PART I

CHAPTER 1

COVID-19, RECOVERY AND RESILIENCE

COVID-19, RECOVERY AND RESILIENCE

KEY FIGURES

-3.1 % EU business R&D between 2019 and 2020	**+16 %** EU scientific publications in health over 2019 to 2020	**86 %** of EU citizens think that the influence of science and technology is positive

KEY QUESTIONS WE ARE ADDRESSING

- How did COVID-19 impact R&I activities, science and scientists in Europe?
- What role did R&I play in the COVID-19 crisis?
- What is the way forward for R&I policy?

KEY MESSAGES

What do we learn?

- Overall R&D investment in the EU declined during the COVID-19 crisis, with significant differences between sectors. R&D investments increased in health and ICT while sectors like automotive recorded drops.
- The COVID-19 pandemic led to a surge in R&I output in the health sector as measured by scientific publications. It has also demonstrated the importance of data and digital technologies to support policy action to address the health risks.
- Measures to contain the pandemic have generated an important change in the way firms operate, acting as a catalyst for the digital transition.
- The pandemic demonstrated the key role of science, yet female and young researchers have been negatively affected by the pandemic.

What does it mean for policy?

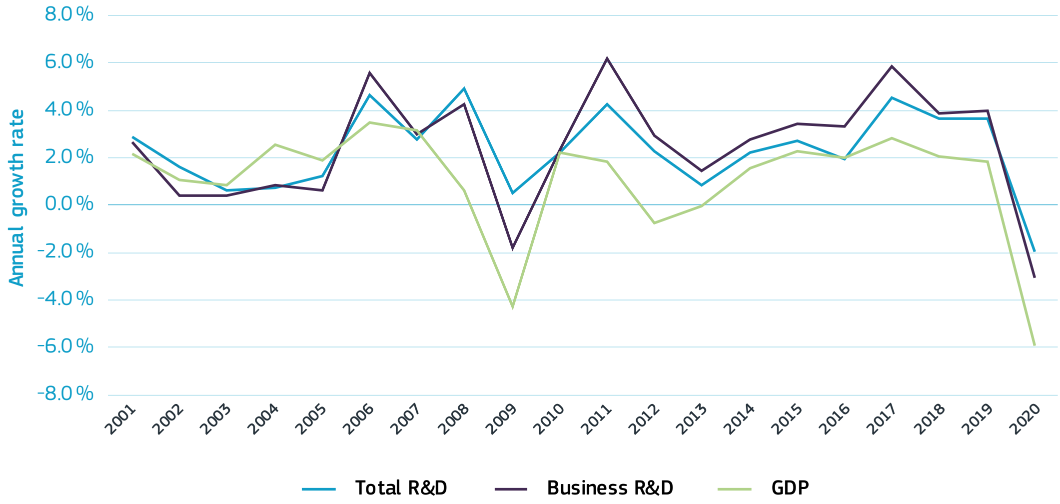
- The pandemic has provided us with the opportunity to 'build forward better' and aim for a more sustainable, more digital and in particular a more resilient Europe.
- In a post-pandemic world, well-directed research and innovation have the potential to ease the social and territorial divides, and achieve a cohesive and inclusive innovation-driven growth of countries, regions and companies.
- R&I is dependent on a experimentation-driven and socially-connected educational and research system.

The COVID-19 crisis is unprecedented. It has disrupted our lives, economy and society and the world has been struggling to contain the pandemic. While research and innovation (R&I) have been at the core of the response to the pandemic itself in the areas of virology, vaccines development, treatments and diagnostics, it is also crucial in the economic recovery from the crisis. R&I is not only essential to spur economic activity, but also to accelerate the transitions that our planet and society need – a new economy for health, wellbeing and equality in a broad sense. R&I also helps in building system-wide resilience. Technologies already help alleviate, at least partially, the severity of the economic shock, with digital technologies being at the core of business continuity in several sectors. Overall, R&I has played a role of paramount importance in fighting the pandemic, and it will also be vital in the longer term and in the aftermath of the crisis as a key driver of the recovery.

1. How COVID-19 has impacted R&D efforts in Europe

Research and development activities tend to be pro-cyclical (Barlevy, G. 2007, Fatas, A. 2000, Rafferty, M. C. 2003, Comin, D., & Gertler, M. 2006). This means that R&D moves in tandem with economic growth: R&D declines during recessions and increases during economic booms. During recessions, different factors may cause R&D investors to face reduced incentives to invest in innovation creation and adoption. For instance, in sectors with a faster obsolescence rate of knowledge or with more difficulties in protecting intellectual property (e.g. higher positive externalities), expected declines in demand may lead to the postponement of innovative activities (Fabrizio and Tsolmon, 2014). Similarly, R&D spillovers and the quasi-public nature of knowledge may lead investors to weigh more short-term profits than long term profits (Barlevy, 2007; Sedgley et al., 2019). The aggregate pattern may also be explained by micro dynamics, most notably when firms face credit constraints that have severe implications for investment decisions, especially in risky innovative projects (Aghion et al., 2012) or for start-ups that rely heavily on external sources of capital (Howell et al., 2020). Empirical evidence supports the cyclicality between R&D and output, and further develops on the link between the slow-down of R&D spending and its implications for innovation diffusion, its adoption and long-run growth (Anzoategui et al., 2019).

Figure 1-1: Annual growth rate of EU GDP, Total R&D expenditure and business R&D expenditure (in constant prices), 2001-2020



Science, research and innovation performance of the EU 2022

Source: Source: Eurostat (online data code: rd_e_gerdtot and nama_10_gdp)

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EU R&D investment declined during the COVID-19 crisis (see Figure 1-1), with a decrease of 1.9% in constant prices[1]. This decrease is largely driven by the decline of private R&D (3.1% in constant prices[2]). The COVID-19 pandemic has impacted quite significantly business dynamism. Employment and firm entry have dropped from 2019 to 2020 (see Figure 1-2) and not yet fully recovered to the 2019 levels by mid-2021[3]. The ECB also reported an initial surge in demand for credit from enterprises in 2020 in the euro area, reflecting emergency liquidity needs (ECB, 2020). But overall, the number of business bankruptcies has decreased after the outbreak of the COVID-19 pandemic, most likely as the result of the massive policy support issued by national governments and through the EU programmes. It appears that small R&D investing firms in the EU have suffered on average more than big R&D investing firms during the pandemic (Grassano et al., 2021).

The impact of the crisis on R&D was significantly different among sectors. When considering the top 2500 R&D investing companies worldwide, some sectors positively affected by the crisis have increased their R&D investments, namely Health (9.5%), ICT Services (9.9%) and ICT Producers (6.1%). However, most other sectors experienced R&D investment reductions, in particular Aerospace & Defence (-19.8%) and Automobiles (-6.1%). The latter are however still the strongest R&D investors in the EU, thus

1 Growth rate in current prices is -0.4%.

2 Growth rate in current prices is -1.5%.

3 Eurostat.

Figure 1-2 a): COVID-19 impact on employment and business registrations

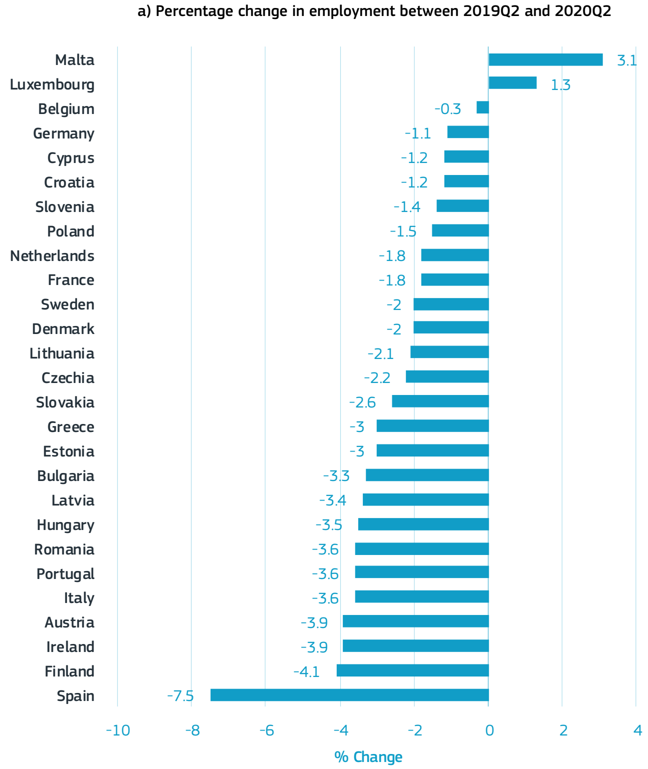
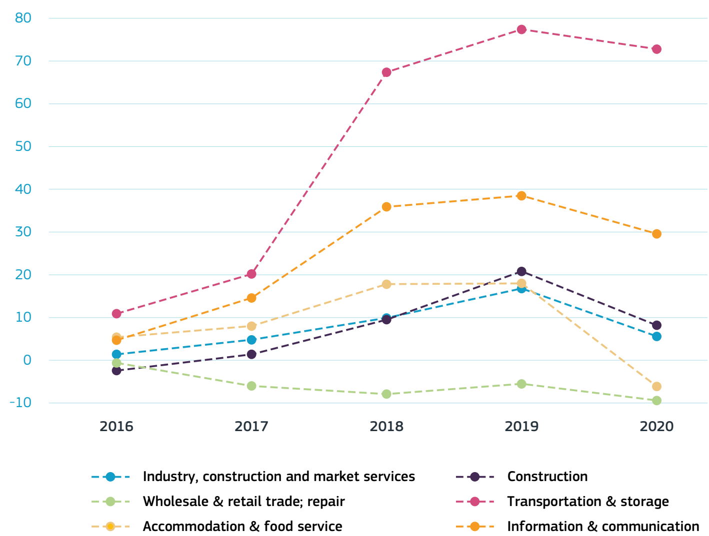


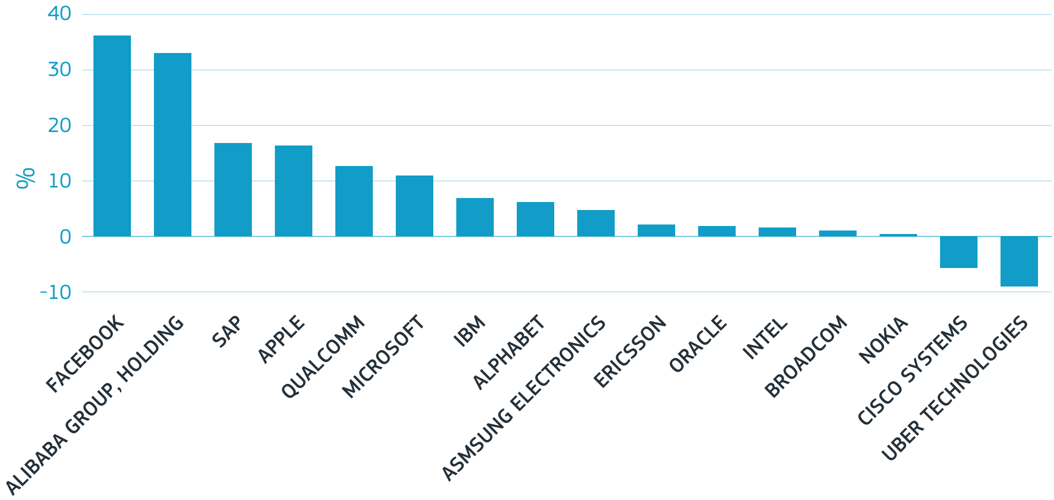
Figure 1-2 b): Business registrations in EU per industry sectors (percentage change - index 2015=100)



Source: DG Research and Innovation - Common R&I Strategy and Foresight Service - Chief Economist Unit based on Eurostat (online data code: sts_rb_a and namq_10_a10_e)

Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-2.xlsx

Figure 1-3: Growth in R&D spending for the software, computer services and electronic equipment sector (% change from 2019 to 2020)

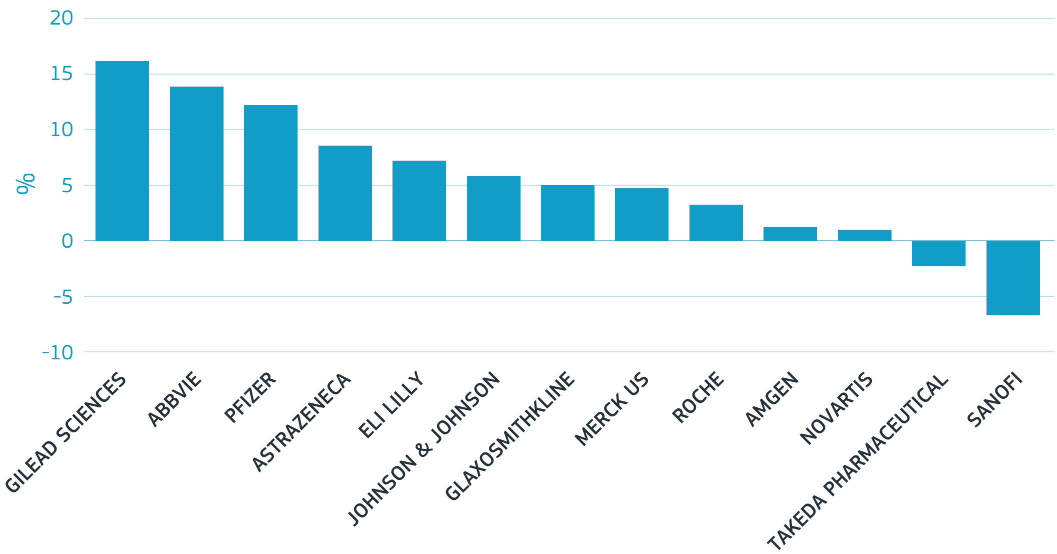


Science, research and innovation performance of the EU 2022

Source: OECD Main Science and Technology Indicators Highlights on R&D expenditure, March 2021 release (Link).

Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-3.xlsx

Figure 1-4: Growth in R&D spending for the pharmaceuticals and biotechnology sector (% change from 2019 to 2020)

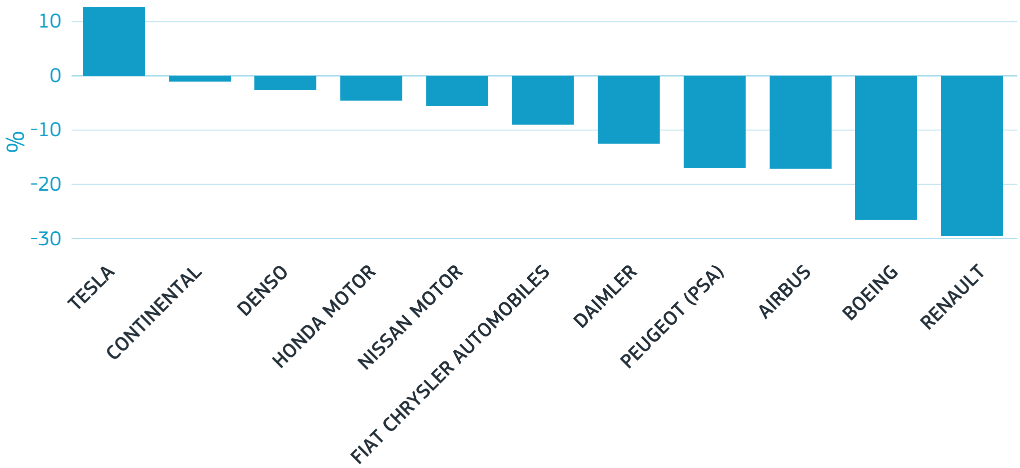


Science, research and innovation performance of the EU 2022

Source: OECD Main Science and Technology Indicators Highlights on R&D expenditure, March 2021 release. (Link).

Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-4.xlsxx

Figure 1-5: Growth in R&D spending for the automotive, aerospace and defence sector (% change from 2019 to 2020)



Science, research and innovation performance of the EU 2022

Source: OECD Main Science and Technology Indicators Highlights on R&D expenditure, March 2021 release. (Link).

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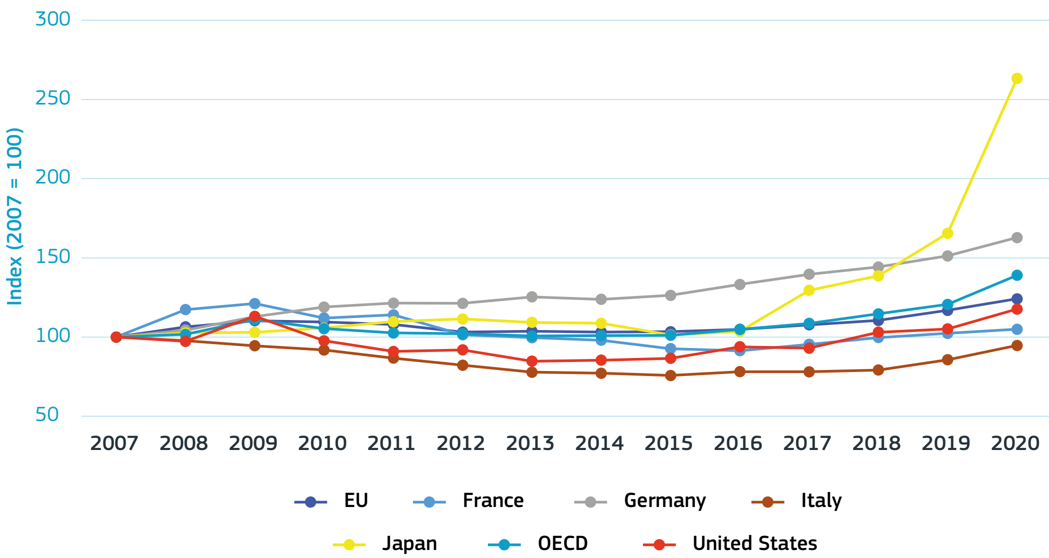
Figure 1-6: Total Government Budget Allocation to R&D at constant prices and PPP $, 2007-2020



Science, research and innovation performance of the EU 2022

Source: OECD Main Science and Technology Indicators (MSTI) database. (Link).

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causing an overall R&D decline, while also in the EU ICT and Health companies increased, albeit having a lower share in the total (JRC, 2021).)

Public R&D spending increased in 2020 by 6.2 % in real terms in the EU (15.2 % across OECD countries, Figure 1-6). This figure represents a relevant increase compared to 2019, when public R&D budgets went up by around 3 %. This may be the result of a combination of planned boost to R&D funding plans before the pandemic and additional emergency support for health-related R&D to develop vaccines and treatments in response to the COVID-19 pandemic.

The comparative resilience of industrial R&D investments – also in sectors witnessing a reduction in 2020 – shows their strategic importance (JRC, 2021). This underlines the need for policies effectively mobilising and accelerating the growth of private R&D spending. To support a strong and resilient recovery, policy interventions should boost technology diffusion, provide the right conditions and incentives for start-ups, and ensure business-friendly framework conditions to enable experimentation and promote an efficient allocation of resources (OECD, 2021a).

During the crisis, the European Innovation Council (EIC) introduced a combination of support in the form of grants, investments and business acceleration services, particularly to the benefit of start-ups and SMEs. Besides, the EIC has introduced greater flexibility in its operations to accommodate the needs of their beneficiaries and changing market conditions. Specific services were also proposed to foster resilience, for example tailor-made advice on reducing greenhouse gas emissions and a women leadership programme. The **Marie Skłodowska-Curie Actions (MSCA)** programme used a similar approach. MSCA introduced measures to support researchers and organisations in implementing their projects and allowed modifications to research activities, including more flexible approaches regarding budget and working conditions.

The European Institute of Innovation and Technology (EIT) also mobilised its multi-disciplinary innovation communities and launched specific targeted initiatives to support innovators powering high impact solutions to tackle the COVID-19 pandemic in the fields of health, climate change, digitisation, food, energy, urban mobility, manufacturing and raw materials. The EIT investment supported new innovation projects as well as highly innovative start-ups, scale-ups and SMEs crucial to the European's economy's fast recovery.

2. A surge in health R&I

The COVID-19 pandemic has demonstrated the crucial importance of R&I and policy cooperation to rapidly deliver solutions. (OECD, 2021a; Borunsky, Correia, Martino et al., 2020; Paunov, C. and Planes-Satorra, 2021). As the crisis hit so suddenly and so severely, coordination at EU level has been challenging. However, R&I actions have been an essential part of the coordinated EU response to the public health threat (European Commission, 2021a). These actions focused on funding and financing R&I in virology, vaccine development, treatments, translating research findings into public health policy, and citizen outreach and communication. Horizon 2020 has played a central role in mobilising funds on COVID-19-related R&I projects. It has shown that the EU can be agile in mobilising its tools. The ERAvsCorona Action Plan also set out key measures at an early stage that the Commission services and the Member States have been activating to coordinate, share and

Box 1-1 Manifesto for EU COVID-19 Research

The Manifesto for EU COVID-19 Research is a policy statement providing guiding principles for beneficiaries of EU funded research grants to ensure that their results are made available in a timely and affordable manner to guarantee the highest potential impact in the fight against COVID-19. It is an integral part of the EU Research and Innovation contribution to the common European response to the coronavirus outbreak.

The set of guiding principles anchored in the Manifesto are:

- Make the generated results, whether tangible or intangible, **public and accessible** without delay, for instance on the Horizon Results Platform, on an existing IP sharing platform, or through an existing patent pool.
- Make scientific papers and research data available in **open access** without delay and following the FAIR principles via preprint servers or public repositories, with rights for others to build upon the publications and data and with access to the tools needed for their validation. In particular, make COVID-19 research data available through the European COVID-19 Data Platform.
- Where possible, grant for a limited time, **non-exclusive royalty free licences** on the intellectual property resulting from EU-funded research. These non-exclusive royalty free licenses shall be given in exchange for the licensees' commitment to rapidly and broadly distribute the resulting products and services under fair and reasonable conditions to prevent, diagnose, treat and contain COVID-19.

So far, more than 650 organisations (including universities, research institutes and private companies) and more than 1 875 individuals endorsed the Manifesto from all over Europe and beyond. The Manifesto also generated a high level of engagement from SMEs (more than 180 SMEs endorsements). International organisations such as the World Health Organization and the Medicines Patent Pool have endorsed it as well. This shows a clear commitment and strong engagement towards a better valorisation of research results, leaving no one behind.

The Commission has extended the Manifesto by one year, until 1 January 2023, aiming to allow Manifesto endorsers to maintain their initiatives under the current Manifesto principles and to offer the possibility for others to still endorse it and engage in concrete actions to facilitate the sharing and access to IP in response to the COVID-19 pandemic.

jointly increase support for R&I. At the EU level, the European COVID-19 research data platform has aimed at speeding up and improving the sharing, storage, processing of and access to research data and metadata on COVID-19. The European Commission also launched in September 2021 the European Health Emergency preparedness and Response Authority (HERA) to prevent, detect, and rapidly respond to health emergencies. The Manifesto for EU COVID-19 Research was also launched in 2020 to maximise the accessibility of research results in the fight against COVID-19 (Box 1-1).

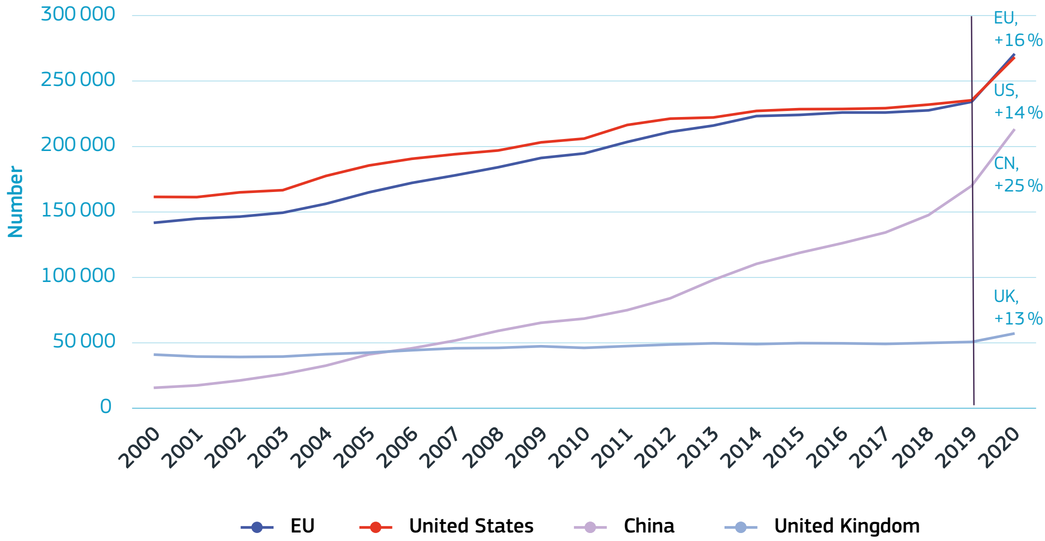
The European Commission has a long tradition of supporting research into infectious diseases and epidemics. Between 2007 and 2019, EUR 4.1 billion[4] was invested in research into infectious diseases through the 7th Framework Programme and Horizon 2020. For example, investments in vaccine research and innovation that preceded the current pandemic enabled the development of the mRNA vaccine technology, recognised as a major breakthrough in the COVID-19 pandemic.

Mugabushaka (2021) identifies almost 3 000 publications related to COVID-19 and relevant previous coronavirus research[5] funded by the EU's R&I Framework Programme, including 1 277 in 2020 (Figure 1-7). Marie Skłodowska-Curie Actions (MSCA), the European Research Council (ERC) and the Health Programme account for about 80 % of them. These cover a diverse range of research fields and over half are internationally co-authored. One-third of the publications entirely rely on EU funding. The key outcomes of this EU-funded research include among others: the development of the first diagnostic tool, published almost immediately after the release of the Sars-cov2 virus genome; discoveries of SARS-CoV-2 neutralising antibodies; the first results of clinical trials testing the efficacy of drugs used to treat rheumatoid arthritis in COVID-19 patients; and the findings of epidemiological studies which have been used, among others, in WHO clinical guidelines and other guidance documents.

4 Source: https://ec.europa.eu/info/research-and-innovation/research-area/health-research-and-innovation/coronavirus-research-and-innovation_en

5 Based on the COVID-19 database.

Figure 1-7: Evolution of scientific publications in health(1), 2000-2020



Science, research and innovation performance of the EU 2022

Source: DG Research and Innovation - Common R&I Strategy and Foresight Service - Chief Economist Unit based on Science-Metrix using Scopus database.

Note: (1)Fractional count of publications in the area of health, demographic change and wellbeing

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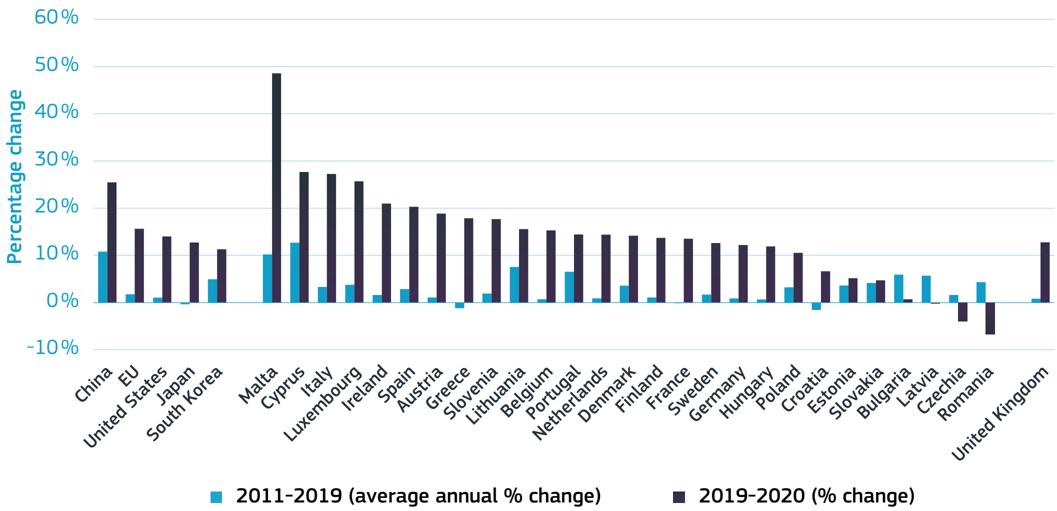
Beyond the EU R&I Framework Programme, the COVID-19 pandemic was, as expected, responsible for a surge in scientific output in health in the EU landscape in 2020 (Figures 1-7 and 1-8). The EU and US, already in the lead before the crisis, experienced an increase of respectively 16% and 14% in publications in health between 2019 and 2020, which is drastically higher than their pre-COVID growth rates (2% for the EU and 1% for the US over 2011-2019). China's scientific output in health presents a rapid evolution over the last decade (11% annual increase over 2011-2019), but also an impressive increase of 25% between 2019 and 2020 due to the pandemic. Publications in the UK, also an important scientific producer on the global stage (4% of publications worldwide), increased by 14% in 2020 (compared to a 0.8% average annual change over 2011-2019). Within Member States, most countries experienced a major increase in their publications in health, with the exception of Latvia, Czechia and Romania.

These increases at the onset of the pandemic were driven by publications in basic medicine, clinical medicine and health sciences (see Table 1-1). While the number of publications in basic medicine and health sciences was multiplied by 3 in the EU, US and China, the most significant increases can be found in publications in clinical medicine, which increased by more than 400% in the EU and US, and by more than 600% in China. At the same time, other areas in medical science showed a decrease in scientific output in 2020. This holds in particular for medical biotechnology – which accounts for more than 70% of publications worldwide in medical and health science (75% in the EU).

Figure 1-8: Impact of Covid-19 on scientific publications in health[1]



Science, research and innovation performance of the EU 2022

Source: DG Research and Innovation - Common R&I Strategy and Foresight Service - Chief Economist Unit based on Science-Metrix using Scopus database.

Note: [1]Fractional count of publications in the area of health, demographic change and wellbeing

Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-8.xlsx

Figure 1-9: Scientific publication in health-related topics[1]

		2011-2019 (average annual % change)	2019-2020 (% change)
Basic medicine	EU	2%	203%
	United States	0%	168%
	China	9%	208%
Clinical medicine	EU	2%	437%
	United States	1%	448%
	China	14%	620%
Health sciences	EU	5%	181%
	United States	2%	178%
	China	11%	233%
Medical biotechnology	EU	1%	-7%
	United States	1%	-6%
	China	9%	-2%
Other medical sciences	EU	2%	-22%
	United States	0%	-1%
	China	7%	-13%

Science, research and innovation performance of the EU 2022

Source: DG Research and Innovation - Common R&I Strategy and Foresight Service - Chief Economist Unit based on Science-Metrix using Scopus database.

Note: [1]Fractional count of publications by Frascati fields

Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-9.xlsx

Innovation by the corporate sector also rapidly increased in response to the pandemic. Hundreds of clinical trials targeting COVID-19 drugs and vaccines were launched by the biopharmaceutical industry to address the health emergency. **Emerging technologies**, in particular, engineering biology and robotics, have shown potential in keeping health systems afloat, thereby contributing to enhance social and economic resilience. For example, biofoundries can improve the reliability and reproducibility of bio-manufacturing, with mRNA vaccines being amenable to this approach (OECD, 2020c). Also, because of the lack of time and resources available, especially at the beginning of the crisis, there was a surge of frugal innovations. Harris et al. (2020) identify three frugal innovation approaches in responding to the COVID-19 threat: repurposing, reuse and rapid deployment. This includes for example the repurposing and reuse of existing materials for the rapid production of ventilator machines by Mercedes and Tesla.

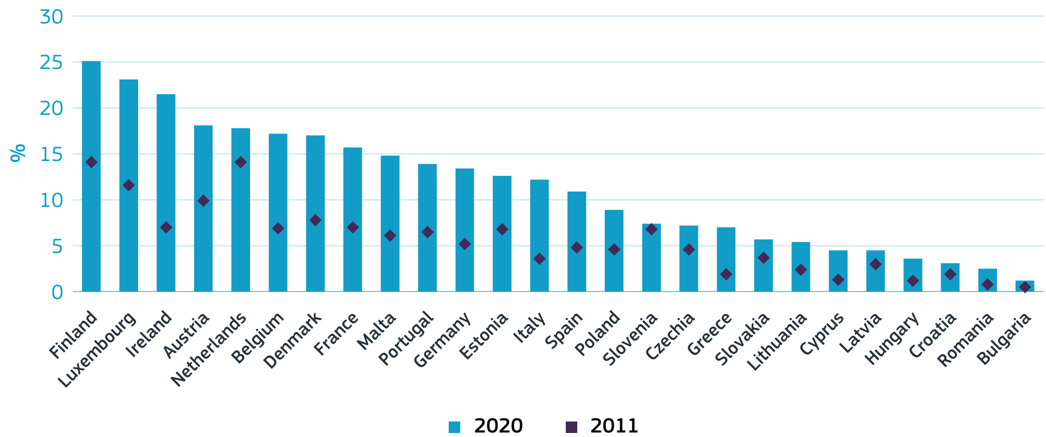
The COVID-19 pandemic demonstrated the importance of data and digital technologies to support the health sector. The resilience of the health service delivery system has relied on epidemiological surveillance, using data and artificial intelligence, openly accessible, machine-readable, interoperable data, together with telemedicine and mobile health applications (Negreiro Achiaga, 2021; Borunsky et al, 2020). **AI-related applications** have been effectively applied to detect visual signs of COVID-19 on images from lung CT scans, monitor changes in body temperature in real time, provide an open-source data platform to track and monitor the spread of the disease through population screening, and help identify potential treatments and cures. **Additive manufacturing** (commonly known as 3D printing) has been mobilised to address the shortages of personal protection equipment and ventilators (Borunsky et al., 2020). The logistical challenges and consequent supply chain disruptions due to restricted movements and the rise of infections called for the mobilisation of versatile technologies that could be rapidly deployed in response to emergencies (Longhitano et al., 2021).

3. COVID-19 as a catalyst for the digital transition

The COVID-19 pandemic triggered a massive change in the way firms operate. While teleworking[6] was already a widespread practice in several sectors before the onset of the COVID-19 pandemic (He et al, 2020), it has significantly accelerated with the outbreak. The lockdown measures to combat the spread of the virus have led to a change in work practices, with employees' homes becoming a forced extension of the traditional workplace (Contreras et al, 2020). Nevertheless, the measures adopted to contain the spread of the virus determined an acceleration in the digitalisation of the economy and the society as a whole (Peleaz et al. 2020).

The percentage of employed persons usually working from home increased from 5.4% in 2019 to 12% in 2020[7]. Similarly, the share of self-employed workers usually working from home also experienced an increase over the same period, from 19.4% in 2019 to 21.9% in 2020. There are however pronounced differences across Member States. Finland (25.1%), Luxembourg (23.1%) and Ireland (21.5%) report the highest share of people working from home in 2020, while in Romania and Bulgaria this share is less than 1% (Figure 1-9). According to a survey conducted between April and May 2020, when most of EU Member States were facing the first lockdown, about 36% of EU

Figure 1-10: Share of employed persons usually working from home 2019 vs 2020, per EU Member State[(1)]



Source: Eurostat (online data code: lfsa_ehom)
Note: [(1)]2020 data not available for Sweden
Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-10.xlsx

6 According to the Eurofound definition, 'teleworking refers to a form of organising and/or performing work, using information technology, in the context of an employment contract/relationship, where work, which could also be performed at the employer's premises, is carried out away from those premises, on a regular basis, as defined in the European framework agreement on telework. The characteristic feature of telework is the use of computers and telecommunications to change the usual location of work'.

7 Eurostat.

employees started to work remotely as a direct result of the pandemic (Eurofound, 2020a). Nevertheless, the COVID-19 overall led to a deterioration of the labour market conditions in EU. Employment declined in all Member States as a result of the pandemic. At sectoral level, an opposite trend was observed only in sectors such as insurance, computer programming and telecommunications, characterised by jobs easily carried out from home and requiring low social interactions (European Commission, 2021b).

According to the 2020 Digital Economy and Society Index (DESI), EU enterprises are becoming more digitalised. The share of enterprises using big data[8] has risen in comparison to the results of DESI 2018 (from 10% to 12%)[9]. Big data usage has been particularly useful after the outbreak of the virus as a key tool to manage servers, as well as to store and process large amounts of user- and machine-generated information. E-commerce has also played a relevant role in allowing business to continue during the lockdowns. In 2020, the share of enterprises having received orders online was 18%, and e-commerce turnover increased from 18% to 20% between 2019 and 2020[10].

However, the digitalisation process comes with its own challenges. Innovation and digitalisation proved to be firms' best weapons against the challenges posed by the pandemic, allowing companies to ensure business continuity during the period of lockdowns.

Furthermore, teleworkers appear to be satisfied with remote working when they are provided with the necessary IT equipment to carry out their job activities, do not have to do significantly overtime, and when remote working does not interfere with their family time (European Commission, 2021b). Nevertheless, the structural changes since the beginning of the COVID-19 crisis determined a radical transformation of inter-personal relationships, with significant social consequences (Pelaez et al., 2021). As noted by Contreras et al. (2020), COVID-19 has significantly affected the organisation of work. The massive shift to exclusively remote working and/or hybrid formats as a result of the lockdown measures have come along with social and professional exclusion, tension and anxiety (Contreras et al., 2020; Eurofound, 2020a). An online survey carried out by Eurofound[11] reports a reduction in life satisfaction and happiness during the first period of lockdowns. In April 2020, the average life satisfaction score was 6.3 on a scale of 1 to 10, showing a decrease compared to the score given in 2016 (7.0)[12]. Similarly, average happiness also experienced a reduction, decreasing from 7.4 in 2016 to 6.4 in April 2020. Mandatory teleworking is reported as one of the key determinants of this trend. The massive increase of exclusive home working has blurred work-life boundaries, negatively impacting several job quality indicators as a result of the increased sense of isolation, and emotional and physical draining (Eurofound, 2020b).

8 Big data refers to the large, diverse sets of information that grow at ever-increasing rates, and are too complex to be dealt with traditional data processing methods. Big data may be analysed computationally to reveal patterns, trends, and associations, especially relating to human behaviour and interactions.

9 DESI 2020, European Commission

10 Digital economy and society (Eurostat).

11 Eurofund (2020b).

12 European Quality of Life Survey (EQLS), 2016.

Although the phasing out from COVID-19 measures has brought people back to traditional work premises, **teleworking keeps remaining an important part of work life**. This is particularly the case of big cities, where the share of remote job posting has significantly increased since the onset of the pandemic (Kleine-Rueschkamp and Adrjan, 2021). This trend suggests that hybrid work is likely to become the consolidated practice in the post-pandemic phase, especially in those sectors better predisposed to teleworking activities.

4. Impact of COVID-19 on the scientific community

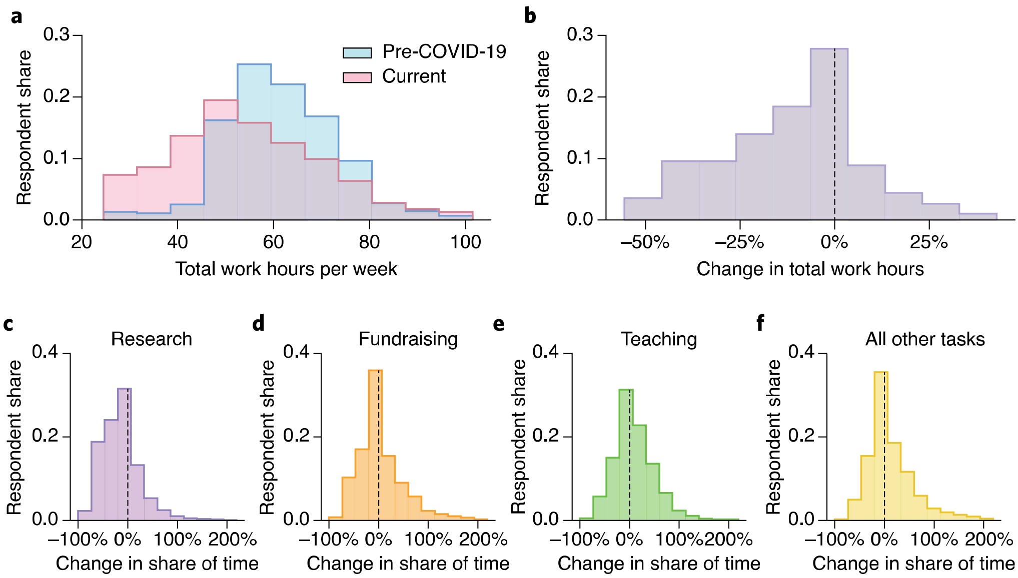
4.1 How researchers coped with the pandemic

The scientific community populating our universities and research centres has also been affected by the pandemic (Sachini et al. 2021). Indeed, while COVID-19 related research was running at unprecedented speed, most of non-COVID-19 related health research (including cancer research) was scaled down. The limitations to international travel, together with lockdowns, closures and social distancing implied that most of research experiments and fieldwork had to be stopped, postponed or cancelled (Ledford, 2020, Servick et al. 2020). Labs closed and job openings were cancelled (Woolston, 2020a and 2020b).

COVID-19 significantly increased the mental strain of researchers. The pandemic broadly impacted on researchers' mental strain, research time, paper submission rate and way of doing research. Yet such impacts interacted with our societal and academic structures, resulting in widening pre-existing inequalities and inflating associated costs. In this context, female researchers and young scholars paid a heavier price (Woolston, 2020c; Viglione, 2020; Gibson et al. 2020; Gewin, 2020; Deryugina et al., 2021; Vincent-Lamarre, 2020; Squazzoni et al 2021). According to a survey among researchers in Greece, 53.3% of the respondents reported that they were experiencing a high to very high level of personal psychological strain due to the lockdown and social distancing measures. Additionally, 53.7% of the researchers said the lockdown had taken a toll on their family environment, adding a further burden. Below 8% of researchers stated that they experienced no personal or family mental strain (Sachini et al., 2021). The study also found that female researchers experienced a substantially higher level of personal as well as family mental strain than male researchers did.

The COVID-19 pandemic negatively impacted researchers' productivity and working hours. Fields of research with physical labs and women researchers with children were the most affected. Myers et al. (2020) surveyed 4535 faculties from American and European universities to uncover the impact of the COVID-19 pandemic on researchers' productivity. The study finds an overall decline in total working hours, with the average dropping from 61 hours per week pre-pandemic to 54 hours in the first months of the pandemic (Figure 1-10). Furthermore, the impact was distributed unevenly across research fields, with the areas of research that rely on physical laboratories and time-sensitive experiments (biochemistry, biological sciences, chemistry, and chemical engineering) facing the largest declines in research time. Fields that are less equipment-intensive (mathematics, statistics, computer science and economics) showed the lowest declines in research time. Finally, women researchers, particularly those with young children, experienced the highest decline in time devoted to research, with possibly adverse effects on their careers in the long-term. Figure 1-8 shows how the impact of COVID-19 on research time has been drastically different across research fields, reaching a negative percentage change of around 40% for biochemistry, biology, engendering and other lab-based sciences, while more

Figure 1-11: Changes in levels and allocations of work time



Science, research and innovation performance of the EU 2022

Source: Myers, K. R., et al. (2020)
Notes: a, Distribution of total hours spent on work pre-pandemic and at the time of the survey. b, Distribution of changes in total work hours from pre-pandemic to time of survey. c–f, Distribution of percent changes in the share of work time allocated to research (c), fundraising (d), teaching (e) and all other tasks (f).
Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-11.xlsx

limited impacts of around 10% are found in mathematics, computer science, economics, and other non-lab-based subjects of research. Deryugina, T. et al. (2021) employed a global survey to a broad range of academics across various disciplines (19905 respondents) together with a difference-in-differences approach to estimate the effects of COVID-19 disruptions on the gender gap in academia. The findings show that female academics, particularly those who have children, report a disproportionate reduction in time dedicated to research relative to what comparable men and women without children experienced, clearly identifying how housework and childcare still burden on women (Figure 1-12).

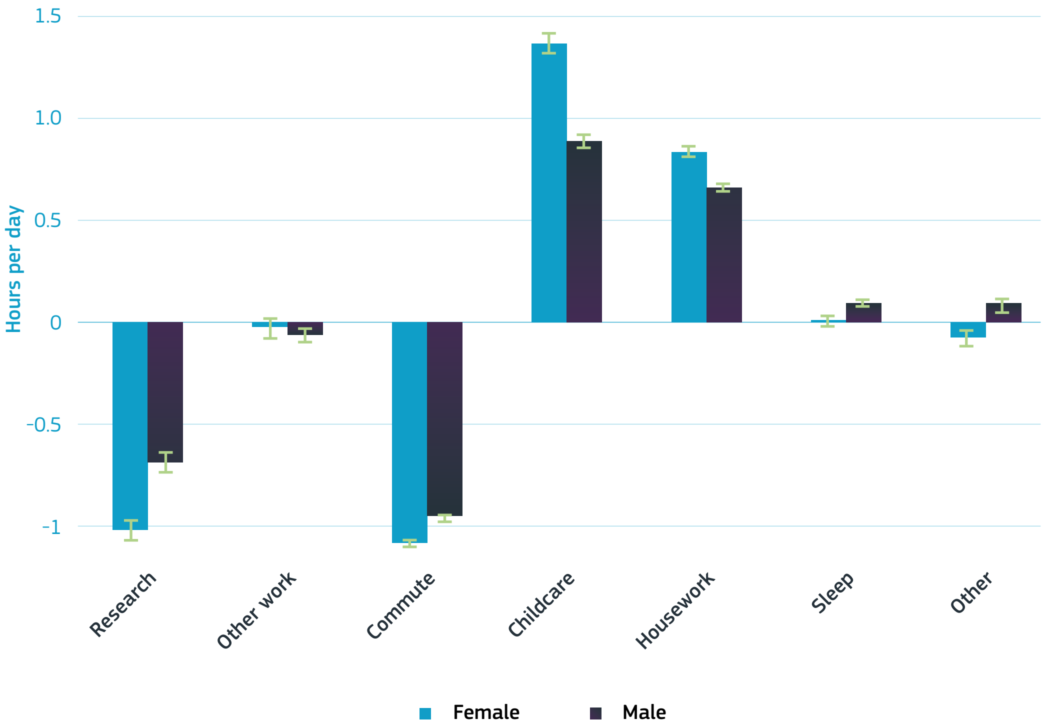
Figure 1-12: Field and group-level changes in research time

Source: Myers, K. R., et al. (2020)

Notes: a, Field-level average changes in research time. b, Group-level average changes in research time. c, Changes in research time associated with important features of scientists or their fields, after controlling for other factors. To untangle different factors, the authors use a Lasso regression approach to select features that are most predictive of declines in research time. Error bars indicate 95% confidence intervals.

Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-12.xlsx

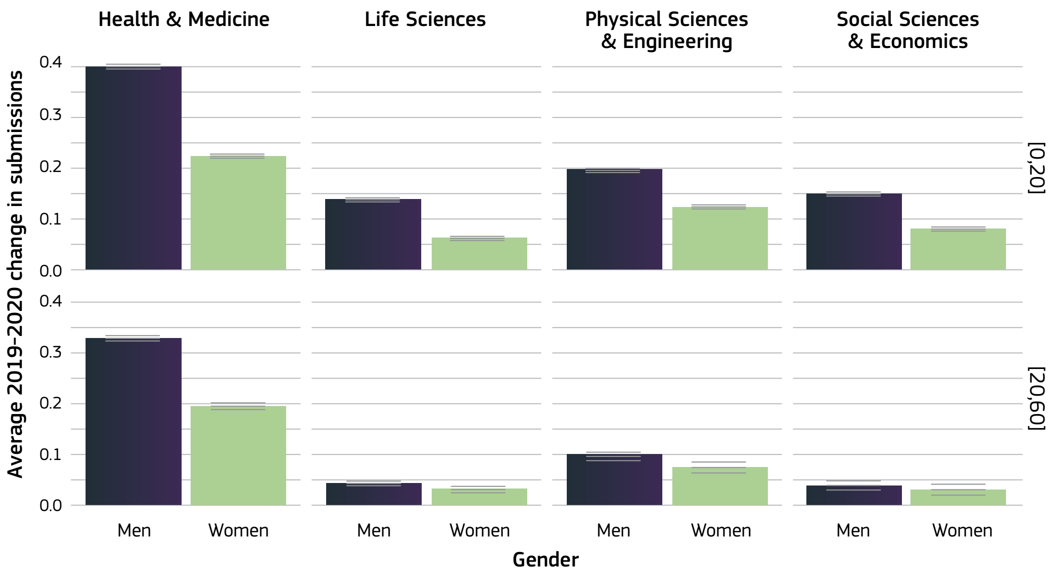
Figure 1-13: Changes due to COVID-19 disruptions in the number of hours spent on each activity by gender



Source: Deryugina, T. et al. (2021)
Notes: Error bars represent 95% confidence intervals using robust standard errors.
Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-13.xlsx

Despite the reduction in research time during the pandemic, the submission rate of research papers increased. During the first months of the pandemic there has been an unusual high submission rate of academic articles, likely due to the sense of urgency and novelty of topics (Kambhampati et al. 2020, Else, 2020). However, the heterogeneous effect of the pandemic on research time and mental strain across gender spilled over to paper submissions and publications (cf. Squazzoni et al., 2021). Similarly, women researchers contributed less to COVID-19-related research and made less pre-print articles during the pandemic, compared to their male peers (Vincent-Lamarre, 2020). Figure 1-13 shows how the increase in research paper submissions during the pandemic has been sharply unequal among gender and research subjects.

Figure 1-14: Changes in submissions



Source: Squazzoni, F et al. (2021).

Note: The graph depicts the average change in submissions by research area and age, the latter variable including authors in the first cohort (less than 20 years from their first publication) in the first group with older authors in the second. Bars represent standard errors.

Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-14.xlsx

Young scholars have been disproportionally affected by the pandemic. Compared to senior staff, PhDs and Postdoc researchers could to a lesser extent rely on past co-authors and research groups to continue their research activities during the pandemic. Fry et al. (2020) showed how during the pandemic senior researchers preferred to cooperate with known colleagues, reducing collaborations with colleagues outside their network. Nature's worldwide survey, interviewing 7670 postdocs working in academia, depicts a gloomy picture (Woolston, 2020b). About 61% of the respondents report that the pandemic has negatively affected their career prospect, 13% were sure to have lost a job offer due to the pandemic, 80% had troubles performing experiments and 60% had troubles discussing research ideas with their peers.

Many universities have frozen hiring, pushing many young researchers to wait one year or look for alternatives outside academia. This was more pronounced in the US and UK, as higher education systems in the EU have more stable income streams from public funding (Woolston, 2020a).

Scientific production increased during the COVID-19 pandemic, carrying a risk of compromising quality. As noted earlier, a sense of urgency fostered the scientific community to work, and fast, on COVID-19 related topics. Academic journals speeded up their peer-review process and researchers more quickly put working paper versions of their work online. Some evidence also suggests an increase in dubious and retracted research, and an occasional lowering of normal scientific standards as a price that is paid for rushed research (Pai, M. 2020, Else, H. 2020). These elements are to be crucially considered when talking about science communication, as compromised scientific quality can easily erode public faith in research.

4.2 Do Europeans still trust in science?

An intellectual tour de force by scientists led to the development, with an unprecedented swiftness, of safe and effective COVID-19 vaccines. Gupta et al. (2021) estimated that within the first five months after the beginning of the vaccination programme, 140 thousand lives were saved in the US thanks to the vaccines. Worldwide numbers are several orders of magnitude more massive, and rising day by day.

Yet, objective success does not imply perceived success. There is a wide and broad literature on the relationship between science accomplishments and science perception of the broader public. As an example, it is found that scientific disputes are found to diminish general public trust in science due to misunderstanding by the public of how science operates (Dieckmann et al., 2019).

In the EU, there is a high level of trust in science, yet a slightly lower level of trust on the reliability of scientists. Research shows that it easier to erode trust in scientists and leaders than in science itself. Indeed, science is perceived more as a great tool which may fail in biased hands (Aksoy et al. 2020, Eichengreen et al. 2021). The 2021 release of a Eurobarometer survey shows that 9 in 10 EU citizens (86 %) think that the overall influence of science and technology is positive. However, in line with the empirical literature, scientists are perceived as more intelligent than reliable, with 89 % of EU citizens defining them as intelligent and only 68 % considering them as reliable.

During periods of emergency, misunderstood lively academic debates and societal/ political pressures can damage popular trust in science. Scientific debates are common and crucial for the development of new ideas. However, in the public sphere such debates may erroneously be interpreted as fundamental disagreements among scientists. Furthermore, in periods of crisis with inflated pressure on the scientific community to quickly produce and disseminate scientific findings, discord among different experts (or the perception thereof) can feed distrust. Sceptics may find it symptomatic for scientists' bias or dishonesty (Eichengreen et al., 2021). At the same time, political and electoral interests can incentivise political leaders to dismiss or undermine scientific expertise (Friedman et al., 2020).

In times of pandemics, popular trust in scientists and political institutions tends to erode, unless political institutions act in a timely manner. Aassve et al. (2021) find that the global pandemic caused by a lethal influenza virus in 1918-19 (commonly called Spanish Flu) had long-lasting negative consequences for individuals' social trust, also carrying over into later generations. Using epidemics data for 142 countries from 1970, Aksoy et al. (2020) also find a negative impact of past exposure to epidemics on individuals' confidence in political institutions and leaders. Eichengreen et al. (2021), employing data for 138 countries on global epidemics since 1970, find that past epidemic exposure has no impact on views of science as an endeavour, yet it significantly reduces trust in scientists and in the benefits of their work. On the other hand, Fluckiger et al. (2019) find that exposure to the Ebola epidemic in West Africa enhanced trust in government, particularly when governments managed to respond with timely measures.

Trust in science can face fatigue due to contradictory statements from authorities and experts. Battiston et al. (2021) found that in Italy responsiveness to COVID-19 information from experts weakened over time, likely due to attention fatigue and contradictory statements from health authorities and experts.

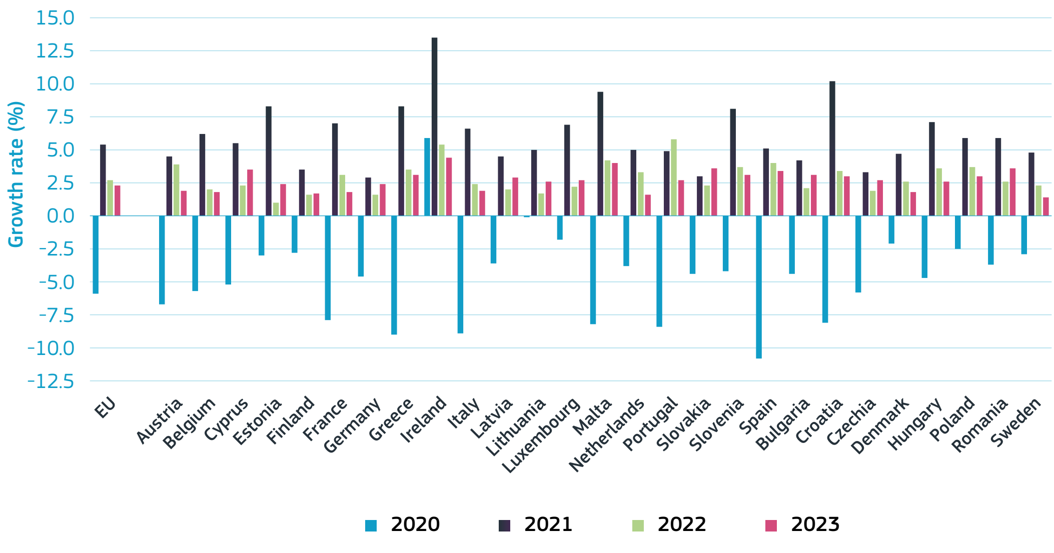
To sum up, the impact of pandemics on trust in science is not exclusively related to its successes to develop effective vaccines, but also depends on the endorsement of scientific insights by the government, and on an ability to develop an inclusive communication strategy. Hence, as the voluntary participation in vaccination programmes is heavily related to individuals' trust in science and health authorities (Sturgis 2021), the cultivation of scientific social trust through well-informed communication and nudging activities acquires an elevated degree of priority and importance.

5. The way forward

5.1 Recovery and resilience

Due to the pandemic and associated policy responses to contain the virus, the EU recorded a historic drop in economic activity in 2020, corresponding to a decrease of 5.9% of GDP compared to 2019[13]. This was mitigated to a certain extent by the adaptation of firms and households to cope with the new situation and continued strong policy support. **The EU economy initially seemed to recover from the recession faster than expected** (Figure 1-14). Growth perspectives in the short run are supported by a continuously improving labour market, favourable financing conditions and the deployment of the Recovery and Resilience Plans (RRP) developed under the Recovery and Resilience Facility (RRF) (European Commission, 2022a). However, **the war in Ukraine**, as well as the disturbances in global trade caused by the drastic COVID-19 containment measures still applied in parts of **China**, are **likely to dampen the expected post-pandemic economic recovery**. According to the Spring 2022 forecast of the European Commission (European Commission, 2022b), as a consequence of these developments real

Figure 1-15: Economic Forecast (GDP growth, volume)



Source: Spring 2022 Economic Forecast (DG ECFIN) and Eurostat.
Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-15.xlsx

13 Source : Eurostat. Real GDP growth rate.

GDP growth in the EU is expected at 2.7 % in 2022 and 2.3 % in 2023, which is down from the 4.0 % and 2.8 % predictions of the winter 2022 interim forecast.

The Recovery and Resilience Facility, with a budget of EUR 672.5 billion, is at the core of the NextGenerationEU programme, the post-COVID recovery programme agreed by EU leaders mid-2020. It will support large-scale reforms and investments, through plans submitted by the Member States. **R&I is an indispensable component to deliver on Europe's recovery and increase resilience**, i.e. withstanding and coping with challenges and undergoing transitions, and making Europe's green and digital transformation a reality. Through the RRF, the Commission encourages Member States to strongly invest in R&I, with seven flagship areas at its core that range from clean technologies and renewables to buildings efficiency, and to strengthen national and regional R&I systems. Under the RRF, countries have to dedicate at least 20 % of the funds to the digital transition and at least 37 % to the green transition.

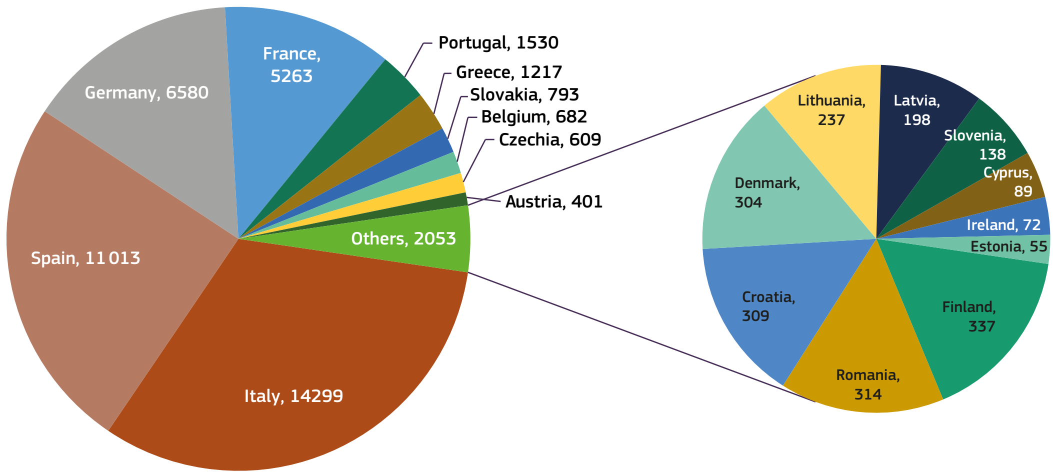
The overall expenditure for R&I in the Recovery and Resilience Plans is significant. All approved RRPs[14] include a total of 224 measures related to R&I (55 reforms and 169 investments) for a budget of around EUR **44.4 billion**[15]. The amount of R&I investments in the RRPs represents typically between 4 % and 13 % of the RRF grants allocation of a country, with a few outliers below or above this range and an average of about 10 % (Figures 9 and 10).

For several Member States, the Recovery and Resilience Facility can be instrumental in the development of their R&I system, shaping it in the years to come, and with a real transformative impact should the efforts be maintained over time. For example, in several Eastern and Southern Member States, which are characterised by high RRF grants allocation and low R&D intensity, the investments included in the RRPs amount to over one year of (pre-COVID) public investments in R&I. Moreover, in some of those countries, these investments are linked to important R&I policy reforms (see Box 1-2).

14 The recovery and resilience plans of the following 22 Member States have been approved so far: Austria, Belgium, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Ireland, Italy, Germany, Greece, Latvia, Lithuania, Luxemburg, Malta, Portugal, Romania, Slovakia, Slovenia, and Spain.

15 This amount corresponds to the total estimated costs of all measures addressing research, development and innovation priorities, including those directly related to the green or digital transitions.

Figure 1-16: Absolute expenditure allocation to R&I projects in Recovery and Resilience Plans per Member State in million EUR

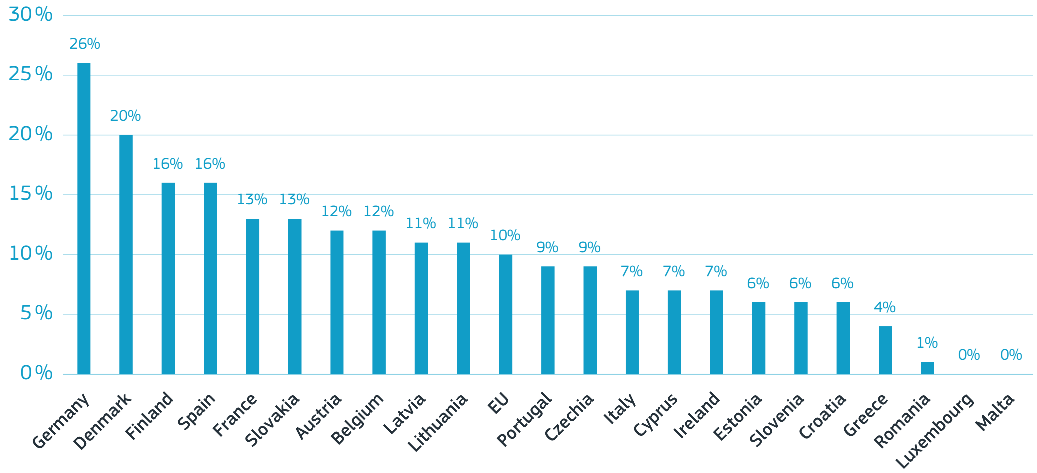


Science, research and innovation performance of the EU 2022

Source: Recovery and Resilience Scoreboard - Thematic analysis: research and innovation.

Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-16.xlsx

Figure 1-17: R&I allocation as a percentage of total allocation per Member State in Recovery and Resilience Plans



Science, research and innovation performance of the EU 2022

Source: Recovery and Resilience Scoreboard - Thematic analysis: research and innovation.

Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-17.xlsx

Box 1-2: Research and innovation in the Recovery and Resilience Plans (RRPs)

The **R&I reforms** typically plan to:

- reduce the **fragmentation of the scientific research system** through the consolidation of scientific research institutions;
- **increase the attractiveness of research careers in public institutions** through changes to the recruitment, salary and career management policies (for key areas in particular), including with increased possibility for mobility and combining public research with private activity;
- **reduce the administrative burden** related to the access to public funding for R&I activities;
- support **knowledge and technology transfer** (from public research institutions to private companies) through the creation of appropriate entities (offices, agencies) and the removal of barriers to academia-business collaboration;
- **improve the coordination between the different levels of governance** of R&I and education policies, in order to respond to skills needs and enhance employability, especially for the young.

The RRPs include both horizontal and thematic R&I investments, consisting in financial support for R&I activities and infrastructures.

The **horizontal** R&I investments account for slightly more than one third of the total R&I investments. They include a variety of cross-cutting measures such as strengthening of innovation ecosystems, upgrade of research infrastructures, grants for researchers, support for business innovation including start-ups and SMEs, facilitation of public-private R&I cooperation and the support of existing or new regional clusters.

The **thematic** R&I investments are targeted at a number of specific areas.

The green transition will be facilitated by R&I investments notably in the fields of:

- energy (17 % of total R&I expenditure; including, e.g., development of hydrogen solutions);
- environment (6 %; e.g., support for public and business R&I in the environmental field, research in innovative green technologies);
- transport/smart mobility (4 %; e.g., development of electro-mobility); and
- circular economy (3 %; e.g. development of re-use and recycling technologies).

R&I investments in **digital technologies** account for approximately 15 % of total R&I expenditure and include, for instance, development of advanced technologies (micro-processors, cloud, quantum computing, etc.), cybersecurity, 5G, as well as digital technologies of a more horizontal impact.

Another important area of R&I investments is **health** (5% of total R&I expenditure). These investments include, for example, the development of alternative production processes for nuclear medicine for cancer treatment or the establishment of a centre for precision medicine.

Several Member States also included investments to support Horizon Europe Partnerships and the funding of projects receiving a Seal of Excellence (i.e. projects which were judged to deserve funding under Horizon Europe but could not be financed due to budget limitations).

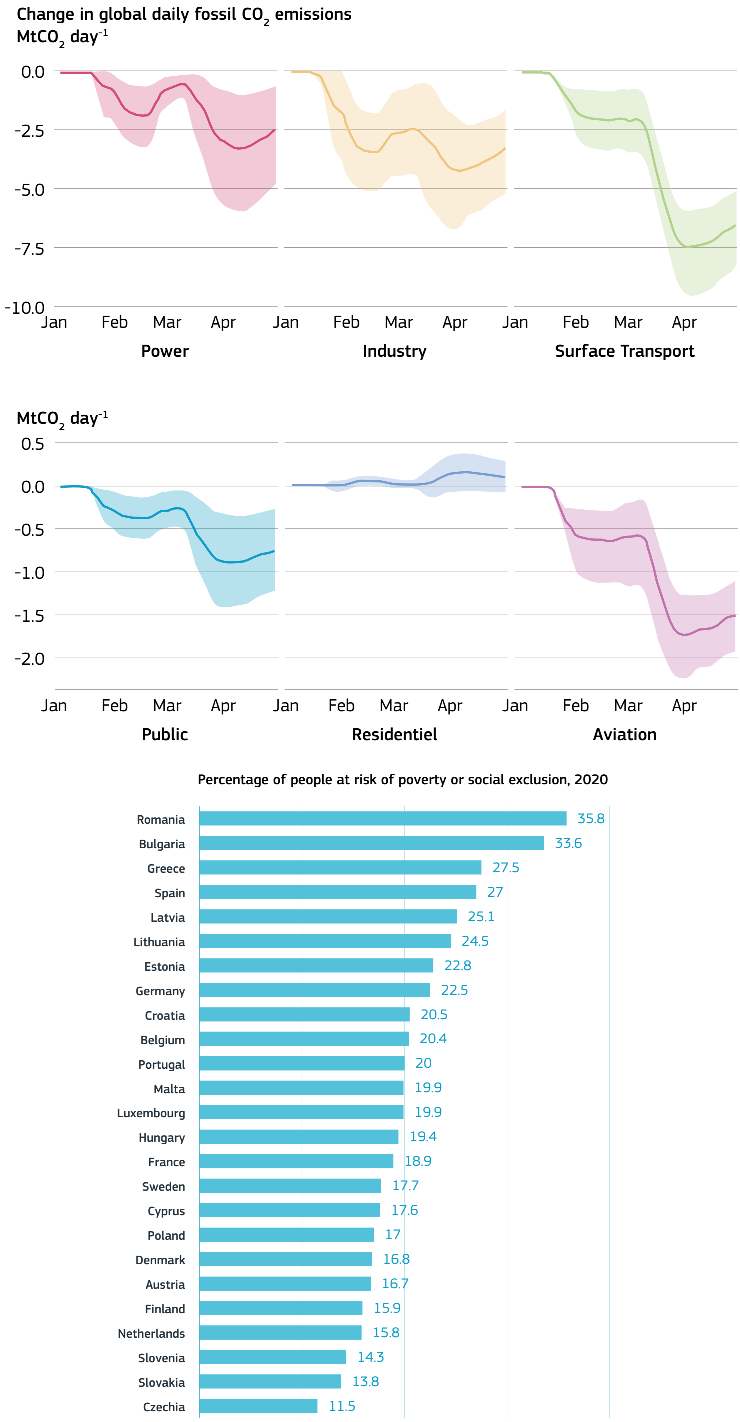
The existence of zombies can hamper the recovery. Zombie firms are financially distressed firms with unviable business models (see also Chapter 4.2). Such firms can survive for example due to inefficient credit allocation resulting from malfunctioning financial markets and inefficient solvency regimes (Schivardi et al., 2017; Azevedo et al., 2018; Caballero et al., 2008; Adalet McGowan M. et al, 2017). Labour and capital embedded in these zombie firms are inefficiently used. Overall productivity improvements can be achieved if labour and capital can be reallocated towards more efficient firms.

Education and training of employees and managers can help this reallocation process, and foster resilience. More education and functional experience by management teams of firms, as well as new knowledge and experience brought by outsider CEOs exporting firms, may reduce the probability for companies of becoming financially distressed and may contribute to enhanced productivity and resilience of the economy against shocks, such as the pandemic COVID-19 (Bloom and Van Reenen, 2010; OECD, 2021b).

5.2 Building forward better

While the pandemic has delivered a blow to our economies, it has also shown that we can change the way we live and consume very rapidly if we see the imperative to do so. During 2020, daily global CO_2 emissions decreased by 17% by early April 2020 compared with the mean 2019 levels, with just under half from changes in surface transport (see Figure 1-11). CO_2 levels were lower for all regions in the world. Emissions in individual countries decreased by 26% on average in 2020, with the largest decrease for South America, by up to approximately 40% (Le Quéré et al., 2020). While it will do little to address the issue of air pollution in the long term, it does offer an interesting perspective on discussions about the impact of a decrease in consumption on anthropocentric climate change as well as on the speed of consequences as changes take place. The EU and its Member States are now working on a common 2050 vision of sustainability (European Commission, 2018; 2019). Stepping up horizon scanning and foresight efforts and improving the uptake of partnerships with citizens will prove crucial in this respect.

Figure 1-18: Change in GHG emissions during the pandemic and percentage pf people at risk of poverty and social exclusion



Source : Le Queré et al (2020) and Eurostat (online data code: ilc_peps01n).
Stat. link: https://ec.europa.eu/assets/rtd/srip/2022/figure-1-18.xlsx

Developing and deploying breakthrough technologies that eliminate emissions throughout the physical economy is critical. To do so, we need to tap the power of markets to fund these innovations— for example, **by finding creative ways to finance technologies or by levelling the playing field so they can compete with fossil fuels**. This can mean revising financial and tax incentives offered to industries with a large contribution to climate impacts, or offering similar support to (yet) underdeveloped industries. Furthermore, governments and corporations need to adopt policies that will make it faster and cheaper to make the transition, and leaders will need to reward those who take difficult steps (Gates, 2021). Diffusion of such green technologies will in turn stimulate the creation of sustainable jobs, such as circular economy jobs, urban and rural rewilding and preventive health services.

The pandemic has put even more pressure on the most vulnerable, including low-income households or households living in remote areas, as well as small firms, and has highlighted the extent to which the current system is falling short on social needs and the need for resilience and sustainability. For instance, the rates of food insecurity in the US got closer to 30% or higher during the pandemic, and spiked to 36% in 2020 (+20% compared to pre-Covid levels) (Bath, 2020). In Europe, in 2020, European Food Bank associations registered a surge of +34.7% of people in need and that most beneficiaries are people who have lost their job as a consequence of COVID-19. Besides, while the COVID-19 outbreak affects all segments of the population, early evidence indicates that the health and economic impacts of the virus are being borne disproportionately by poor people (UN, 2021). These deep-rooted issues need a paradigm shift that is slow to happen. Digitalisation and artificial intelligence, for example, should be optimised for social impact in order to prioritise their use for the good of people. Similarly, the design of cities and rural communities can be rethought with new models of social safety nets and creative procurement policies.

The EU needs to support a cohesive and inclusive innovation-driven growth of countries, regions and companies by fostering synergies between Horizon Europe and other EU programmes targeting R&I (such as cohesion policy and parts of InvestEU). The Commission can also support Member States and regions in designing and implementing better innovation policies and reforming national and regional research and innovation systems through the Technical Support Instrument (TSI). R&I can also be promoted through place-based policies to boost underutilised potential and strengthen regional innovation systems, by encouraging public support to R&I also for laggard firms, and by ensuring that Europeans have the skills required to effectively use the new technologies. Such an innovation system requires governance that balances experimentation and precaution and addresses the unpredictable outcomes and impacts of innovation (EEA, 2021).

This requires a multi-level, whole-of-government approach to policy. Such an integrated approach would for example allow promoting coherent investments across European and national actors, but also facilitate on-the-ground experimentation. These innovative approaches could bring better exploitation of the fruits from R&I, increased participation of civil society in R&I, and a faster and more just transition. In this optic, 'growth' should go beyond simple GDP monitoring, and evaluate the resilience and participation of citizens in building a future they feel part of (OECD, 2020b).

Experts[16] also recommended an assessment of the responses to the crisis with the objective of drawing lessons from policy responses at every level of government. It was recommended to operationalise the more successful ones into short- and long-term R&I actions capable of improving the role of R&I policy in crisis management. As such the COVID-19 pandemic has already proven fertile, as ideas have already found their way to policymakers, such as the development of rapid response capabilities for emergency data collection and organisation, critical technology mapping, and also the consideration and protection of knowledge-intensive companies as actors of European resilience. Preparedness, monitoring and evidence-based policies are also needed to address growing instabilities, disruptions and uncertainty about our future.

More generally, the COVID-19 crisis showed that Europe needs not only to prepare for the challenges we know, but needs to be ready for new ones. The rising environmental, geopolitical, economic and social instability in the world increases the likelihood of extreme events with disruptive effects, and with potentially unknown specific shape. The recent conflict in Ukraine is another illustration of this.

Extreme events have, however, shown strong signs in a foresight sense, and should, therefore, serve as a basis to complete reflections made to adjust the EU's R&I policy in light of the recent crises, i.e. resilience of the R&I systems.

The pandemic has provided us with the opportunity to 'build forward better' (ESIR, 2021; Giovannini et al., 2021; OECD, 2021a; Martin & Mullan, 2021; EEA, 2022) and aim for a more sustainable and inclusive Europe. We have learned from the past that policy objectives to combat a crisis should not only be limited to economic or public finance objectives. Furthermore, a transition to a sustainable society and economy is necessary to protect human health, and COVID-19 can be seen as a 'late lesson' from an early warning (EEA, 2022). Today there is a clear political commitment to build back better (Stern et al., 2020, 2021), and equip public and private entities with support and tools fit for a green, inclusive and resilient recovery. As the Expert Group on the Economic and Societal Impact of Research and Innovation (ESIR) puts it: 'Greater resilience by design, not by disaster'.

16 Dixson-Declève et al. (2020).

References

Aassve, A., Alfani, G., Gandolfi, F., & Le Moglie, M. (2021), 'Epidemics and trust: the case of the spanish flu', *Health economics*, 30(4), pp. 840-857.

Adalet McGowan M., Andrews D. Millot V. (June 2017), *Insolvency regimes, zombie firms and capital reallocation*, OECD economics department working papers no. 1399.

Aghion, P., Askenazy, P., Berman, N., Cette, G., & Eymard, L. (2012), 'Credit constraints and the cyclicality of R&D investment: Evidence from France', *Journal of the European Economic Association*, 10(5), pp. 1001-1024.

Agley, J. (2020), 'Assessing changes in US public trust in science amid the COVID-19 pandemic', *Public Health*, 183, pp. 122-125.

Alexandre, F., S. Cruz and M. Portela (2021), *Financial distress and the role of management in micro and small-sized firms*, OECD Productivity Working Papers, No. 27, OECD Publishing, Paris, https://doi.org/10.1787/2014873c-en.

Almeida, A., Figueiredo, H., Cerejeira, J., Portela, M., S ´a, C., and Teixeira, P. (2017), *Returns to postgraduate education in portugal: Holding on to a higher ground?*, IZA Discussion Paper No. 10676.

Anzoategui, D., Comin, D., Gertler, M., Martinez, J. (2019), 'Endogenous Technology Adoption and R&D as Sources of Business Cycle Persistence', *American Economic Journal, Macroeconomics*, 11 (3), pp. 67-110.

Azevedo N., Mateus M. Pina A. (2018), *Is bank credit going to the most productive firms? Portuguese Economic Growth.*

Barlevy, G. (2007), 'On the cyclicality of research and development', *American Economic Review*, 97(4), pp. 1131-1164.

Battiston, P., Kashyap, R., & Rotondi, V. (2021), 'Reliance on scientists and experts during an epidemic: Evidence from the COVID-19 outbreak in Italy', *SSM-population health*, 13, 100721.

Bloom N., Van den Reenen J. (2010), 'Why do management practices differ across firms and countries?', *Journal of Economic Perspectives*. Vol 24 n°1. Why Do Management Practices Differ across Firms and Countries? - American Economic Association (aeaweb.org).

Borunsky et al (2020), *Can R&I save the Day*, R&I Paper Series.

Bryan, K., J. Lemus and G. Marshall (2020), *Innovation During a Crisis: Evidence from Covid19*, SSRN Electronic Journal

Caballero R., Hoshi T., Kahsyap A.(December 2008), 'Zombie lending and depressed restructuring in Japan', *American Economic Review*, 98(5), pp. 1943-77.

Comin, D., & Gertler, M. (2006), 'Medium-term business cycles', *American Economic Review*, 96(3), pp. 523-551.

Contreras, F.; Baykal, E., and Ghulam Abid (2020), 'E-Leadership and Teleworking in Times of COVID-19 and Beyond: What We Know and Where Do We Go', *Front. Psychol.*, https://doi.org/10.3389/fpsyg.2020.590271.

Deryugina, T., Shurchkov, O., & Stearns, J. (2021, May), 'COVID-19 disruptions disproportionately affect female academics', In *AEA Papers and Proceedings*, 111, pp. 164-68).

Dixson-Declève, S., Balland, P., Bria, F., et al. (2020), *Protect, prepare and transform Europe: recovery and resilience post COVID-19*, Publications Office.

Dieckmann, N. F., & Johnson, B. B. (2019), 'Why do scientists disagree? Explaining and improving measures of the perceived causes of scientific disputes', *PLoS One*, 14(2), e0211269.

ECB (2020), April 2020 euro area bank lending survey, Press Release, 20 April 2020.

EEA (2021), *With people and for people: Innovating for sustainability*, Briefing no. 09/2021.

EEA (2022), COVID-19: *Lessons from sustainability?*, Briefing.

Eichengreen, B., Aksoy, C. G., & Saka, O. (2021), 'Revenge of the experts: Will COVID-19 renew or diminish public trust in science?', *Journal of Public Economics*, 193, 104343.

Eichengreen, B., Saka, O., & Aksoy, C. G. (2020), *The Political Scar of Epidemics* (No. w27401), National Bureau of Economic Research.

Else, H. (2020), 'How a torrent of COVID science changed research publishing-in seven charts', *Nature*, pp. 553-553.

ESIR (2021a), *Protect, prepare and transform Europe – Build forward better" ESIR virtual seminar,* European Commission (europa.eu).

Eurofound (2020a), Living, working and COVID-19: *Methodological annex to round 1*, Dublin.

Eurofound (2020b), *Living, working and COVID-19,* COVID-19 series, Publications Office of the European Union, Luxembourg.

European Commission. (2018), *A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy*, Brussels, 28.11.2018 COM(2018) 773 final.

European Commission (2019), *The European Green Deal*, Brussels, 11.12.2019 COM(2019) 640 final.

European Commission (2020), *Europe's moment: Repair and Prepare for the Next Generation*, COM(2020) 456 final.

European Commission (2021a). *EU research and innovation in action against the coronavirus: Funding, results and impact.* Publication Office of the European Union, Luxembourg.

European Commission (2021b), Directorate-General for Employment, Social Affairs and Inclusion, *Employment and social developments in Europe 2021: towards a strong social Europe in the aftermath of the COVID-19 crisis: reducing disparities and addressing distributional impacts: annual review*, Publications Office, https://data.europa.eu/doi/10.2767/049867

European Commission (2022a), *European Economic Forecast. Winter 2022*, Institutional Paper 169.

European Commission (2022b), *European Economic Forecast. Spring 2022*, Institutional Paper 173.

European Food Banks Federation (September 2021), *COVID-19: a unique opportunity for a real change. FEBA Report 01*, FEBA_Report_Survey_COVID_Sept2021.pdf (eurofoodbank.org).

Fabrizio, K. R., & Tsolmon, U. (2014), 'An empirical examination of the procyclicality of R&D investment and innovation', *Review of Economics and Statistics*, 96(4), pp. 662-675.

Fatas, A. (2000), 'Do business cycles cast long shadows? Short-run persistence and economic growth', *Journal of Economic Growth*, 5(2), pp. 147-162.

Ferrazzi M., Savsek S. (July 2020), *COVID-19 economic update*. European Investment Bank report, COVID-19 economic update – July 17, 2020 (eib.org).

Fluckiger, M., Ludwig, M., & Sina Önder, A. (2019), ‚Ebola and state legitimacy', *The Economic Journal*, 129(621), pp. 2064-2089.

Friedman, L., & Plumer, B. (2020), *Trump's response to virus reflects a long disregard for science,* New York Times, 28.

Fry, C. V., Cai, X., Zhang, Y., & Wagner, C. S. (2020), 'Consolidation in a crisis: Patterns of international collaboration in early COVID-19 research', *PLoS One*, 15(7), e0236307.

Gates B. (Avril 23rd 2021), *My climate message for world leaders*, Bill Gates (gatesnotes.com).

Gauchat, G. (2012), 'Politicization of science in the public sphere: A study of public trust in the United States', 1974 to 2010, *American sociological review*, 77(2), pp. 167-187.

Gewin, V. (2020), 'The career cost of COVID-19 to female researchers, and how science should respond', *Nature*, 583(7818), pp. 867-869.

Gibson, E.M. et al. (2020), 'How support of early career researchers can reset science in the post-COVID19 world', *Cell*, 181(7), pp. 1445-1449.

Giovannini, E., Hidalgo, C., Huang, A., et al. (2021), *Transformation post-COVID: the future of European universities*, Publications Office.

Grassano, N., Hernandez Guevara, H., Fako, P., Tuebke, A., Amoroso, S., Georgakaki, A., Napolitano, L., Pasimeni, F., Rentocchini, F., Compano, R., Fatica, S. and Panzica, R., (2021), *The 2021 EU Industrial R&D Investment Scoreboard*, EUR 30902 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-44399-5, doi:10.2760/559391, JRC127360.

Gupta, S., Cantor, J., Simon, K. I., Bento, A. I., Wing, C., & Whaley, C. M. (2021), 'Vaccinations Against COVID-19 May Have Averted Up To 140,000 Deaths In The United States: Study examines role of COVID-19 vaccines and deaths averted in the United States', *Health Affairs*, 40(9), pp. 1465-1472.

Harris, M., Bhatti, Y., Buckley, J. and Sharma, D. (2020), 'Fast and frugal innovations in response to the COVID-19 pandemic', *Nature Medicine*, 26, pp. 814–817.

He, S., Lai, D., Mott, S., Little, A., Grock, A., Haas, M. R., et al. (2020), 'Remote e-work and distance learning for academic medicine: best practices and opportunities for the future', *J. Grad. Med. Educ*, 12, 256–263. doi: 10.4300/JGME-D-20-00242.1.

Howell, S. T., Lerner, J., Nanda, R., & Townsend, R. R. (2020), *Financial distancing: How venture capital follows the economy down and curtails innovation* (No. w27150), National Bureau of Economic Research.

JRC (June 2021), *The impact of COVID-19 on top R&D investors: first insight into 2021 EU Industrial R&D Investment*, JRC125712. .sb2021_pb_21june2021.pdf (europa.eu).

Juchnowicz, M.; Kinowska, H. (2021), *Employee Well-Being and Digital Work during the COVID-19 Pandemic*, Information, 12, 293. https://doi.org/10.3390/info12080293.

Kambhampati, S. B., Vaishya, R., & Vaish, A. (2020), 'Unprecedented surge in publications related to COVID-19 in the first three months of pandemic: A bibliometric analytic report', *Journal of clinical orthopaedics and trauma*, 11(Suppl 3), S304.

Kelly Servick, A. C., & Giorgia Guglielmi, G. V. (2020), 'Labs go quiet as researchers brace for long-term coronavirus disruptions', *Science*.

Kleine-Rueschkamp, L., and Adrjan, P. (2021), *After the Boom? COVID-19 and European City Labour Markets: Shortage of lower paid and non-remote job postings risks widening urban inequality*, https://www.oecd.org/local-forum/blog/.

Le Quéré C., JacksonR., Jones M., Smith A., Abernethy S., AndrewR., De-Gol A., Willis D., Shan Y., Canadell J., Friedlingstein P., Creutzig F., Peters G. (July 2020) 'Temporary reduction in daily global CO_2 emissions during the COVID-19 forced confinement', *Nature Climate Change*, Vol 10. 647-653. https://doi.org/10.1038/s41558-020-0797-x.

Ledford, H. (2020), 'Coronavirus shuts down trials of drugs for multiple other diseases', *Nature*, 580(7801), pp. 15-17.

Longhitano, G. A., Bitencourt Nunes, G., Candido, G., Lopes da Silva, J., V. (2021). *The role of 3D printing during COVID-19 pandemic: a review*, Progress in Additive Manufacturing 6, pages 19–37, https://doi.org/10.1007/s40964-020-00159-x.

López Peláez, A., Erro-Garcés, A., Pinilla García, F.J., Kiriakou, D. (2021), 'Working in the 21st Century. The Coronavirus Crisis: A Driver of Digitalisation, Teleworking, and Innovation, with Unintended Social Consequences. Information', 12(9), 377.

Martin, K., Mullan, Z. (2021), 'Building forward better', *The Lancet Global Health*, 9, Supplement 1, pp. S1-S2.

Mugabushaka, A. (2021), *Meeting the pandemic challenges : contribution of EU R&I funding to COVID-19 related research*, European Commission Publications Office.

Muoio D. (May 2020), *COVID-19's 'unprecedented stress' on social services drives demand for innovative SDOH programs*, MobilHealthNews.

Myers, K. R., et al. (2020), 'Unequal effects of the COVID-19 pandemic on scientists', *Nature human behaviour,* 4(9), pp. 880-883.

Negreiro Achiaga, M. (2021), *The rise of digital health technologies during the pandemic,* European Parliamentary Research Service.

OECD (2020a), *Responses to the crisis have drawn upon the innovative potential of businesses, Responses to the crisis have drawn upon the innovative potential of businesses*, OECD Publishing, Paris.

OECD (2020b), *Beyond Growth: Towards a New Economic Approach*, New Approaches to Economic Challenges, OECD Publishing, Paris, https://doi.org/10.1787/33a25ba3-en.

OECD (2020c) *Building forward better by strengthening resilience*, OECD Publishing, Paris.

OECD (2021a), *Before the COVID-19 crisis, OECD countries stepped up R&D investments*, https://www.oecd.org/sti/msti-highlights-march-2021.pdf.

OECD (2021b), OECD *Science, Technology and Innovation Outlook 2021: Times of Crisis and Opportunity*, OECD Publishing, Paris.

OECD, (February 2021c). *Business dynamism during the COVID-19 pandemic: Which policies for an inclusive recovery*? OECD Publishing, Paris.

Pai, M. (2020), 'Covidization of research: what are the risks?', *Nature medicine*, 26(8), pp. 1159-1159.

Paunov, C. and Planes-Satorra, S. (2021), *Science, technology and innovation in the time of COVID-19*, OECD Science, Technology and Industry Policy Papers 99, OECD Publishing.

Pollin R., Garrett-Peltier H., Heintz J., Scharber H. Green Recovery: *A Program to Create Good Jobs and Start Building a Low-Carbon Economy*, Center for American Progress (2008), Green Recovery: A Program to Create Good Jobs & Start Building a Low-Carbon Economy (repec.org).

Rafferty, M. C. (2003), 'Do business cycles influence long-run growth? The effect of aggregate demand on firm-financed R&D expenditures', *Eastern Economic Journal*, 29(4), pp. 607-618.

Sachini, E., Labrianidis, L., Sioumalas-Christodoulou, K., Chrysomallidis, C., Siganos, G., Belouli, A., & Karampekios, N. (2021), 'Research on Researchers. Coping during COVID-19. Results on a Nation-Wide Survey', *Science & Public Policy*, 48(4), pp. 451–461.

Schivardi F. Sette E., Tabellini G. (July 2017), *Credit misallocation during the European financial crisis,* Voxeu.org Credit misallocation during the European financial crisis, VOX, CEPR Policy Portal (voxeu.org).

Sedgley, N. H., Burger, J. D., & Tan, K. M. (2019), 'The symmetry and cyclicality of R&D spending in advanced economies', *Empirical Economics*, 57(5), pp. 1811-1828.

Si, S, Cullen, J., Ahlstrom, D. and Jiang Wei (2018), 'Special Issue: Business, Entrepreneurship and Innovation Toward Poverty Reduction', *Entrepreneurship & Regional Development*, 30:3-4, pp. 475-477.

Squazzoni, F., Bravo, G., Grimaldo, F., García-Costa, D., Farjam, M., & Mehmani, B. (2021), 'Gender gap in journal submissions and peer review during the first wave of the COVID-19 pandemic. A study on 2329 Elsevier journals', *PloS one*, 16(10), e0257919.

Stern N., Valero A. (November 2021), 'Innovation, growth and the transition to net-zero emissions', *Research Policy*. Vol 50. Issue 9. 104293. https://doi.org/10.1016/j.respol.2021.104293.

Stern, N. Unsworth S., Valero A., Zenghelis D., Rydge J., Robins N. (July 2020), *Strategy, investment and policy for a strong and sustainable recovery: An action plan*, Centre for Economic Performance. A CEP COVID-19 analysis Paper No.005. cepCOVID-19-005.pdf (lse.ac.uk).

Sturgis, P., Brunton-Smith, I., & Jackson, J. (2021), 'Trust in science, social consensus and vaccine confidence', *Nature Human Behaviour*, 1-7.

CHAPTER 1

UN (April 2020), *The social impact of COVID-19. The Social Impact of COVID-19*, DISD (un.org).

Viglione, G. (2020), 'Are women publishing less during the pandemic? Here's what the data say', *Nature*, 581(7809), pp. 365-367.

Vincent-Lamarre, P., Sugimoto, C. R., & Larivière, V. (2020), 'The decline of women's research production during the coronavirus pandemic', *Nature index*, 19.

Woolston, C. (2020a), 'Junior researchers hit by coronavirus-triggered hiring freezes', *Nature*, 582(7812), pp. 449-450.

Woolston, C. (2020b), 'Pandemic darkens postdocs' work and career hopes', *Nature*, 585(7824), pp. 309-312.

Woolston, C. (2020c), 'Seeking an exit plan for leaving academia amid coronavirus worries', *Nature*, 583(7817), pp. 645-647.