain the figures for R&D expenditures in 2020 from the annual reports of 97 listed firms. Their aggregate R&D expenditures in 2019 were €85.0 billion, thus representing 95% of the R&D expenditures of our 137 listed firms. This implies that the 97 firms in our sample were particularly high R&D spenders in 2019.

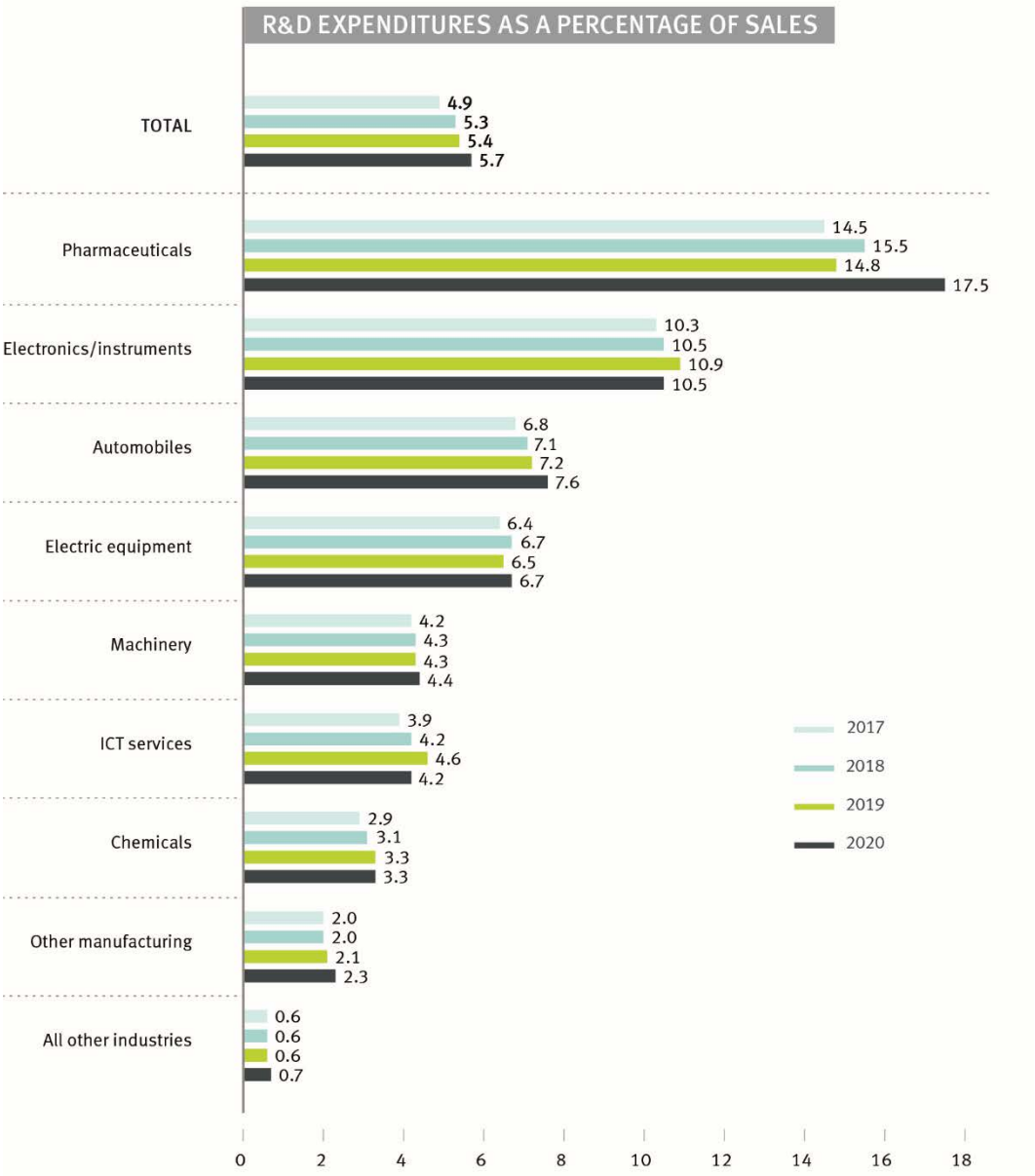
In 2020, the global R&D expenditures of these 97 German firms were 1% lower than the 2019 level (see Figure 5). In previous years, this group of corporations reported increasing global R&D expenditure, though the year-to-year rate of change was declining, from +8% in 2017 to +7% in 2018 and +5% in 2019. Firms from four industries increased their global R&D expenditures in 2020. The highest increase took place in the pharmaceutical industry, which also includes biotechnology firms. The 20% increase observed was more than twice as high as the industry's largest increase of 9% over the previous three years. However, a large part of this rise in R&D expenditures from 2019 to 2020 can be attributed exclusively to BioNTech. Firms offering ICT services, including software programming, report a 6% increase in global R&D expenditure in 2020, which is lower than in previous years. Similarly, firms from the electronics/instruments industry show an increase of 1% in 2020, also falling short of previous years' increases. Firms in the electrical equipment industry show a small rise of 1% in their global R&D expenditures in 2020. Declining R&D expenditures in 2020 are reported by firms from the chemical (-2%), automobile (-5%) and machinery industry (-9%), as well as those in all other manufacturing industries (-7%) and all other (non-manufacturing) industries (-7%). The strong decline in global R&D spending among firms in machinery industries mirrors their relatively high exposure to the negative economic impacts of the Covid-19 crisis, as revealed, for instance, by the industries' high share of short-time work.

FIGURE 5: ANNUAL CHANGE IN GLOBAL R&D EXPENDITURES OF LARGE R&D PERFORMING GERMAN FIRMS BY INDUSTRY

Sample: 97 large R&D performing firms headquartered in Germany. Source: Firms' annual reports.

The average R&D intensity of firms generally continued along its previous development and increased again in 2020 (see Figure 6). R&D intensity is the ratio of a firm's global expenditure on R&D to its global sales. Its continued increase implies that German firms maintained the trend towards investing a higher share of their sales in R&D despite the Covid-19 crisis. Rising average R&D intensities are found in all industries, with the exception of electronics/instruments and ICT services. The pharmaceutical industry records the highest increase in R&D intensity from 2019 to 2020 and shows with 18% the highest R&D intensity in 2020 overall. The significant decline in global R&D spending recorded by the machinery, automobile and chemical industries in 2020 was accompanied by an even stronger decline in global sales, as their R&D intensities were actually higher in 2020 than in 2019. However, these results only hold for high R&D performing firms, while Sauer and Wohlrabe (2021) find a decrease in the average R&D intensity of manufacturing firms in 2020.

FIGURE 6: AVERAGE R&D INTENSITY OF LARGE R&D PERFORMING GERMAN FIRMS BY INDUSTRY



R&D intensity: A firm's global R&D expenditures divided by its global sales. Sample: 97 large R&D performing corporations headquartered in Germany.
Source: Firms' annual reports.

6. Impacts of the Covid-19 crisis on innovation activities of firms in Germany

We also provide a more detailed preliminary assessment of the impact of the Covid-19 crisis on the innovation activities of firms in Germany during 2020 based on information from the 2021 survey wave of the MIP. The 2021 survey wave includes several questions focusing particularly on Covid-19 and its effects on firms' innovation performance and strategy. The survey started in February 2021 and is ongoing.

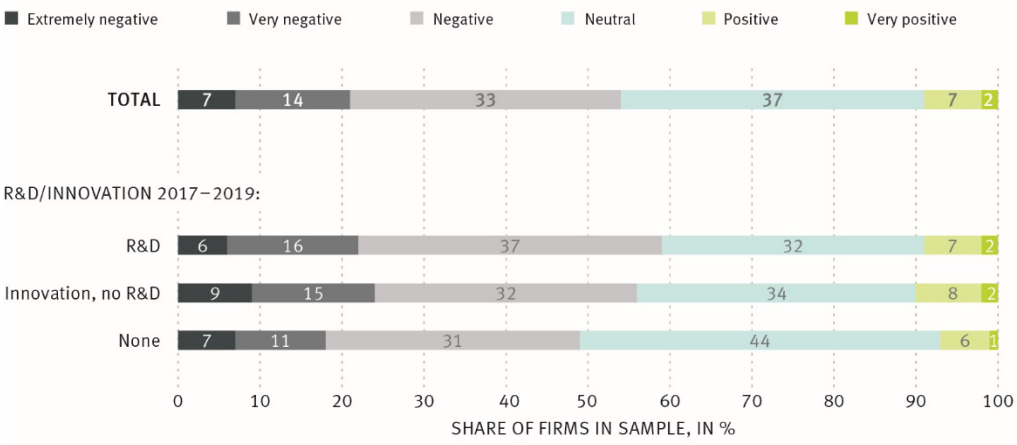
The results presented here, therefore, need to be interpreted as first indications, and not final conclusions.[4]

We examine the consequences of the Covid-19 crisis separately for firms with different pre-crisis innovation activities between 2017 and 2019:

- Firms active in internal or external R&D (38% of the sample)
- Firms not active in R&D, but engaged in other innovation activities (27% of the sample)
- Firms neither active in R&D, nor in other innovation activities (34% of the sample)

The overall impact of the Covid-19 crisis on firms in Germany differs only slightly according to their innovation status (see Figure 7). Compared to non-innovative firms, there is a higher share of R&D active firms reporting a negative impact and a lower share reporting a neutral impact. The same holds for firms conducting innovation activities other than R&D. Firms that do not conduct any innovation activities thus show the highest share of neutral impact and the lowest share of negative impact. However, the share of these R&D/innovation-active firms experiencing positive impacts from the pandemic is higher than among firms with no innovation activities. Besides this, only a few R&D/innovation-active firms were able to use the opportunities provided by the crisis, a much larger share were affected negatively.

FIGURE 7: GENERAL IMPACT OF THE COVID-19 CRISIS ON FIRMS IN GERMANY BY TYPE OF INNOVATION ACTIVITY IN THE PRE-CRISIS PERIOD



"General impact" refers to the consequences of Covid-19 (and related government measures) on the overall business activities of the firm. Non-weighted tabulation of firms that had participated in the 2021 survey of the Mannheim Innovation Panel by mid-April and in at least one of the three survey waves between 2018 and 2020. Number of observations: n=3,938. Source: ZEW, Mannheim Innovation Panel.

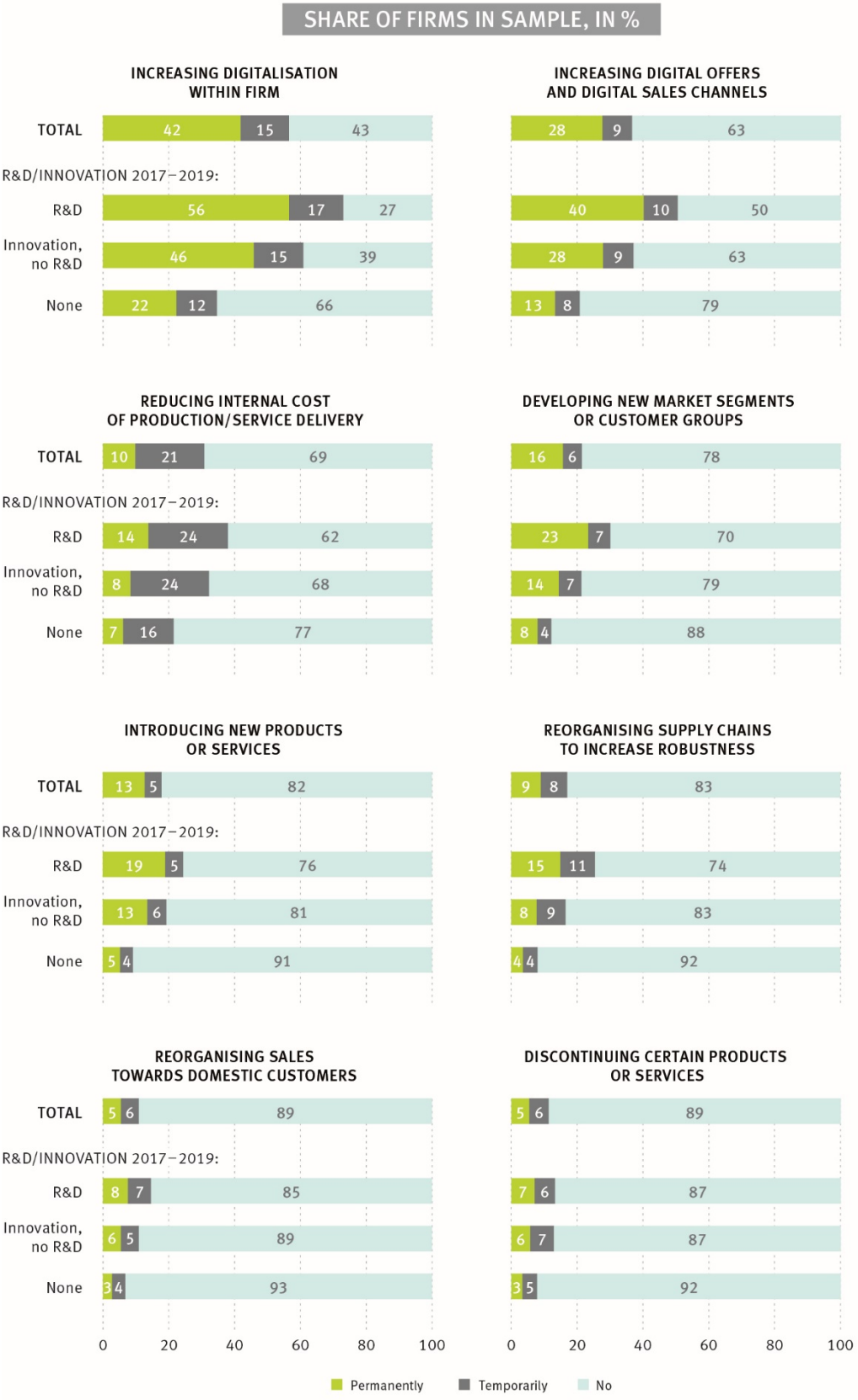
The fact that a much higher share of firms in all three groups of innovation status were affected negatively than positively largely mirrors the situation in SMEs, since the vast majority of firms in the sample fall into this category. Comparing this result with the findings presented above on large R&D performing firms suggests that SMEs were hit harder by the pandemic than large firms.

The strategic measures implemented by firms in 2020 to deal with the Covid-19 crisis differed depending on their pre-crisis innovation status. Firms active in R&D reacted the most often by implementing certain permanent or temporary measures. Firms with no innovation activities were least likely to react and firms conducting innovation activities other than R&D took the middle position (see Figure 8).

[4] Furthermore, when interpreting the results, it is important to recognise that the survey does not include a number of industries which were affected the most by lockdown measures. This applies to the retail trade, accommodation and restaurants, and personal and entertainment services.

Firms' main strategic response to the Covid-19 crisis was to enhance digitalisation (see Figure 8). This holds for both: i) the digitalisation of internal processes and ii) the extension of digital offers and digital sales channels. Compared to other types of strategic measures, these digitalisation strategies were predominantly implemented permanently. Reducing internal costs was another measure frequently undertaken to counter the crisis – the implementation of this measure, however, is intended to be more temporary. In addition, accessing new market segments, introducing new products or services as well as reorganising supply chains were frequent strategies – while the latter is equally likely to be a permanent or a temporary step, the two former measures are considered to be of permanent nature. Reorganising sales to focus more on domestic customers or abandoning products or services were rare responses to the crisis.

FIGURE 8: STRATEGIC RESPONSES TO THE COVID-19 CRISIS AMONG FIRMS IN GERMANY BY TYPE OF INNOVATION ACTIVITY IN THE PRE-CRISIS PERIOD



Non-weighted tabulation of firms that had participated in the 2021 survey of the Mannheim Innovation Panel by mid-April and in at least one of the three survey waves between 2018 and 2020. Number of observations: 3,912–3,919. Source: ZEW, Mannheim Innovation Panel.

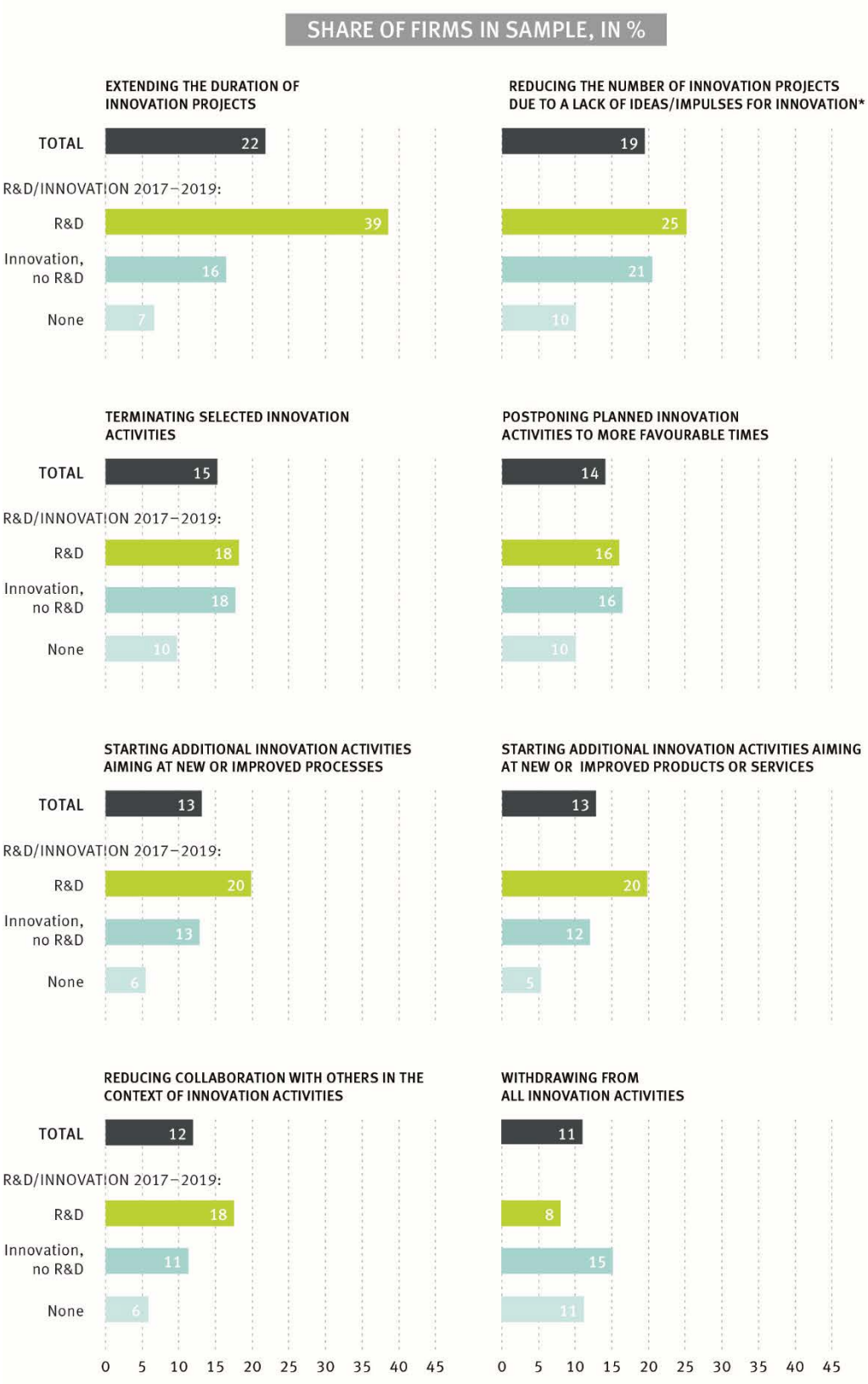
Similar to the observation regarding strategic measures, R&D performing firms also changed their innovation activities the most often in response to the Covid-19 crisis. Firms conducting innovation activities, but not R&D, were the second most often to do so, and firms active in neither the least often (see Figure 9).

The two most frequently reported internal changes introduced to counter the crisis were extending the duration of innovation projects and reducing the amount of innovation activities due to a lack of innovation ideas. In total, around 19%–22% of the observed sample made these changes, though this was predominantly driven by R&D performing firms. Stopping selected innovation activities as well as postponing innovation activities were measures undertaken by around 14%–15% of the observed sample and, thus, represent relatively frequent responses to the Covid-19 crisis.[5] These changes were just as likely to be introduced by firms with R&D as firms conducting innovation activities, but no R&D.

A significant share of firms (13%), particularly those active in either R&D or innovation, also embarked on additional innovation activities aimed at introducing new or improved products, services or processes. About 12% of the sample reduced their innovation collaboration and 11% withdrew from innovation activities altogether. Firms were thus slightly more likely to introduce new or improved products, services or processes, than to reduce collaboration and withdraw from innovation activities. However, R&D performing firms were most likely to start additional innovation activities, whereas withdrawing from innovation activities was a response most frequently given by innovating firms which did not perform R&D before the pandemic.

[5] Similarly, the survey on innovative German firms undertaken by BMWi in April 2020 finds that the two most frequent responses to the crisis were to extend the duration of R&D projects (75%) and to pause R&D projects (54%) (BMWi 2020).

FIGURE 9: CHANGES IN THE INNOVATION ACTIVITIES OF FIRMS IN GERMANY DUE TO THE COVID-19 CRISIS BY TYPE OF INNOVATION ACTIVITY IN THE PRE-CRISIS PERIOD



Non-weighted tabulation of firms that had participated in the 2021 survey of the Mannheim Innovation Panel by mid-April and in at least one of the three survey waves between 2018 and 2020. Number of observations: n=3,800 (*n=3,117). Source: ZEW, Mannheim Innovation Panel

7. Policy implications

The German innovation survey and the annual reports of large R&D performing German firms suggest that the Covid-19 pandemic did not adversely impact the aggregate innovation activities of the German business sector to a significant extent in 2020. The financial crisis in 2008 and 2009 resulted in an 11% decline in the aggregate innovation expenditure of firms in the German business sector. In 2020, in contrast, firms planned to reduce their innovation expenditures significantly less. Innovation expenditures planned for between March and July 2020 were just 2% lower than the actual aggregate innovation expenditures for 2019. These results from the innovation survey are supported by the annual reports of large R&D performing firms headquartered in Germany. The firms' joint yearly global R&D expenditures in 2020 only decreased by 0.5%.

These aggregate results are more positive than many studies initially expected and are mostly driven by three factors:

- Covid-19 created positive impulses for innovation in a number of industries, particularly pharmaceuticals and ICT services. These industries report increasing R&D and innovation expenditures in 2020.
- Adverse impacts from government measures to combat Covid-19 were less severe than expected after the first lockdown, as demonstrated by low levels of short-time work in October 2020 in most innovation-oriented industries. Consequently, many firms did not reduce their innovation activities as drastically as forecasted at the beginning of the pandemic.
- Large firms and R&D intensive firms were more resilient to the Covid-19 crisis than SMEs and less innovative firms. As the former are responsible for the majority of innovation expenditures in the German business sector, the overall impact of Covid-19 on spending levels seems to be moderate.

Qualitative data from the ongoing 2021 innovation survey on the firms' strategic response to Covid-19 and corresponding adaptations to their innovation activities suggest that firms with high innovation capacities tended to be more resilient to likely negative consequences. Many of these firms accelerated the digitalisation of internal processes and products, reached out to new markets and customer groups, and introduced new products and processes. All these activities are mostly of a permanent nature, i.e. they will strengthen the firms' competitiveness for the years to come. Short-term (temporary) reactions mainly relate to reducing internal costs, reorganising sales to focus on domestic customers, and discontinuing to offer certain products – though all these measures, apart from those related to digitalisation, have been implemented by a small share of, predominantly highly innovative, firms. Firms with no innovation activities at all were much less likely to react to the Covid-19 situation, also because a larger share of these firms were not strongly affected by the pandemic.

With respect to the innovation process, Covid-19 resulted in the reorganisation of innovation activities, particularly by extending the duration of ongoing projects, and starting fewer new projects due to a lack of ideas for new innovations. At the same time, new projects for product and process innovation were fed into the pipeline. All these responses are significantly more likely among highly innovative firms (i.e. firms that engaged in R&D before the pandemic) as compared to firms that innovated without engaging in R&D, and firms that were not innovating at all prior to the crisis. Only with respect to stopping ongoing innovation activities and shifting innovation to more favourable times we found no differences between firms with medium to low innovation capacities and R&D performing firms. Among R&D performers, almost all firms continued to invest in innovation. Only a very small share of firms withdrew from any innovation activity as a result of the Covid-19 measures.

For innovation policy, these results may increase confidence in a rapid recovery and a return to the growth path in R&D and innovation that has characterised the German innovation system since 2006. There are areas for caution, however:

- Innovation activities in SMEs, in industries with low innovation capacity as well as in firms with low innovation capabilities seem to have been hit harder by Covid-19 compared to large firms, R&D intensive firms and firms with R&D activities. This reveals a high innovation resilience in these firms, as the general consequences of Covid-19 tend to be stronger for innovation-active firms compared to non-innovation-active firms. As a consequence, it is likely that Covid-19 will increase the existing gap between a smaller number of innovative (R&D-active) firms and a larger number of firms that increasingly refrain from innovating.
- To combat this trend, which has characterised innovation in Germany for two decades now, policy would have to provide more incentives for firms with low innovation capabilities to upgrade these capabilities, particularly by engaging in R&D. The new R&D tax incentive may fulfil this function, although the entry cost for non-R&D performing firms to start R&D activities tends to be higher than the amount of subsidy provided by the tax incentive (see Spengel et al. 2017). At least equally important is a general policy framework conducive for innovation, including improving the supply of highly qualified personnel as well as financing investment in modernisation and adopting new technologies, particularly with respect to digitalisation.
- Facilitating access to existing R&D support measures is viewed by many firms as a priority for maintaining high levels of R&D activity. In a survey by the Federation of German Industries (Wehmeyer 2020), the measures most frequently mentioned by R&D-active firms included better funding conditions in R&D programmes, increasing the flexibility of the programmes and reducing the administrative burden of using the programmes. Another survey on innovative German firms (BMWi 2020) finds that almost 90% of participating firms call for more rapid and less bureaucratic application procedures for receiving R&D subsidies.

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