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Carsten Fink, Yann Ménière, Andrew A. Toole,
& Reinhilde Veugelers

Resilience and Ingenuity: Global Innovation Responses to Covid-19



UNITED STATES
PATENT AND TRADEMARK OFFICE

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Resilience and Ingenuity

Global Innovation Responses
to COVID-19

CEPR PRESS

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Resilience and Ingenuity

Global Innovation Responses to COVID-19

Edited by Carsten Fink, Yann Ménière,
Andrew A. Toole and Reinhilde Veugelers



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Foreword

The Covid-19 pandemic, which has been such a profound shock to society and economy at a global level, has also had far reaching effects on innovation and creativity world-wide. Key to the monumental response needed to contain the public health crisis and stabilise the global economy has been an ability to provide innovative solutions to complex problems: from the rapid development of vaccines to the introduction of the new technologies that kept business running remotely, not only were innovations needed to beat the pandemic, but, in a post-crisis world, they are also an important catalyst for building resilience to future pandemics. Understanding how the COVID-19 crisis has affected innovative activity around the world is therefore of paramount interest.

This eBook, written as we start to transition from pandemic to recovery, provides a first look at how the COVID-19 pandemic affected the global innovation landscape. It explores how the innovation ecosystem – businesses, research institutions, governments, and individuals – responded to the crisis, and how this response differed across regions, sectors, and industries. It draws on rich empirical patent and trademark data to measure innovative activity at individual and national levels. It also looks at how the widespread disruption affected innovators financially, technologically, and how it changed the focus towards delivering solutions to address the crisis.

Overall, the eBook provides fascinating insights into the performance of the global innovation system and its contribution towards making society more resilient to the evolving shock. It also provides key policy lessons to ensure the innovative landscape is more robust, and better prepared for future crises.

CEPR is grateful to Carsten Fink, Yann Ménière, Andrew A. Toole and Reinhilde Veugelers for their expert editorship of the eBook. Our thanks also go to Anil Shandasani for his skilled handling of its production.

CEPR, which takes no institutional positions on economic policy matters, is delighted to provide a platform for an exchange of views on this important topic.

Tessa Ogden
Chief Executive Officer, CEPR
July 2022

Introduction

Carsten Fink, Yann Ménière, Andrew A. Toole and Reinhilde Veugelers

World Intellectual Property Organisation; European Patent Office;
U.S. Patent and Trademark Office; KULeuven and CEPR

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THE COVID-19 CRISIS AND INNOVATION

The World Health Organization declared the coronavirus (COVID-19) to be a global pandemic on 11 March 2020. Not only has COVID-19 caused massive losses to public health worldwide (the current worldwide death count stands at more than 6.3 million),¹ it also caused major economic havoc worldwide. The decline in global GDP in 2020 turned out to be the biggest annual decline since World War II (IMF 2021). And while most economies have since recovered from the sharp decline, the IMF forecasts the economic losses to continue to add up to US\$22 trillion by 2025 (Gopinath 2021).

Now, as we transition out of the pandemic phase in late June of 2022, it is clear that innovation and learning were critical in the fight against COVID-19. New vaccines, treatments and diagnostics were vital to beat back its spread and health impacts. Beyond public health, the COVID-19 crisis spurred the introduction of new technologies, incited new ways of managing businesses and employees, and prompted new forms of reaching and interacting with customers. Not only were innovations needed to beat the pandemic, they are also an important catalyst for a post-crisis world that is more resilient to future pandemics. And innovations will also be vital for dealing with other intertwined challenges our global society is facing such as climate change, pollution, shortages of clean water, and the need to eradicate poverty. Understanding how the COVID-19 crisis has affected innovative activity around the world is therefore of paramount interest.

This eBook takes a first step toward understanding how the COVID-19 pandemic affected the global innovation landscape. In its various contributions, it examines how actors in the innovation ecosystem – private and not-for-profit organisations, governments, and individuals – responded to the emerging crisis. It also looks at some of the ‘upstream’ responses by scientists and universities as well as individuals who contribute to the creative economy in areas like music and movies. In essence, we are asking: how did the COVID-19 crisis impact the innovation ecosystem globally and in various parts of the world? And how did the innovation ecosystem help to deal with the COVID-19 crisis and its aftermaths?

Why and how can we expect crises like COVID-19 to matter for innovation? Are there any lessons learned from past crises? On the one hand, one may argue that the innovation ecosystem should be robust to crises. Research and development (R&D)

1 <https://covid19.who.int/>

strategies that fuel intellectual property (IP) filings and innovation are thought to be somewhat insulated from short-term fluctuations as they tend to focus on long-term objectives. Patents, trademarks, and copyrights are assets that can store value in the face of uncertainty, providing innovators with options-like tools to buffer against uncertainty. On the other hand, innovators are not immune to operational disruptions or sudden shifts, particularly if they lack deep enough financial buffers or when circumstances are dire enough to revise long-term expectations downwards. During the 2007–08 global financial crisis and the following Great Recession, for example, firms experienced limited access to finance for innovation (Lee et al. 2015) and were less able and willing to invest in innovation (Archebugi et al. 2013). Fiscal contraction in the general economy, in turn, put pressure on demand and public budgets to support research, at least in certain countries (Cruz-Castro and Sanz-Menéndez 2016).

At the same time, crises can also be seen as challenges that fundamentally alter societies' immediate technological needs as well as their future needs. They may thus spur crisis-specific innovations, which could displace or stimulate other innovations in both the short and longer terms. This was manifestly the case for innovative activity during World War II, which prompted major research efforts in the United States to develop military technologies and medical treatments to support the war and laid the foundation for many postwar innovations and innovation policy (Gross and Sampat 2020).

Yet, there is only so much to learn from past experiences to prepare for the future, as each crisis holds unique characteristics. In many ways, the COVID-19 crisis was unlike previous big crises. The Great Depression in the 1930s and the 2007–2009 Great Recession originated in financial markets. By contrast, the COVID-19 crisis was an unexpected global public health crisis, with a quickly spreading dangerous virus requiring not only the availability, distribution and uptake of vaccines and treatments, but also sanitary lockdowns, social distancing measures, and travel restrictions to contain its spread.² These measures affected demand for goods and services, and upended traditional ways of producing goods and supplying services. They had a profound impact on working relationships, supply chains and distribution networks, as well as on mental health, family life, productivity and information flows. Unlike previous crises, the COVID-19 pandemic should be seen as a sequence of health and socioeconomic disruptions that altered decision making at all levels of economic activity, from nations to micro-entrepreneurs.

Partly thanks to lessons learned from the past, the COVID-19 crisis triggered a massive policy response in most economies that provided liquidity to alleviate the adverse effects on economic activity (Gourinchas et al. 2021). For innovators, this helped mitigate the expected drops in credit availability and disposable income needed to maintain current

² The Spanish flu, which affected most of Europe and the United States in 1918, perhaps comes closest to the COVID-19 crisis in terms of size and geographic spread of the public health shock. Other more recent health shocks like the bird flu, the Asian flu, SARS, MERS or Ebola were all much more geographically contained.

investments in the short term, even if not all innovators benefitted equally and even if it may have also provided a lifeline for unsustainable projects, impeding an efficient reallocation process to the most promising innovative projects.

Also, the impact of the pandemic on innovation was not evenly spread across all sectors. Roughly, the service sector, which was more directly affected by social distancing measures, was harder hit than goods production. US data show self-employed and small firms in hospitality, retail, personal services, entertainment, and the arts were among the most affected (Bartik et al. 2020). In certain industries – notably electronics and consumer durables – demand actually spiked, so much so that production supply chains – themselves impacted by the crisis – could not keep up.

Finally, not unlike World War II, the crisis radically shifted demand for new technologies. This was most pressingly the case for the biomedical response to the pandemic – searching for and delivering new diagnostics, vaccines and treatments. But as the crisis unfolded, digital technologies became central to daily (work) life and created demand for new digitally intermediated goods and services as well as transforming the supply of goods and services. The crisis fuelled momentum for many businesses to speed up and intensify the adoption of digital technologies and business models.

Actors in the innovation ecosystem had to respond not only to disruptions and uncertainty in the demand for their innovations, but also to an urgent need for quick, new solutions to fight COVID-19. And all this had to be addressed while handling disruptions in the innovation process, as COVID-19 restrictions and the digital transformation were also affecting the interactions and information exchange within and between innovation actors.

Against this background, the contributions included in this volume provide an empirical assessment of how the innovation ecosystem has performed during the crisis. They look at how the crisis has reshaped the innovation landscape in different parts of the world, in different sectors and technology fields, and for different parts of the innovation ecosystem. Many of the chapters draw on IP filing data as a measure of innovative activity. This partly reflects their timely availability (with some caveats) and the rich breakdowns these data offer.³ In addition, many chapters draw on R&D statistics, start-up activity data, surveys and other indicators to offer insights into the impact of the COVID-19 crisis.

The chapters in this eBook can be divided into various strands depending on the unit of analysis they take (country, sector, technology, innovation actors) and whether they look at how the crisis affected the process of supplying innovations and/or how it affected the performance of the innovation ecosystem, and/or how innovators could deliver new solutions to address the crisis, making society more resilient to the shock.

³ Notwithstanding the availability of aggregate patent filing statistics, the content of patent applications, including their technology classifications, is not usually known publicly until 18 months after the 'priority' filing date (see also the Outlook section at the end of this chapter). This is not the case with the content of trademark applications, which becomes publicly available soon after filing.

IMPACT ACROSS THE WORLD: MUCH SIMILARITY, SOME DIVERGENCE

The first part of the eBook reviews the impact of the crisis through the lens of IP rights. Chapters 1 to 10 – contributed by IP offices and IP economists – provide insights into the short-term response of innovative and creative industries at the global and national levels, as measured by their IP filings and grants during the first two years of the pandemic. They draw a comprehensive picture of the unfolding of the crisis in the IP world, from which a number of important lessons emerge.

First, the impact of the pandemic on the filing of IP rights has been less severe compared to previous crises such as the bursting of the dotcom bubble in the early 2000s or the Great Recession. With some exceptions, patent filings were negatively impacted, but declines proved shallow and short-lived – typically confined to the weeks and months following the onset of the pandemic in March 2020.

The chapters also show substantial heterogeneity in IP performance across countries. This was to be expected, as the size of the demand and supply shocks differed between countries, reflecting differences in the spread of the virus, in policy responses, and in the strength and resilience of national innovation ecosystems. China, hit hardest at the beginning of the pandemic, stands out as the least impacted economy, seeing steady growth of national and international patent filings even in 2020, the first year of the pandemic. (As a caveat, it is important to note that the analysis of China's innovation performance in Chapter 7 does not consider the most recent COVID-19 wave in 2022 and its repercussions for China's economy and innovation system).

A further analysis of the contents and origins of patent filings reveals a differentiated impact of the pandemic across industries and technologies. Statistics on patent filings by technology field consistently show that the crisis amplified technology trends that predate the shock. Specifically, the first two years of the pandemic have seen a growth of patenting in technologies related to health (e.g. pharmaceuticals, biotechnologies, medical technologies) and in digital technologies (e.g. digital communication, computer technologies). While already on the rise before 2020, the urgent needs created by the pandemic further boosted innovation in these two fields. Conversely, the COVID-19 crisis aggravated the relative decline of patenting in more traditional technology sectors, such as mechanical engineering.

It is noteworthy that China and the Republic of Korea largely benefitted from this trend, thanks to their specialisation in digital innovation. Both countries showed sustained activity of large incumbent firms as well as local startups in this sector during the pandemic. Their record levels of international patent filings also played an important role in mitigating the impact of the crisis on patent applications in other jurisdictions. By contrast, the relative specialisation of Germany and Japan in more traditional engineering-based industries may explain why the crisis affected patent filings from these

two countries more severely. Brazil – aside from China, the only other middle-income economy covered in this volume – also showed less resilient patenting performance as the pandemic unfolded.

Overall, evidence points to a certain resilience of innovation investments and continued interest in commercialising inventions already in the pipeline. Evidence from the US shows, for instance, that R&D expenditures by companies exhibited less volatility than investments in physical capital. The robustness of international patent filings after the initial shock also indicates that multinational companies have generally been able to maintain or resume long-term investment in innovation. However, the crisis seems to have impacted some categories of smaller, budget-constrained innovators more severely. As shown in the second part of this eBook, US and European small and medium-sized enterprises (SMEs) often had to scale down their investments in patented innovations and report a lack of funding for such investments. Evidence from Brazil also reveals that patenting decreased more among individual micro-entrepreneurs, micro-enterprises and small businesses than among larger companies, with one notable exception: there was a considerable uptake of utility models by local micro-entrepreneurs as the pandemic unfolded.

Next to patent records, trademark filings, which reflect the introduction of new goods and services, were only weakly affected at the start of the pandemic in 2020. This experience differed markedly from previous crises when trademark filings declined in parallel with economic output. Moreover, trademark applications saw a disproportionately strong recovery in 2021 in all the jurisdictions included in this eBook. Healthcare products and ecommerce-related goods and services, broadly mirroring the patenting focus, were one key driver behind this recovery, even if the prominence of different product groups varied across economies.

Both local and international applicants accounted for the strong growth in trademarks. The chapters on the US, Canada, Brazil, and Singapore show strong growth in trademark filings by resident applicants (located inside national borders) early in the pandemic. By the end of June 2020, trademark filings indicate a substantial local response to the pandemic through new product and service introductions. The analysis for Brazil additionally shows that individual micro-entrepreneurs accounted for the fastest growth in trademark activity. More explicit measures of entrepreneurship – presented in the contributions from Australia and the Republic of Korea – confirm a surge in business entries and startup activity in 2021. More generally, many of the contributions in this eBook point to vibrant entrepreneurship unleashed by the crisis riding on the digital technology wave as a general trend. Interestingly, a similar startup boom occurred in the midst of the Spanish flu pandemic in 1919 (Beach et al. 2020), highlighting how societal disruption generates momentum to start new activities for those entrepreneurs willing and able to take the risk amidst high overall uncertainty (see also *The Economist* 2022).

RESPONSES IN THE INNOVATION ECOSYSTEM

The second part of the eBook (chapters 11 to 18) focuses on how different segments of the innovation ecosystem were affected by the COVID-19 pandemic.

Chapter 11 on digital innovation and digital uptake by SMEs uses survey responses to assess the degree to which firms have been adopting new digital technologies as a response to the COVID-19 crisis. On average, both EU and US firms were adopting new digital technologies during the crisis, but the survey also revealed a potential divergence as not all firms were able to take advantage of the new demands for digitisation. In particular, old SMEs in the EU that were already behind the digitisation trend before the COVID-19 crisis were also the least likely to invest in new digital technologies during the crisis.

The potential for the COVID-19 crisis to increase the separation among innovation actors is also evident in the research sector. Looking upstream, Chapter 12 finds that total research time decreased substantially for all academic researchers, but these losses were not uniform across scientific fields of study or types of researchers. The survey evidence presented shows women researchers and researchers with children were heavily affected, which may permanently alter their scientific career opportunities. Moreover, these differences may not be sufficiently addressed, or possibly even accentuated, by some of the policy responses to the crisis by academic institutions.

A next group of contributions zoom in on how the biomedical innovation ecosystem has responded to the crisis. Chapter 13 compares the attention given to COVID-19 and non-COVID life science journal articles using 'altmetrics'. The authors find that attention shifted quickly to COVID-19 publications, which primarily reflected increased references to the pandemic. This came without harm to other non-COVID-19 areas. Moving further downstream to examine evidence from clinical trials, Chapter 14 finds that although experienced drug developers remained the most important sponsors of COVID-19 trials, many COVID trials were started by new firms, again illustrating the vibrant entrepreneurship unleashed by the crisis. The story of the mRNA COVID-19 vaccine, told in Chapter 15, is yet another testimony to the power of entrepreneurship. However, this example also reminds us that obtaining early-stage financial support for innovation can be quite difficult. Only a handful of stubborn scientists, startup entrepreneurs, angel investors and policy officers at the US Defense Advanced Research Projects Agency (DARPA) were willing to fund the high risk of the high-gain mRNA technology in its early years. In hindsight, the COVID-19 vaccines based on mRNA technologies made crucial contributions to overcoming the impacts of COVID-19, but we could easily have missed out on them.

The remaining chapters (16, 17 and 18) look at the creative sector, one of the sectors most affected by the COVID-19 crisis. These chapters confirm that health-related restrictions on social interactions and the increased use of digital technologies affected both the

demand for creative products and the supply of creative works and content. On the demand side, data from the US (Chapter 16) and the UK (Chapter 17) show an increase in the consumption of online content, especially among people facing the most severe lockdown measures. Physical distribution of cultural and creative content, as well as cultural performances, plummeted. The decrease in performances had a substantial adverse impact on the income of many cultural workers, as documented in Chapter 18 for self-employed creative professionals in Germany. In fact, musicians and performing artists were the most negatively affected, highlighting the important differences in the impact of COVID-19 across creative industries. Despite the deep disruptions, Chapter 16 argues that the crisis was not really a critical turning point for the creative economy, but rather it accelerated existing trends in the creation and consumption of creative works.

WHAT TAKEAWAYS FOR POLICY?

The macro evidence emerging from the various contributions suggests that innovation ecosystems proved more resilient to the pandemic relative to previous crises. Whereas the Great Depression, the dotcom crash, and the Great Recession were primarily financial in origin and effect, the COVID-19 pandemic has been a sequence of health and socioeconomic disruptions that altered decision making at all levels of economic activity, but it did so unevenly and to different degrees. Although the knowledge, creativity, and inspiration that drive innovation requires ongoing financial support, it is less dependent on physical location and face-to-face interactions than other economic activities. The people, infrastructure and institutions that make up the innovation ecosystem proved to be more agile and adaptable when faced with COVID-19. This is broadly indicated by the relative performance of IP-intensive industries. Indeed, the analysis of the US economy (Chapter 2) found that the output of IP-intensive industries declined by less than that of other industries.

The policy support provided by governments around the world was a key factor contributing to innovation resilience. Fiscal support measures cushioned the demand shocks, helping businesses to stay solvent and workers to stay employed (Gourinchas et al. 2021). The destruction of productive tangible and intangible capital could have been far worse. Monetary policy support, in turn, enabled the continued availability of financing for innovation (WIPO 2021), even if smaller entities at times continued to experience funding difficulties. Venture capital financing reached all-time highs in 2021 and helped to fuel the entrepreneurship wave described above.⁴

As financial conditions have tightened more recently (through 2022), risk capital has sharply declined. This raises the question of whether the loose monetary conditions and fiscal policies during the crisis generated an unsustainable degree of ‘innovative exuberance’.

4 See <https://news.crunchbase.com/business/global-vc-funding-unicorns-2021-monthly-recap> and *The Economist* (2021).

Aside from these macro considerations, the eBook chapters point to the following takeaways for public policy:

- Innovation systems were responsive to the evolving needs of societies. The successful commercialisation of COVID-19 vaccines may be the most visible contribution in this respect. However, the response was broader and extended to the uptake of digital technologies that were in great demand as countries implemented lockdown measures.
- The IP system played a useful role in enabling a market-driven response to the crisis, offering the prospects for returns to innovation investments and facilitating the introduction of new goods and services. It will be important to continue efforts to broaden the IP ecosystem by providing education and increasing awareness among innovators, particularly those in underrepresented communities, of the potential advantages of IP protections, both domestically and internationally.
- In addition, IP assets such as patents, trademarks and copyrights can be used to store and trade value during times of uncertainty. This feature of IP helped innovators to maintain their innovative strategies during the pandemic. However, markets for licensing and trading IP assets remain poorly understood and are not well developed, particularly for SMEs. By creating appropriate framework conditions underpinning the smooth functioning of these markets, public policy could further strengthen the resilience of innovation ecosystems.
- While innovation has been instrumental in finding solutions to the crisis, policymakers should not take the resilience and responsiveness of the innovation system for granted. Chapter 16 on the mRNA technology underlying two of the most successful COVID-19 vaccines finds that this technology could have been easily missed by a short-sighted, risk-averse innovation support system. To be able to count on the innovation system to quickly deliver powerful solutions to societal challenges, innovation policy should take a longer-term, proactive perspective, supporting new ideas which have the potential to become breakthroughs in their early high-risk phases. Continuous investments in scientific research remain crucial in generating the knowledge underlying technological breakthroughs.
- International collaboration amongst scientific researchers, institutions and innovating companies was another key success factor in responding to the crisis. However, concerns may well arise about the continued openness of national innovation systems as the era of hyper-globalisation appears to draw to an end. Governments around the world are now considering – partly as a result of the pandemic – more inward-looking industrial policies to ensure more sovereignty and autonomy on technologies considered to be strategic. There is a risk in this new context that less international collaboration could slow scientific and technological progress everywhere.

- Notwithstanding the picture of resilience emerging from many of the chapters, some innovation actors have clearly experienced adverse effects. In particular, Chapter 11 on digital innovation finds that the overall gap in technological capabilities has widened as a result of the crisis, with SMEs especially at risk of persistently lagging behind. Chapter 12 on the academic research enterprise finds that researchers with childcare obligations – especially women – had less time available for research, with possibly long-term career implications. Addressing such adverse outcomes is a policy imperative for the years to come.

OUTLOOK

This eBook draws a largely positive conclusion on how innovation fared during the COVID-19 crisis. This stems from both how the innovation system contributed to overcoming the crisis and how innovators proved resilient to the pandemic's disruptions. Overall, the COVID-19 innovation response holds important lessons not only for future pandemic preparedness, but also for other mission-oriented innovation policies needed to address long-term societal challenges, notably climate change.

It is important to point out, however, that the crisis is not over at this time (June 2022) and our understanding of its ramifications will remain imperfect for some time to come. For one, while most countries have lifted many of the public health measures put in place to stem the pandemic, COVID-19 mutations are still spreading around the world. For instance, China's economy has seen widespread disruptions in the first half of 2022. There may also be renewed waves of infection once the Northern Hemisphere enters the colder seasons. The management of future infection waves may cause less disruption than during the pandemic's first two years – thanks in large part to recent innovation in biomedical and digital solutions. However, it will surely continue to leave a mark on innovation systems.

More research is needed to deepen our understanding of how innovators responded to the crisis. How do companies reshuffle and prioritise their R&D and IP activities as revenues decline and uncertainty about markets increase? How will the accelerated adoption of digital technologies, changes in workplace practices, and other lasting disruptions prompted by the crisis affect the performance of innovation ecosystems? In addition, a full assessment of the impact of the pandemic will need to consider the contraction of innovation finance seen so far in 2022, and in which ways the policy support measures – especially generous monetary and fiscal measures – may have contributed to unsustainable 'innovation exuberance'.

As explained in Chapter 1 on the international IP filing response, IP offices typically publish patent applications with a delay of 18 months after their filing. Thus, patents for inventions that took place after March 2020 only started to become public in September 2021. Studies analysing the rich bibliographical data contained in those patent documents – including technology fields, applicants and inventors – have only become meaningful in

2022 and beyond. It is our hope that such studies can shed further light on how different innovation stakeholders reacted to the crisis, how firm and inventor collaboration evolved in the course of the crisis, and whether the gender gap in patenting widened or narrowed as a result of the pandemic.

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PART I

Impact across the world:

Much similarity, some divergence

CHAPTER 1

How the COVID-19 crisis affected international intellectual property filings

Carsten Fink, Ryan Lamb, Bruno Le Feuvre and Hao Zhou

World Intellectual Property Organization

The COVID-19 crisis prompted sudden and profound changes in innovation practices and strategies. While many of these changes concerned homegrown activities, innovators also adjusted their international outlook. In this chapter, we look at this latter dimension through the lens of international patent and trademark filings. We will do so, in part, by comparing the evolution of international intellectual property (IP) filings in the course of the pandemic to previous economic crises. The emerging trends and patterns provide useful insights, not only into how innovators responded but also more broadly into the very nature of the crisis.

INTERNATIONAL PATENT APPLICATIONS

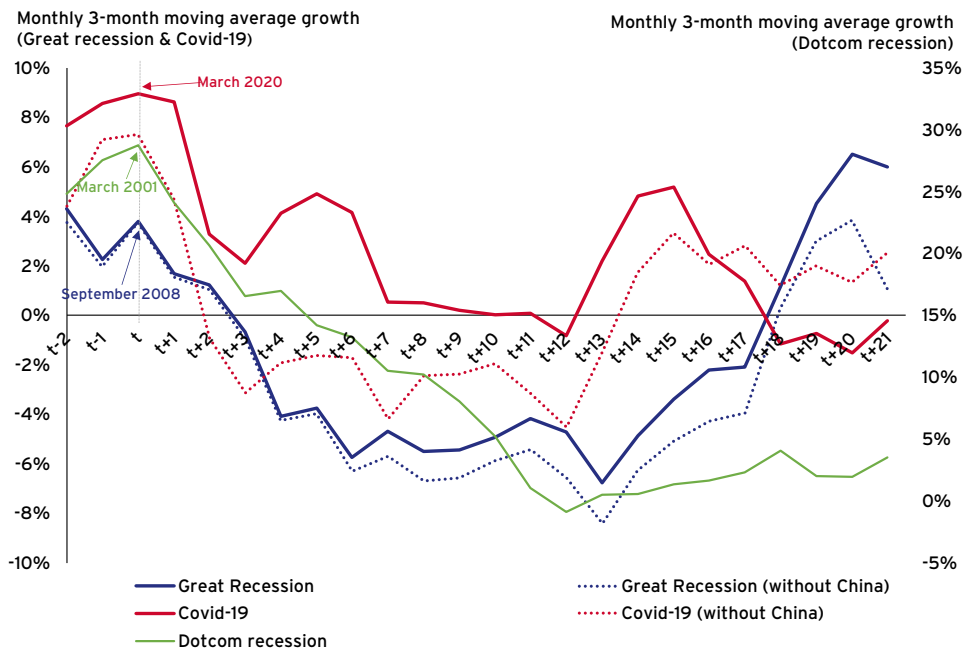
During previous crises, international patent filings decelerated and declined in some proportion to economic output (Figure 1). Pressure on corporate IP budgets, curtailed innovation financing and subdued startup activity have been the main transmission channels (e.g. Hardy and Sever 2020). The COVID-19 crisis was no different in this respect. International patent filings were growing exceptionally fast at the outset of the crisis, but decelerated quickly from March 2020 onwards and settled at around zero growth 12 months into the crisis. However, the overall crisis impact seems more muted in the case of the pandemic compared to the Great Recession of the late 2000s and the bursting of the dotcom bubble in the early 2000s.

What explains this more muted crisis response? One key difference is that applications from China have grown to account for one-fifth of overall international patent applications, combined with the fact that Chinese applications kept growing at a high rate, especially throughout 2020.¹ Removing Chinese applications from the total shows a crisis path that is, in fact, similar to that of the Great Recession (Figure 1). One may still consider the COVID-19 trend to look favourable compared to the Great Recession, given

¹ International patent applications from China have declined from July 2021 onwards. However, this reflects the phase-out of patent filing subsidies as announced by the Chinese government (see https://english.cnipa.gov.cn/art/2021/5/20/art_1340_159520.html).

that the overall economic output decline was steeper for the former than for the latter.² The unique sectoral impact of the COVID-19 crisis – with relatively more innovation-intensive service activities less heavily hit – may be one explanation. In addition, financing for innovation continued to be available throughout most of the pandemic, except in the initial stages of the crisis when overall financial market uncertainty briefly soared (WIPO 2021: 16). This differed notably from the Great Recession, where broader financial market turbulence curtailed innovation financing, and the dotcom crisis, which resulted directly from exuberance in innovation finance.

FIGURE 1 INTERNATIONAL PATENT APPLICATIONS IN CRISIS TIMES



Notes: International patent applications refer to applications filed in the international phase of the Patent Cooperation Treaty (PCT). The figures presented are monthly three-month moving average growth rates relative the same period in the previous year. Patent counts are based on the international filing date of PCT applications, either at national/regional patent offices or directly at WIPO.

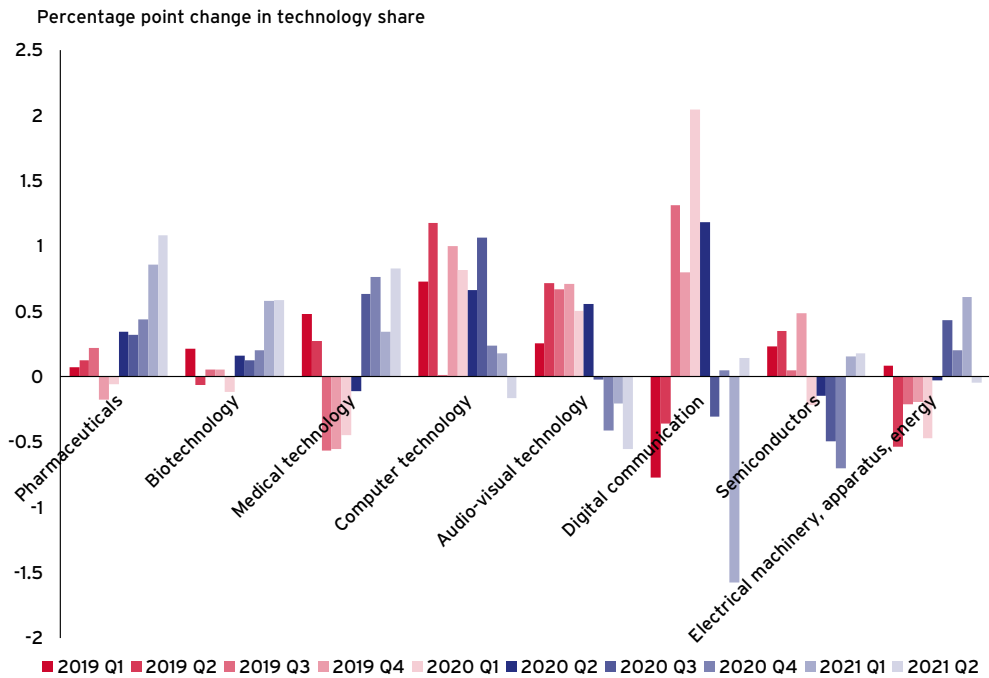
Source: WIPO IP Statistics Database.

Did the COVID-19 crisis prompt a shift in the kinds of technologies for which innovators sought international patent protection? The nature of the crisis response – in which technological innovation played a central role – makes this an especially relevant question. Figure 2a depicts the percentage point changes in the share of selected technology fields in the quarters preceding the onset of the pandemic and the quarters thereafter. It shows that the three health-related technology fields – biotechnology, medical technology

² According to the IMF, real GDP declined by 0.1% in the world in 2009, compared to 3.1% in 2020; for advanced countries, the declines were 3.3% in 2009 and 4.5% in 2020 (see https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/OEMDC/ADVEC/WEOORLD).

and pharmaceuticals – saw their share of international patent applications increase. This increase came to some extent at the expense of information and communication technologies – notably, audiovisual technology and digital communication – that were among the fastest growing fields before the pandemic and then saw declining filing activity in the months following the pandemic’s onset.

FIGURE 2A THE RESPONSE ACROSS TECHNOLOGY FIELDS (BY INTERNATIONAL FILING DATE, QUARTERLY)



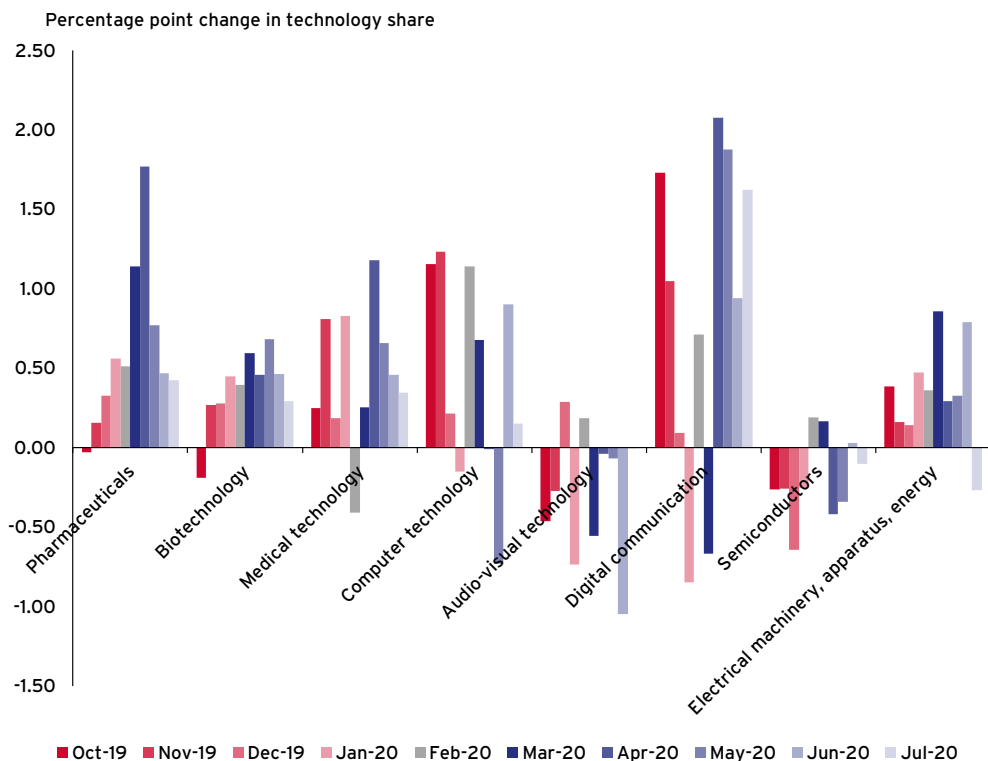
Notes: Percentage point changes are relative to the share of a given technology field in total international patent applications filed in the same quarter of the previous year. As technology fields are only available once PCT applications are published, the shares shown are estimates that take into account historical publication delays in different technology fields. The technology fields presented are the one that experienced the largest changes among the top 20 technology fields. The incompleteness of technology fields explains why share changes do not sum to zero.

Source: WIPO IP Statistics Database and WIPO (2022).

That health-related technology fields showed the greatest dynamism in the course of the pandemic may seem logical. But it is not entirely obvious. Most international patent applications under WIPO’s Patent Cooperation Treaty are based on so-called priority applications that are filed up to 12 months before in national or regional patent offices. In other words, the inventions underlying most of the international patent applications filed in 2020 and early 2021 predate the pandemic. The shift in technology fields illustrated in Figure 2a thus primarily reflects a shift in the desire of patent applicants to seek protection for their inventions beyond their national borders. One way to interpret this shift is that the pandemic has led innovators to reassess the commercial potential of their inventions, with upgraded prospects for health-related technologies.

One can assess the invention response to the pandemic by looking at international patent applications according to their date of priority filing. However, the time window for doing so is still narrow. To illustrate, BioNTech filed a priority patent application on its coronavirus vaccine at the European Patent Office (EPO) on 22 April 2020. The company then filed an international patent application based on this EPO priority patent on 16 April 2021.³ WIPO published the international patent application on 28 October 2021. This timeline is typical – it takes about 18 months from the date of priority filings for international patent applications to see the light of day. This means that detailed information on international patent applications for inventions that took place after March 2020 – the onset of the pandemic – only started to emerge in the final quarter of 2021.

FIGURE 2B THE RESPONSE ACROSS TECHNOLOGY FIELDS (BY PRIORITY FILING DATE, MONTHLY)



Notes: Percentage point changes are relative to the share of a given technology field in total international patent applications filed in the same month of the previous year, whereby the filing date is the earliest priority date. The technology fields presented are those presented in Figure 2a. The incompleteness of technology fields explains why share changes do not sum to zero.

Source: WIPO IP Statistics Database and WIPO (2022).

3 See WO/2021/213924. Note that the international patent application lists additional priority applications filed at the EPO after 22 April 2020.

Figure 2b depicts the percentage point share changes in the same technology fields as in Figure 2a, but based on the priority filing date of international patent applications. In addition, due to the more limited time window, it presents monthly rather than quarterly changes up to July 2020. The share changes similarly suggest a growing share in the health-related technology fields. Except for pharmaceuticals, however, there is no visible structural break that could be attributable to the onset of the pandemic. Neither is there such a break for the other technology fields – except possibly digital communication, which saw strong growth in the months following the pandemic’s onset. However, a fuller assessment of the invention response to the crisis will invariably need to await the availability of additional data following the pandemic’s onset.

INTERNATIONAL TRADEMARK APPLICATIONS

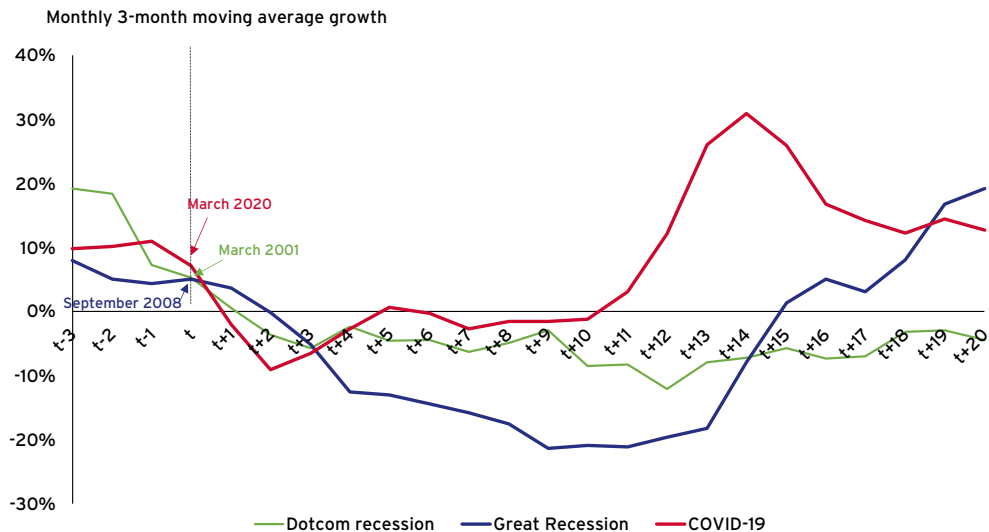
Applications for trademark applications capture the introduction of new goods and services as well as the creation of new companies. Historically, trademarks have been the IP form for which applications have correlated most closely with the business cycle. Research even suggests that trademark filings are a leading indicator of recessions (deGrazia et al. 2019). Figure 3 depicts the evolution of international trademark filings in the course of the three crises discussed earlier.⁴ There is broad similarity in the initial response to the crisis onset – a sharp decline in applications. However, there are considerable differences in the recovery paths. In the case of the dotcom crisis, it took around two years – beyond the period covered in Figure 2 – for international trademark applications to grow again. The Great Recession saw the steepest decline, but a strong recovery after just over a year. The COVID-19 crisis stands out in showing the shallowest decline, followed by an extraordinary boom in international trademark applications about a year into the crisis.

What is behind this trademark boom? The recovery of the global economy following the steep decline in economic output in 2020 is clearly the driving force. At the same time, the demand for international trademarks during the crisis also reflects the commercialisation of new goods and services that are directly linked to the pandemic and its disruptions. This is most visible for personal protective equipment (PPE). Figure 4 shows a sharp increase in the number of international trademark applications in Nice class 10 – encompassing “surgical, medical, dental and veterinary apparatus, instruments and articles generally used for the diagnosis, treatment or improvement of function or condition of persons and animals”. Going further, Table 1 presents the top ten keywords in the goods and services descriptions of trademarks in class 10 that have seen the largest

⁴ Similar to many PCT applications, international trademark applications filed under WIPO’s Madrid System are based on earlier applications – so-called basic mark filings – in national and regional trademark offices. In most cases, brand holders file their international trademark applications within six months of their basic mark application.

absolute increases in 2020 and 2021. The large increases for “masks”, “protection”, “face”, “gloves” and “sanitary” showcase the commercialisation of PPE in the course of the pandemic.

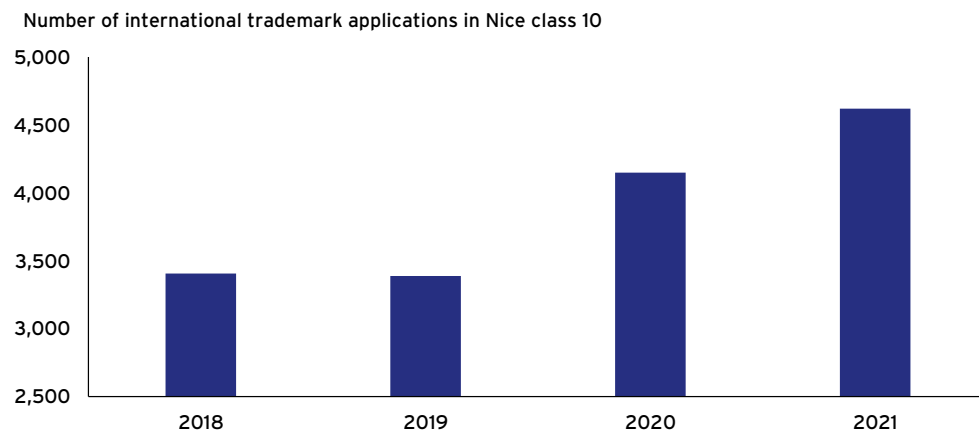
FIGURE 3 INTERNATIONAL TRADEMARK APPLICATIONS IN CRISIS TIMES



Notes: International trademark applications refer to applications filed under WIPO's Madrid System. Figures are presented according to the Madrid filing date.

Source: WIPO IP Statistics Database.

FIGURE 4 COMMERCIALISATION OF PPE VISIBLE IN TRADEMARK FILINGS



Notes: International trademark applications refer to applications filed under WIPO's Madrid System. Figures are presented according to the Madrid filing date.

Source: WIPO IP Statistics Database.

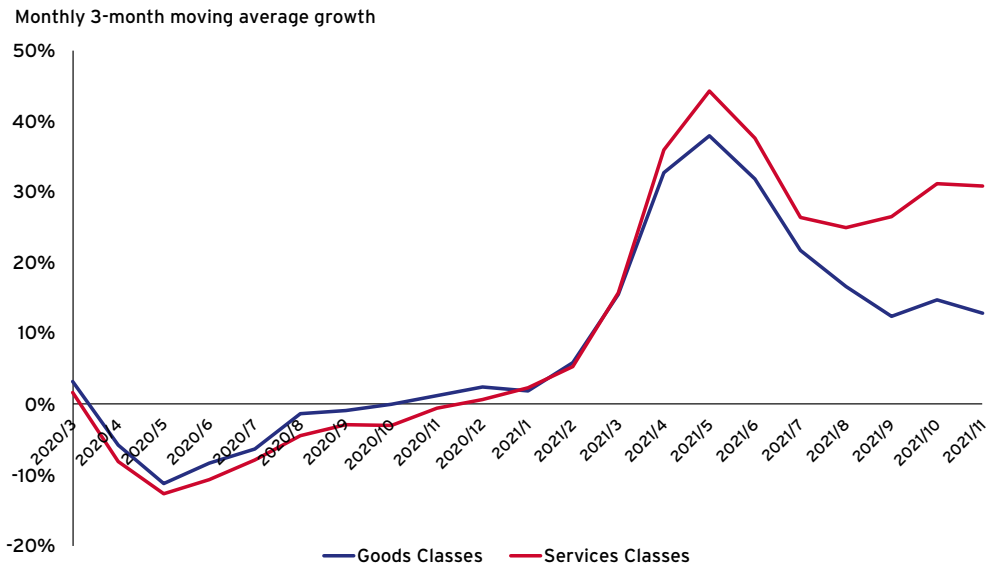
TABLE 1 KEYWORD COUNTS IN NICE CLASS 10

| Keyword | 2019 | Average 2020-2021 | Increase |
|----------------|-------------|------------------------------|-----------------|
| medical | 12,924 | 17,601 | 4,677 |
| masks | 342 | 2,100 | 1,758 |
| surgical | 3,133 | 4,056 | 923 |
| protection | 356 | 1,222 | 866 |
| diagnosis | 1,418 | 2,017 | 599 |
| face | 188 | 694 | 506 |
| gloves | 283 | 764 | 481 |
| sanitary | 45 | 472 | 427 |
| personal | 251 | 659 | 408 |
| therapeutic | 1,163 | 1,520 | 357 |

Notes: Keyword counts refer to the number of times different keywords appear in the goods and services descriptions of international trademark applications, confined to class 10. The keywords shown are the top ten keywords with the largest increases from 2019 compared to the average of 2020 and 2021, ignoring words - such as conjunctions and prepositions - that do not by themselves contribute meaningfully to the descriptions.

Source: WIPO IP Statistics Database.

However, the commercialisation of new goods and services prompted by the crisis goes far beyond PPE. Indeed, Nice class 10 accounts for less than 3% of total international trademark applications and it cannot account for the extraordinary increase in applications in 2021. While most Nice classes experienced rapid growth in 2021, the economic recovery prompted particularly strong growth in trademarks for new services (Figure 5). This may, at first, seem surprising. The pandemic’s containment measures have generally shifted consumption patterns towards goods and away from services (de Soyres et al. 2022). But it may precisely be the disruptions in the service sector that have given rise to particularly fast product innovation.

FIGURE 5 TRADEMARK SERVICE CLASSES SEE PARTICULARLY FAST GROWTH

Notes: International trademark applications refer to applications filed under WIPO's Madrid System. Figures are presented according to the Madrid filing date and, in contrast to Figure 3, refer to application class counts. Goods classes include Nice classes 1-34; services classes include Nice classes 35 to 45.

Source: WIPO IP Statistics Database.

No single service class explains the faster services over goods growth. Financial services, telecommunications services and transport services saw the fastest growth, but hospitality, medical services and R&D services also outpaced growth for goods trademarks. The broad definition of service classes in the trademark system make it difficult to further pinpoint the service activities with the fastest growth. However, it is again insightful to look at trends in keywords used in the description of services contained in trademark applications. Table 2 lists the top 20 keywords that registered the largest increases from 2020 to 2021. The top four keywords – “software”, “computer”, “information”, and “online” – and several others among the top 20 suggest what may be loosely described to as a shift towards digitalisation and ecommerce.⁵ This attests to the special nature of the COVID-19 crisis and the crisis recovery, with economic disruptions and accelerated adoption of digital technology prompting an especially fast rate of new goods and services entering the marketplace.

5 Ragoussis and Timmis (2022) draw similar conclusions analysing website birth dynamics and the uptake of website technology.

TABLE 2 KEYWORD COUNTS IN SERVICES CLASSES

| | 2020 | 2021 | Increase |
|-------------|-------------|-------------|-----------------|
| computer | 61,247 | 74,026 | 12,779 |
| software | 44,348 | 60,042 | 15,694 |
| information | 45,661 | 58,106 | 12,445 |
| online | 31,082 | 42,368 | 11,286 |
| management | 32,104 | 39,570 | 7,466 |
| data | 28,031 | 36,248 | 8,217 |
| consultancy | 27,096 | 33,869 | 6,773 |
| design | 25,317 | 33,164 | 7,847 |
| advertising | 29,642 | 32,933 | 3,291 |
| development | 23,065 | 29,683 | 6,618 |
| electronic | 22,926 | 28,851 | 5,925 |
| research | 23,071 | 28,575 | 5,504 |
| retail | 19,970 | 27,910 | 7,940 |
| field | 20,394 | 27,738 | 7,344 |
| rental | 22,707 | 26,874 | 4,167 |
| internet | 18,248 | 22,906 | 4,658 |
| network | 18,655 | 22,449 | 3,794 |
| provision | 17,634 | 21,658 | 4,024 |
| financial | 14,771 | 21,384 | 6,613 |
| education | 17,752 | 21,355 | 3,603 |

Notes: Keyword counts refer to the number of times different keywords appear in the goods and services descriptions of international trademark applications in Nice classes 35 to 45. The keywords shown are the top ten keywords with the largest increases from 2020 to 2021, ignoring words - such as conjunctions and prepositions - that do not by themselves contribute meaningfully to the descriptions.

Source: WIPO IP Statistics Database.

CONCLUSION

Viewed through the lens of international IP filings, the COVID-19 pandemic has mirrored previous economic crises in one respect: it has prompted a temporary downturn in IP activity. At the same time, the downturn caused by the pandemic appears shallower compared to past crises and relative to overall output declines. In addition, the evidence presented in this chapter suggests that innovation responded in a way that reflects the unique nature of the pandemic. Patent data indicate an almost immediate uptick in patenting for health-related technologies, although it remains too early to assess the true invention response to the pandemic. In addition, trademark data point to extraordinary dynamism in the introduction of new goods and services, fostered by the pandemic's disruptions and the accelerated adoption of digital technologies.

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CHAPTER 2

Immunity to the COVID-19 shock? The case of US innovation

27

Walter G. Park, Andrew A. Toole, Gerard Torres and Richard D. Miller
American University; US Patent and Trademark Office (USPTO); USPTO; USPTO

1 INTRODUCTION

The coronavirus pandemic has created much hardship in health and care for families and communities, strained hospital facilities, disrupted school systems, and restricted travel and other social activities. The economic consequences have also been dire. The temporary ‘lockdowns’ of several business operations, schools, and certain services that were put into place to help contain the virus led immediately to a sharp recession, with double-digit unemployment rates not seen in decades.¹ The economic effects still linger in early 2022, with inflationary pressures brought about by disruptions to supply chains, labour shortages, and many pandemic restrictions that are still in effect.²

Yet, amid all the economic upheaval, innovation in the US economy has shown remarkable resilience. Research and development (R&D) investments by companies, flows of inventions, and new company formations have been robust. In this chapter, we analyse the performance of US innovation during the COVID-19 era. We present data on R&D, patenting, and trademark applications and discuss the factors that helped to maintain the strength of US innovation during the pandemic.

Three takeaways about the COVID-19 experience and innovation in the US are:

- The output of goods and services in industries that use patents, trademarks, and copyrights intensively experienced less of a decline than in other industries.
- Investments in knowledge (e.g. R&D) showed greater stability than investments in physical capital as economic uncertainty increased due to the pandemic.
- The ability to obtain intellectual property protection allowed companies to store value and recoup investments in knowledge, but recoupment opportunities vary by technological field.

1 Information on the dates that US states implemented shelter-in-place orders is available from the Kaiser Family Foundation at www.kff.org/policy-watch/stay-at-home-orders-to-fight-covid19/.

2 The Census Bureau, through its Small Business Pulse Survey (SBPS), has been monitoring the economic impacts (Buffington et al. 2021a). The survey makes clear the *heterogeneity* across industry groups. For example, construction and finance and insurance have been able to return to normal operations much sooner than manufacturing and accommodation and food services.

US companies that invest in knowledge-generating activities, rely more heavily on high-skilled labour and use relatively more intellectual property weathered the COVID-19 recession substantially better. Part of the reason is that lockdown policies differentially hurt companies that rely on face-to-face business relationships by suddenly and dramatically reducing the demand for their products and services. Other policies, such as Operation Warp Speed, the Coronavirus Aid, Relief, and Economic Security (CARES) Act, and the Paycheck Protection Program, provided trillions in loans and grants to stimulate vaccine research, help American citizens, and prop up US businesses.³ However, innovative companies enjoyed another ‘shot of immunity’ stemming from the nature of knowledge investments and intellectual property. Investments in knowledge such as R&D are often directed at longer-term competitive objectives as opposed to meeting immediate customer needs. The information gleaned from these investments tends to be more adaptable than physical structures and equipment that result from tangible capital investments. The results from investments in knowledge can often be repurposed and recovered, and are therefore not necessarily lost or sunk costs. Moreover, intellectual property can be used to store value during times of uncertainty. Patents, trademarks, and copyrights are tradeable assets that can be held to be sold in the future when economic circumstances improve.

To investigate the overall performance of US companies that innovate, we examine real gross output (in 2012 dollars) produced by companies in intellectual property (IP)-intensive industries against that of non-IP-intensive industries during the time of COVID-19 (Figure 1).⁴ We normalise real gross output to the fourth quarter of 2019, giving that quarter an indexed value of one for IP-intensive industries, non-IP-intensive, and the overall economy (i.e. the combined IP-intensive and non-IP-intensive industries). This quarter was chosen because the first cases of infection in the US occurred in January of 2020 and segments of the country started going into lockdown in March of 2020.⁵

Figure 1 shows that companies in IP-intensive industries suffered a smaller output loss following the initial COVID-19 shock than did the non-IP-intensive industries. Signs of economic trouble emerged around the end of the first quarter of 2020, so that by the second quarter of 2020, the US economy experienced recessionary pressures from business shutdowns, job losses, and consumer pessimism.⁶ In the second quarter of 2020, output in IP-intensive industries was a little over 90% of what it was in the last quarter of 2019; however, output in non-IP-intensive industries was about 85% relative to the last quarter of 2019. Both IP-intensive and non-IP-intensive industries gradually recovered

3 See The White House (2021) for discussions of these policies.

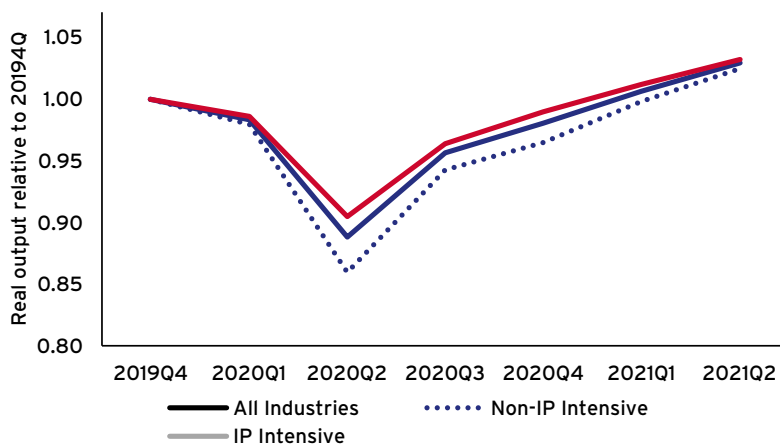
4 IP-intensive industries include the patent-intensive industries such as chemicals, electrical and electronic equipment, computers and communications equipment, medical devices, motor vehicles, ship, railroad, and aerospace building; copyright-intensive industries such as sound recordings, motion pictures, software publishing, newspapers, radio and television broadcasting, data processing; and trademark-intensive industries such as manufacturing and services (overlapping with copyright and patent industries). For more about US IP-intensive industries, see Economics and Statistics Administration and USPTO (2012).

5 The U.S. Centers for Disease Control and Prevention COVID Data Tracker contains extensive information on COVID-19 cases, deaths and more (<https://covid.cdc.gov/covid-data-tracker/#demographicsovertime>).

6 For a chronology of US business cycle events, see www.nber.org/research/business-cycle-dating.

their output of goods and services. By early 2021, the IP-intensive industries reached the same level of real output as in the last quarter of 2019. The non-IP-intensive industries would do so by the end of the first quarter of 2021.

FIGURE 1 US REAL GROSS OUTPUT



Note: Gross real output by industry. The gross output measure, seasonally adjusted at annual rates, is used, and converted into real 2012 dollars using its chain-type price index.

Source: Authors' calculations based on US Bureau of Economic Analysis Interactive Tables (www.bea.gov).

2 THE US INNOVATION EXPERIENCE, 2019-2021

2.1 Knowledge investments: R&D

From our snapshot look at real output, companies that innovate appear to stand apart from the general economy. Digging deeper into the different kinds of investments companies can undertake – namely, investments in R&D versus investments in physical capital – we observe further distinguishing features of innovation, particularly its relative stability over the business cycle.

Data on R&D and physical capital investments were obtained from 652 leading patenting companies in the US. These companies accounted for 83.3% of private sector R&D in 2019.⁷ Looking at this group of companies permits a comparison between intangible and tangible investment behaviour. Indeed, Table 1 shows a contrast in behaviour between physical capital investment and investments in R&D.⁸ First, it is apparent that the rate of physical capital investment is far more volatile than R&D. The rate of capital investment to sales fluctuated from -12.3% to 27.6%, while the rate of R&D to sales remained within the range of 7.3% to 8.5%.⁹

⁷ For this calculation we used Table 2 of the National Science Foundation (NSF) National Patterns of R&D Resources 2019-2020 Data Update, which reports that business R&D was \$443.6 billion (in real 2012 dollars) in 2019. The companies in our dataset accounts for over four-fifths of this amount.

⁸ The sources of data are in the appendix table.

⁹ The negative value of capital investment is attributable to gross investment being less than capital depreciation.

TABLE 1 INVESTMENT RATES: PHYSICAL CAPITAL INVESTMENT VERSUS R&D

| | Rate of physical capital investment to sales | Rate of R&D investment to sales |
|---------------------------------|----------------------------------------------|---------------------------------|
| 2019:Q1 | 10.3 | 7.7 |
| 2019:Q2 | 1.9 | 7.4 |
| 2019:Q3 | -1.6 | 7.3 |
| 2019:Q4 | 14.9 | 7.5 |
| 2020:Q1 | 27.6 | 8.1 |
| 2020:Q2 | -12.3 | 8.5 |
| 2020:Q3 | -4.5 | 7.8 |
| 2020:Q4 | 17.2 | 7.6 |
| 2021:Q1 | -3.4 | 7.8 |
| 2021:Q2 | 3.3 | 7.6 |
| 2021:Q3 | 1.8 | 7.5 |
| <i>Mean</i> | 5.0 | 7.7 |
| <i>Standard deviation</i> | 11.5 | 0.3 |
| <i>Coefficient of variation</i> | 2.3 | 0.04 |

Notes: R&D is research and development expense; physical investment is the change in the stock of capital. The mean, standard deviation, and coefficient of variation are calculated over the period shown. The coefficient of variation equals the ratio the standard deviation to the mean, an indicator of the volatility (or spread) in the investment rates relative to the average investment rate. The bolded rows mark the period of the initial COVID-19 shock on business operations.

Source: S&P Capital IQ (www.capitaliq.com).

The relative volatility can be measured more formally with the coefficient of variation, which shows the ratio of the standard deviation (a common measure of the fluctuation or spread in values) to the mean.¹⁰ Whereas the coefficient of variation for the rate of physical capital investment is 2.3 – meaning that the amount of fluctuation in the rate of investment was more than twice that of the average physical capital investment rate – the coefficient of variation for the rate of R&D investment is only 0.04; that is, the amount of fluctuation was largely within 4% of the mean rate of R&D investment.

¹⁰ Dividing by the mean is especially useful since it makes the coefficient of variation scale-free. Standard deviations depend on the unit of measurement. It is best to view the spread in values relative to the mean to gain perspective.

The smoothness of R&D compared to physical capital investment can be partly explained by adjustment costs, particularly related to R&D employment.¹¹ However, it can also be explained by the opportunity to transfer R&D outcomes into valuable IP assets. These assets can be sold or licensed, making knowledge investments relatively more reversible (i.e. easier to recoup). Economic theory shows the value of postponing investments tends to increase as uncertainty rises, particularly for less reversible investments such as many forms of physical capital (e.g. buildings, and equipment).

A second notable aspect of the results is that investment in physical capital declined while that of R&D increased during the COVID-19 recession (see the second quarter of 2020 in Table 1). The rate of physical capital investment declined further in the third quarter of 2020 before rebounding in the fourth quarter of that year. The rate of R&D investment held steady as these fluctuations in physical capital investment occurred. By the third quarter of 2021, the rate of physical capital investment was still lower than at the start of the pandemic recession. The rise in R&D investment to sales in the second quarter of 2020 reflects investments in the health care, as medical devices and pharmaceutical companies responded to the spike in demand caused by COVID-19 and participated in emerging responses (e.g. Operation Warp Speed). It also reflects the COVID-driven shift in market demand from face-to-face transactions to digital commerce. Remote work and schooling increased the demand for digital tools for business and education.

2.2 Patenting

Turning to patents, we focus on the number of utility (or ‘invention’) patent applications filed at the US Patent and Trademark Office (USPTO) in three technological areas: digital, health, and all other ‘traditional’ technologies. Each area is defined by grouping patents using their technology classification assigned by the USPTO under the Cooperative Patent Classification (CPC) system.¹²

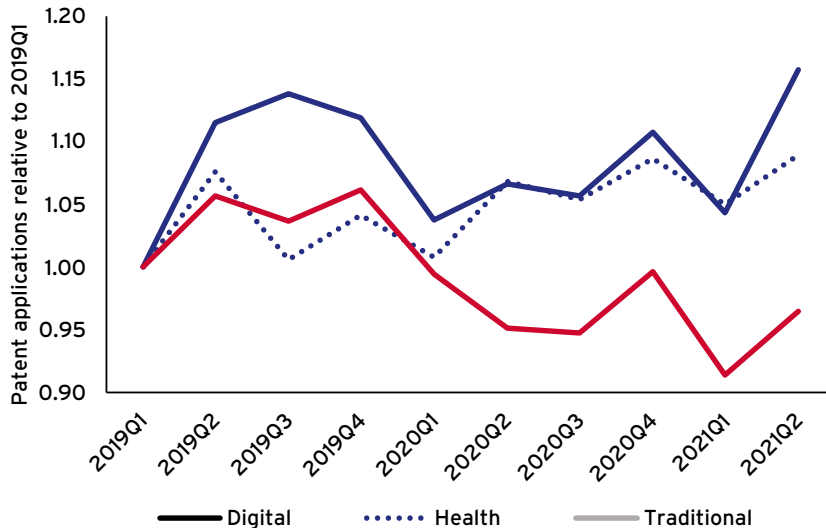
Figure 2 anchors the graphs of patent applications to the first quarter of 2019; that is, the applications are indexed to one (by dividing through by the number of applications filed in the first quarter of 2019). Thus, the graphs represent the growth of applications over time and indicate whether, at any given point, applications were higher or lower than they were in the first quarter of 2019. Consistent with the developments in R&D, the figure shows that patent applications in the digital and health areas by US-based inventors rose shortly after the COVID-19 recessionary shock. Patenting in these fields continued to stay robust during the summer of 2020 and grew faster by the fourth quarter of 2020, just before the vaccination rollout. We observe differences across technological fields. During the initial and later pandemic periods, the number of patent applications from

11 Laying off and rehiring high-skilled R&D workers imposes substantial adjustment costs on companies.

12 Applications are classified using the most recent, first-listed CPC symbol for the application's patent family. CPC symbols are mapped to WIPO technology classification using a concordance provided by WIPO and in some instances supplemented by our judgement. Information on the classification of the technology in the application as well as data on the applicant and assignee of the application are only available through the end of June 2021. This limitation does not apply to the trademark application data.

the traditional technologies remained below what they were in the first quarter of 2020. In contrast, patenting in digital and health technologies are above pre-pandemic levels in the second quarter of 2021 and greater than in the first quarter of 2020.

FIGURE 2 PATENT APPLICATIONS FROM US-BASED INVENTORS BY INDUSTRY GROUP



Notes: Utility (invention) patent applications filed by receipt date, the date which the application is initially submitted to USPTO. The first-listed CPC symbol for each application is used to classify each application. Origin counts are fractionalised based on each inventor's country code in their mailing address.

Source: Author's calculations based on data from USPTO's Patent Location and Monitoring system (PALM).

Our findings are consistent with Davis et al. (2021), who compare the effects of the COVID-19 recession on employment between STEM (science, technology, engineering, and mathematics) occupations and non-STEM ones. While their focus is on education, interesting parallels can be drawn between STEM education and patent activity, both being important for innovative knowledge-intensive companies. Their study finds STEM employment was more resilient against the effects of the recession. Accounting for various factors that could underlie employment differences between the two broad occupation categories – such as demographics, educational attainment, remote work feasibility, geographic location, among others – the authors find ‘STEM knowledge on the job’ to be the critical factor.¹³ Possession of such knowledge enables workers to find and retain jobs that require fewer routine or manual tasks, making them less vulnerable to trends in automation and job retrenchment during downturns.

¹³ The study uses the O*NET database to derive a measure of the importance of STEM knowledge by occupation. The six STEM knowledge areas considered are: computers, engineering, mathematics, physics, chemistry, and biology. Survey questions would ask respondents how important each of these kinds of knowledge is to the performance of a job.

Davis et al. (2021) also present data on R&D employment, expenditures, and patent applications. The study shows that employment in R&D-intensive industries fell less than overall STEM employment during the first quarter of 2020, followed by a quick recovery.¹⁴ Likewise, R&D spending and patenting also fell during that quarter or shortly thereafter, and then rebounded quickly. The study infers that COVID-19 had a mild effect on US inventive activity and the authors conclude that this was “possibly enabled by STEM employment resiliency” (Davis et al. 2021). Their findings are consistent with our analyses of R&D, patenting, and the characteristics that help make US innovation more resilient, particularly the role of IP assets.

2.3 Trademark filings

Trademarks are commonly associated with the creation and protection of brands, but researchers have also highlighted the usefulness of trademark data as an indicator of innovation and entrepreneurship (Flikkema et al. 2014, Dinlersoz et al. 2018, Castaldi et al. 2020, deGrazia et al. 2020). Compared to patents, trademarks provide a broader signal of innovation by covering more segments of the US economy. For instance, out of 210 US industries considered in a recent USPTO report, 110 are trademark-intensive while only 70 are utility patent-intensive (Toole et al. 2022). Moreover, companies can design and apply for trademarks relatively quickly in response to product- and market-specific business conditions, making trademarks a potential leading indicator of economic outcomes (deGrazia et al. 2020).

The association between trademarks and entrepreneurship largely reflects the use of trademarks by new businesses. Dinlersoz et al. (2018) find that the probability of applying for a trademark for the first time, across all industries, was highest for startups and younger companies less than five years old. During the dot.com boom of the late 1990s, applications for trademarks surged (Graham et al. 2013). This coincided with a surge in new business formations, particularly in the ‘High Tech’ area, according to Goldschlag and Miranda (2016). Trademarks declined sharply in 2007 at the onset of the Great Recession, as did new employer businesses (Dinlersoz et al. 2018, 2021).

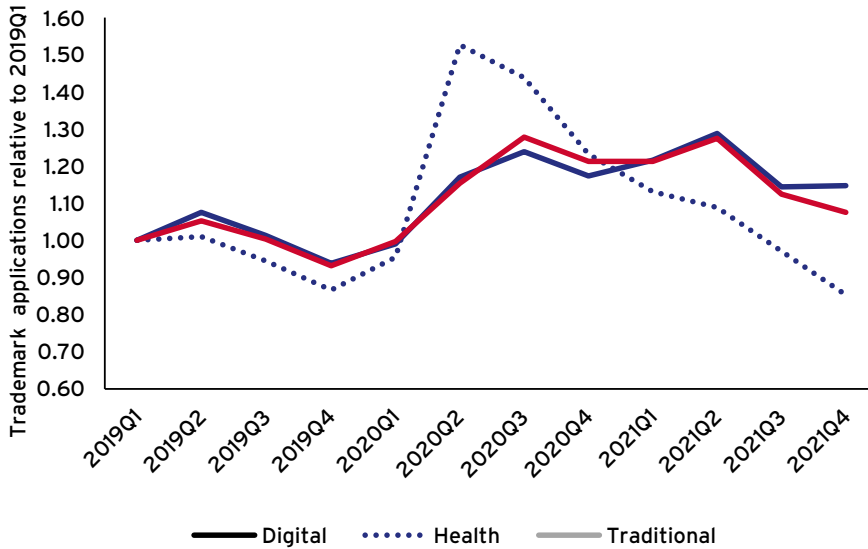
Figure 3 presents trademark applications in goods and services categories that correspond to our three areas of technology: health, digital, and traditional. The filing trends in the US were relatively stable just prior to the pandemic in 2019. They started to edge up at the earliest onset of the pandemic, in the first quarter of 2020. The early trademark response probably reflects decisions by US businesses to pivot production and modes of product and service delivery in response to the emerging pandemic.¹⁵ However, as the pandemic progressed, trademark application filings rose significantly above trend, before

14 The industries examined are computer systems design services, pharmaceutical and medicine manufacturing, software publishers, computer and electronics manufacturing, and scientific R&D services.

15 According to detailed information collected by the US Census Bureau’s Small Business Pulse Survey (SBPS) in April 2020, 6.8% of US businesses shifted production of their goods and services, and 15.2% changed the mode of delivery (Buffington et al. 2021b).

gradually returning to their pre-pandemic levels in 2021. This closely tracks new business registrations documented in Haltiwanger (2021). As the new business registrations spiked in the ‘Professional, Scientific and Technical Services’ industries in 2020, so did the number of trademark filings in digital and health-related products and services. Meanwhile, strong growth in new business registrations in the ‘Retail, Construction, and Trucking and Warehousing’ industries boosted filings in our traditional grouping of trademarks.

FIGURE 3 TRADEMARK APPLICATIONS FROM US-BASED ENTITIES BY INDUSTRY GROUP



Notes: Application classes filed by filing date. Application counts are based on the number of primary NICE classes in the application on the date of filing. The origin is determined by the address information provided by in assignment/ownership records.

Source: Authors' calculations based on USPTO Trademark Reporting and Monitoring System (TRAM).

3 UNCERTAINTY AND THE IMPORTANCE OF SECONDARY MARKETS

Thus far, the three takeaway points emphasised at the outset have been addressed: innovative industries and companies have weathered the COVID-19 pandemic better; innovation investments, such as R&D, behave differently than tangible, physical capital investments; but even among innovative companies, heterogeneity exists in patenting and trademarking trends between digital, health, and other technologies. This section addresses why those technologies, particularly in the digital area, may be relatively more resilient to a cyclical shock.

One clear impact of the COVID-19 pandemic was to increase uncertainty about the economy (Altig et al. 2020, Baker et al. 2020). To understand how greater uncertainty influences choices, economists often use a ‘real options’ framework (Dixit and Pindyck 1994, Abel et al. 1996). This framework has been developed primarily in the context of

physical capital investments – expenditures today to construct production facilities or buy equipment that will yield a stream of returns in the future – but it can also be used to interpret a variety of decisions such as investments in knowledge, decisions to open and close real assets such as coal mines, or even decisions to hire or fire personnel. Dixit and Pindyck (1994) highlight three critical characteristics for using a real option framework: (1) sunk costs, where some fraction of the expenditure cannot be recouped at a later date (also called ‘irreversibility’); (2) the presence of uncertainty about the economic environment; and (3) the ability to delay the investment opportunity.

In the context of COVID-19, a real options perspective suggests that greater uncertainty increases the value of waiting so that decision makers are likely to hold back on investments. This could help explain why the ratio of physical capital investment to sales falls in Table 1, even in high-tech industries. However, uncertainty also increases the ‘zone of inactivity’, meaning ongoing projects may not be abandoned as quickly. For knowledge-related investments such as R&D, projects are likely to be maintained, at least for a while. But there is another very important influence on decision makers in industries that use IP, namely, the secondary market for patents, trademarks, and copyrights. IP acts as a store of value, and opportunities to sell or license IP make investments related to IP more reversible. In other words, these investments can be recouped, at least to some degree, and this offsets the sunk cost condition. Park et al. (2021) explore the influence of exposure to secondary markets for patents and find that greater exposure helps mitigate the effects of economic uncertainty on a company’s decision to file for a patent.

To illustrate this point, Table 2 shows the distribution of IP trading deals for a small but informative sample obtained from a website hosted by IAM Market. The deals include licenses, cross-licenses, and sales, and are broken out by industry. Each deal often involves one or more related patents. Most deals (44%) took place in the digital area (electronic and electrical equipment, software and computer services, network communications, and computing and information technology hardware). This is perhaps not too surprising, as these are areas where innovation can be sequential, cumulative, fragmentable, and therefore constitute tradeable inputs into multiple products.

The health area (medical devices, biotechnology, and pharmaceuticals) appears in 13% of all deals. Here, the secondary market share is relatively smaller than that of the digital technologies, but is almost twice that of the third leading industry group involved in IP transactions, namely, the automobile and parts sector.

TABLE 2 SECONDARY MARKET DEALS IN PATENT RIGHTS: INDUSTRY REPRESENTATION

| Industry group | Counts | Share (%) |
|-----------------------------------|------------|--------------|
| Digital technologies | 393 | 44.0 |
| Health technologies | 116 | 13.0 |
| Automotive and parts | 65 | 7.3 |
| Telecommunications | 46 | 5.2 |
| Manufacturing | 46 | 5.2 |
| Media & entertainment | 31 | 3.5 |
| Electricity | 27 | 3.0 |
| Transport | 27 | 3.0 |
| Security & defence | 26 | 2.9 |
| Household goods | 22 | 2.5 |
| Chemicals | 13 | 1.5 |
| Food, tobacco, & beverages | 13 | 1.5 |
| Oil & gas | 10 | 1.1 |
| Finance | 10 | 1.1 |
| Retail & distribution | 10 | 1.1 |
| Construction & building materials | 7 | 0.8 |
| Test and measurement | 7 | 0.8 |
| Support services | 6 | 0.7 |
| Steel & other metals | 5 | 0.6 |
| Utilities & mining | 5 | 0.6 |
| Leisure & hospitality | 4 | 0.4 |
| Printing | 3 | 0.3 |
| Education | 1 | 0.1 |
| TOTAL | 893 | 100.0 |

Note: Counts of transactions for all technology categories. Each transaction, or deal, consists of one or more patents.

Source: IAM Market (<https://portal.iam-market.com/browse-iptech>, accessed 21 March 2022).

The sample of secondary market deals is therefore quite skewed around a few industry groups, which are the industries demonstrated to be relatively least susceptible to the COVID-19 shock or to have rebounded swiftly from it. The ability to sell IP assets and recoup investments, even if the companies do not actually engage in sales, provides an insurance-like protective effect and thereby helps maintain the momentum to invest in innovative efforts.

4 CONCLUSIONS

Our chapter illustrates the resiliency of innovation despite the difficulties and challenges of the COVID-19 era. While the overall economy experienced losses in output, with consumers and workers contending with the upheavals, IP-intensive industries bore smaller initial losses and rebounded more quickly. R&D exhibited minimal cyclical fluctuation, while investment in physical capital was much more volatile in response to the economic shocks. Patenting and trademarking activities also remained relatively robust, if not bolstered, amid the economic shocks and uncertainties in the economy owing to persistence in the spread and impact of the virus.

Furthermore, while innovation was resilient overall, there exists heterogeneity across technological fields and areas of innovative activity. For example, patenting in the area of digital technologies, with its access to secondary markets and opportunities provided by the transition to virtual and remote work environments, and patenting in the health area, with its call to respond to the public health crisis, fared relatively well compared to the traditional technology areas. Trademarking activities in the digital and traditional goods and services remained strong given the new business creations that found opportunity during the pandemic.

Going forward, it is useful to reflect upon the factors that give innovation its resilience – for example, public policy support, institutions, the educational system, the market environment, organizational competence, and coordination among the different organisations and institutions, to name a few. This chapter has highlighted a few of the important links, focusing primarily on innovative US companies and industries – those that invest in knowledge-generating activities, use high-skilled labour such as workers with STEM degrees, and take advantage of the intellectual property system. STEM education provides the training for inventors and creators, IP institutions (intellectual property offices, international organisations) provide the means for inventors and creators to obtain property rights protection, and secondary markets provide a venue for trading IP rights. Innovation requires resources – financial, human, and technological – as well as infrastructural and institutional reinforcements. The important role that innovation has played in responding to the COVID-19 crises should make us reflect more deeply on the various components that sustain the overall innovation system. If these components and other support mechanisms had not functioned at a high level, the US innovation experience may not have shown the resiliency we observed during the pandemic.

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CHAPTER 3

Impact of the COVID-19 pandemic on trademark activity in Canada

Gray Barski, Alex Lehmann, Diego Santilli and Sean Martineau

Canadian Intellectual Property Office

INTRODUCTION

A traditional trend analysis of trademark activity in Canada is useful in obtaining an overview of the shifts in filing behaviour observed since the onset of the COVID-19 pandemic. However, in order to understand the root causes of the growth in trademark filings, techniques that allow for insight to be drawn from more granular levels of information are needed. The Canadian Intellectual Property Office (CIPO) has taken a data-driven approach that relies on natural language processing (NLP) techniques applied to the words used in trademark applications to understand which factors played a role in bolstering CIPO's trademark filings during the first year of the pandemic (April 2020 to March 2021). The main findings from this research presented below are split into two time periods associated with the filings: the first phase, from April 2020 to September 2020; and the second phase, from October 2020 to March 2021.

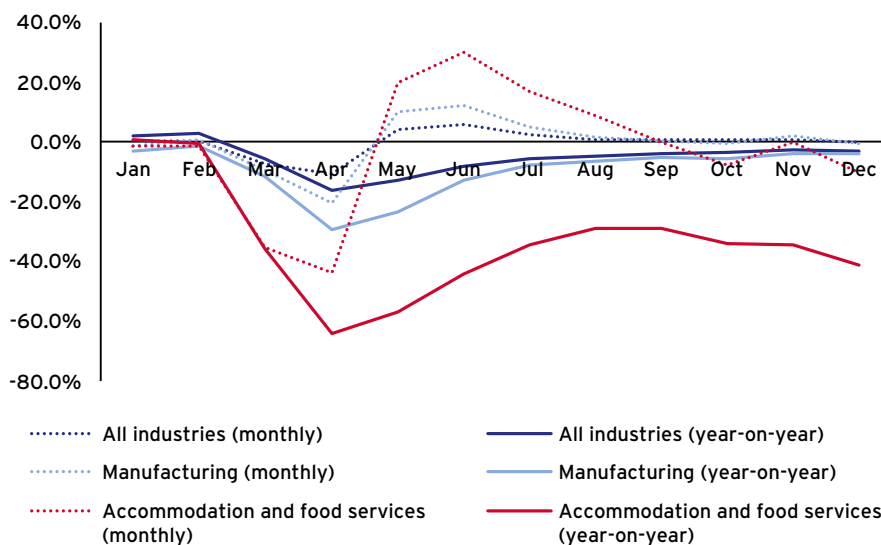
- Filings from Canadian residents and from China bolstered the growth in trademark activity at CIPO throughout the first phase, with the other filing origins in the top ten stagnating until the second phase.
- First-time filers were responsible for driving the growth in trademarks, with resident and Chinese filings accounting for much of the growth during the first phase.
- Few lines of trade grew within the first phase, evidenced by the fact that the growth was confined to just a few application topics. Of these few areas showing early growth, most were associated with social digitisation such as online retail, cloud computing, and consumer electronics.
- A greater number and a wider variety of topics related to trademark applications were observed during the second phase, stemming from a broader range of applicants from diverse industries. Over this phase both experienced and first-time filers played a role in contributing to the growth.

- When comparing the behaviour of first-time filers to experienced filers, first-time filers from China appear to have filed applications on goods that are associated with lower barriers to entry, such as cell phone accessories and PC peripherals.

TRADEMARKS IN CANADA AND THE PANDEMIC: A CONVENTIONAL LOOK

A novel coronavirus (which came to be known as SARS-CoV-2, or COVID-19) emerged in February 2020 and was declared a pandemic by the World Health Organization the following month. Soon after, lockdowns were established around the world to limit the spread of the virus. Many businesses were closed amid widespread fear and uncertainty, and many countries – Canada included – entered deep recessions. For example, during the month of April 2020, Canada saw a decline in GDP of 11% with respect to the previous month, and 16% with respect to April 2019. Figure 1 shows the monthly percentage change in Canada’s real GDP in 2020 with respect to the same month in the previous year, aggregated and for selected industries. Data from Statistics Canada¹ indicate that the growth rates plummeted in March and reached, in general, their lowest point in April. Some specific industries were even more severely affected, such as Manufacturing, with a year-over-year 29% decrease, and Accommodation and Food Services, which was deeply affected by public health measures, with a 64% decrease.

FIGURE 1 CANADIAN MONTHLY REAL GDP FOR ALL AND SELECTED INDUSTRIES, 2020

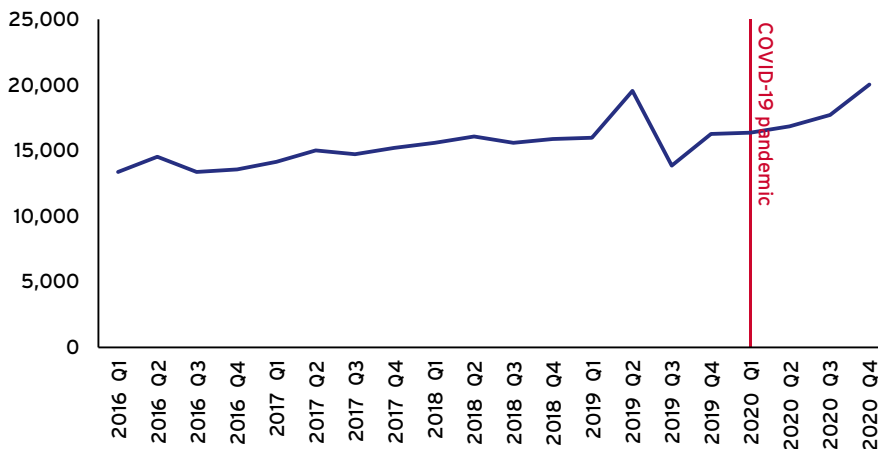


Note: Solid lines represent year-over-year growth, while dotted lines represent monthly growth

1 Table 36-10-0434-01, "Gross domestic product (GDP) at basic prices, by industry, monthly (x 1,000,000)" (www150.statcan.gc.ca/t1/tbl/en/tv.action?pid=3610043401).

Historically in Canada, deep and sudden market contractions such as those observed in early 2020 tended to result in shrinkages in new business ventures amid unfavourable economic conditions and uncertainty. Such contractions could also be observed when looking at intellectual property (IP) activity and, more specifically, trademark filings, which are regarded as a good indicator of economic activity (Hidalgo and Gabaly 2013). The COVID-19 pandemic, however, defied such historical trends: the pandemic heralded record levels of IP activity around the globe. The specific boom in trademark activity presented in Figure 2 suggests that this crisis engendered new realms of commercial opportunity. It should be noted that the spike during 2019 Q2 is from an influx of filings from applicants that were attempting to avoid paying the additional Nice class fees as part of the new filing-fee schema enacted in Canada on 17 June 2019.

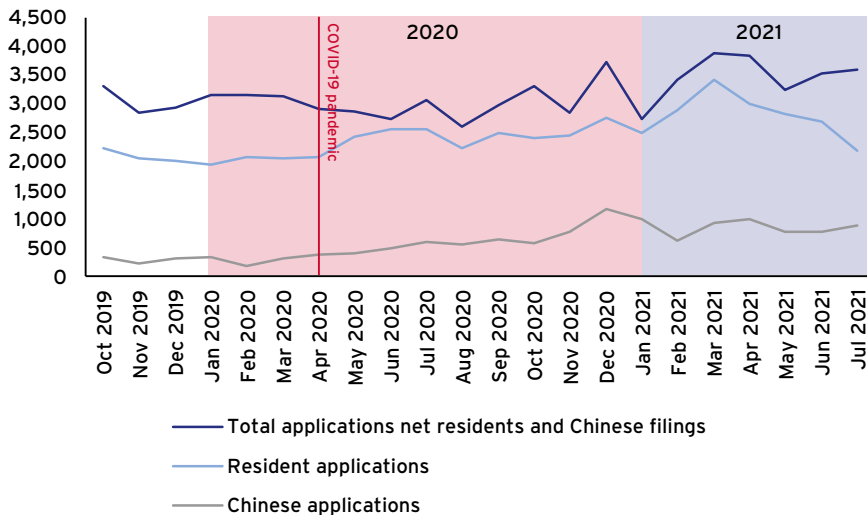
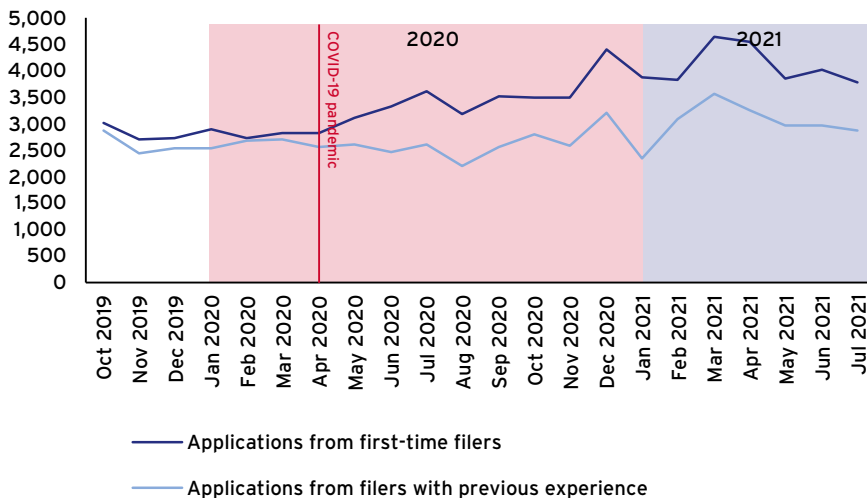
FIGURE 2 QUARTERLY TRADEMARK APPLICATION VOLUME RECEIVED BY CIPO, 2016-2020



FURTHER INSIGHTS FROM TRADEMARK MICRODATA

Canada is a small, open economy. From an IP perspective, this means that foreign entities applying for protection in Canada are a key factor to understand IP filing trends in the country. Figure 3 disaggregates the trademark activity in Canada in 2020 by resident filings, filings from China, and filings by other non-resident origins. The data show that filings from Chinese and Canadian applicants are responsible for the growth in 2020, whereas filings from the other non-resident origins decreased.

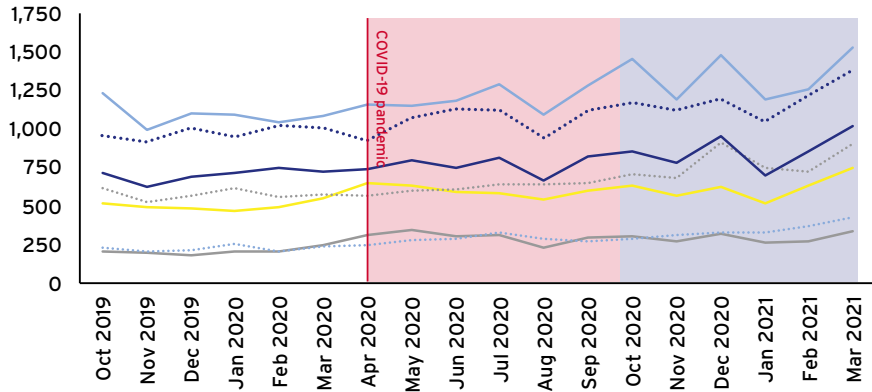
Disaggregating the data based on specific characteristics of the applicants captures a different perspective for interpreting the filing patterns. Figure 4 reveals that the increase in applications was driven by first-time filers. When looking at the country of origin of these, Canadian resident and Chinese filers make up the majority of the growth in the first six months of the pandemic.

FIGURE 3 MONTHLY GROWTH IN TRADEMARK FILINGS IN CANADA BY ORIGIN**FIGURE 4 MONTHLY GROWTH IN TRADEMARK FILINGS IN CANADA BY SELECTED FILING CHARACTERISTICS**

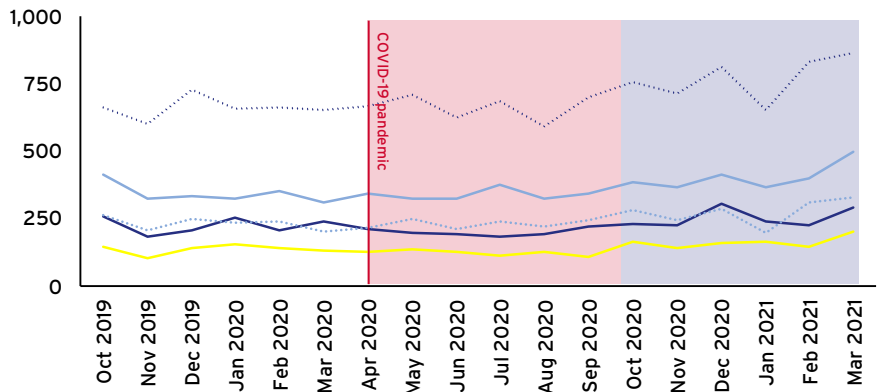
When assessing the prevalence of goods and services applied for based on Nice classes, it is found that there were two phases in trademark growth. The first phase took place in the first six months of the pandemic (April to September 2020), while the second occurred over the following six months (October 2020 to March 2021). During the first phase, class 5 (pharmaceuticals) and class 10 (medical supplies) immediately spiked and then stabilised. Given the nature of the global crisis and the association of these classes with medical and health goods, the cause of these spikes is quite clear. Meanwhile, classes 9 (electronics), 11 (HVAC), 25 (clothing), 35 (business management), and 42 (industrial engineering) grew steadily through April 2021. These trends can be observed in the top

panel of Figure 5. With regards to the bottom panel of the figure, the data show that during the second phase a multitude of classes also began to experience higher usage, after stabilising or decreasing during the first phase.

FIGURE 5 MONTHLY GROWTH IN TRADEMARK FILINGS IN CANADA BY SELECTED NICE CLASSES



- Class 5 (Pharmaceuticals)
- Class 9 (Electronics)
- Class 10 (Medical supplies)
- Class 11 (HVAC)
- Class 25 (Clothing)
- Class 35 (Business management)
- Class 42 (Industrial engineering)



- Class 14 (Precious metals and jewellery)
- Class 16 (Paper and stationery goods)
- Class 18 (Leather goods)
- Class 37 (Construction services)
- Class 41 (Education and online training)

FURTHER ANALYSIS: SHIFTS IN LINES OF TRADE IN CANADA

Thus far, conventional analysis demonstrates that certain Nice classes displayed increased filing activity over the course of the pandemic. However, conventional analysis fails to answer some additional questions about the pandemic's effects on IP trends. Was the trademark activity in Canada intrinsically different from what came before, or simply an increase in volume? Which groups of goods and services within the growing Nice classes were most responsible for driving the growth? The answers to these questions lie deeper within the trademark application data. More specifically, the textual content contained within the goods and services descriptions of a trademark application holds a wealth of information critical to understanding the nuances of the changing market conditions since the beginning of the pandemic, such as changes of demand preferences and responses through variations in the marketing mix.

Insights into these changing conditions linked to innovation are obtained by applying NLP methodologies to the text contained in the goods and services descriptions in applications. This portion of the analysis is based on 352,727 trademark applications received by CIPO between 2010 and 2021; specifically, the goods and services statements on each application serve as the data set for the NLP models employed herein. Identifying these heavily targeted 'lines of trade' reveals the areas where firms see commercial opportunity and serve to indicate those areas experiencing growth amidst the pandemic; here, 'lines of trade' refers to specific types of goods and services offered by firms (e.g. "jackets" or "stock brokerage"). Additionally, linking these trends to external data reveals insights regarding the factors leading to and influencing the growth of trademark activity.

Introducing text analysis into the methodology revealed three major results:

1. The lines of trade that look to be the greatest contributors of growth in trademark applications during the first phase of the pandemic were medical and viral protection products, and also those associated with social digitisation such as online retail, cloud computing, and consumer electronics.
2. The lines of trade targeted by firms varied depending on region and time after the onset of the pandemic. The nature and degree of this variation depended on local industry and time elapsed since pandemic onset.
3. First-time filers from China (the fastest growing demographic of trademark filers after the pandemic began) filing in Nice class 9 (the most targeted Nice class) were considerably more likely to file trademarks for personal communications and entertainment. This is likely due to the relatively lower barriers to entry for those lines of business when compared to others.

These results are examined in greater detail below.

Protective and communications equipment led trademark growth

As previously indicated, certain Nice classes grew rapidly following the onset of the pandemic. A natural question, then, regards which particular goods and services within these Nice classes were responsible for driving their growth. Out of all of the goods and services within these rapidly-growing Nice classes, which topics were primarily associated with the growth for each Nice class?

Figure 7 reveals the lines of trade displaying the greatest growth in popularity during the pandemic and the most common wording found in trademark applications. The top-six lines of trade are all clearly associated with the pandemic – some have to do with protection against infection (protective equipment in classes 9 and 10, sanitizers and disinfectants in class 5), while others relate to a stay-at-home society (online commerce in class 35, consumer electronics accessories in class 9) and also home entertainment in the form of video games (class 41).

Within each of these lines of trade, the diversity of associated application wording varies as well. For example, online retail is dominated by references to “online sale” while protective headgear is more balanced between various forms of protective masks. We see references to masks among the most common wording for general medical personal protective equipment as well.

FIGURE 6 HIGHEST-GROWTH TOPICS IN THE FIRST PHASE

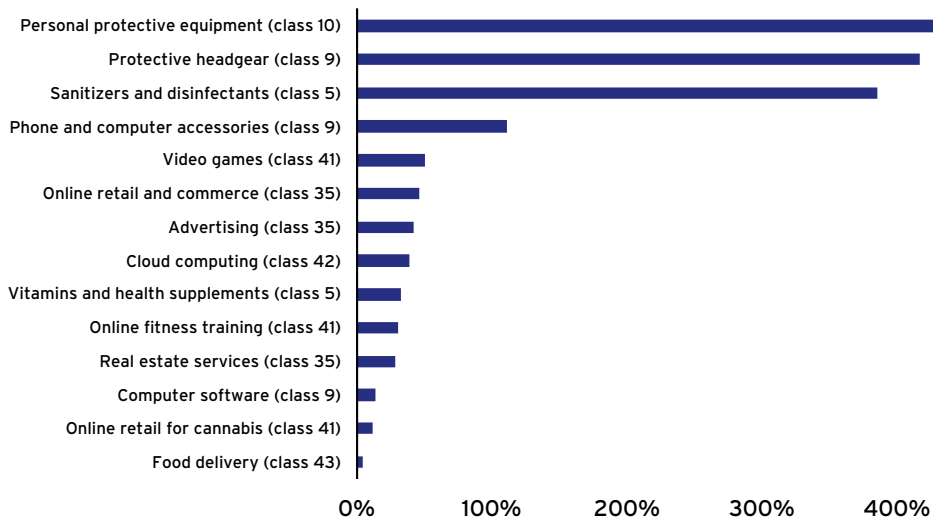
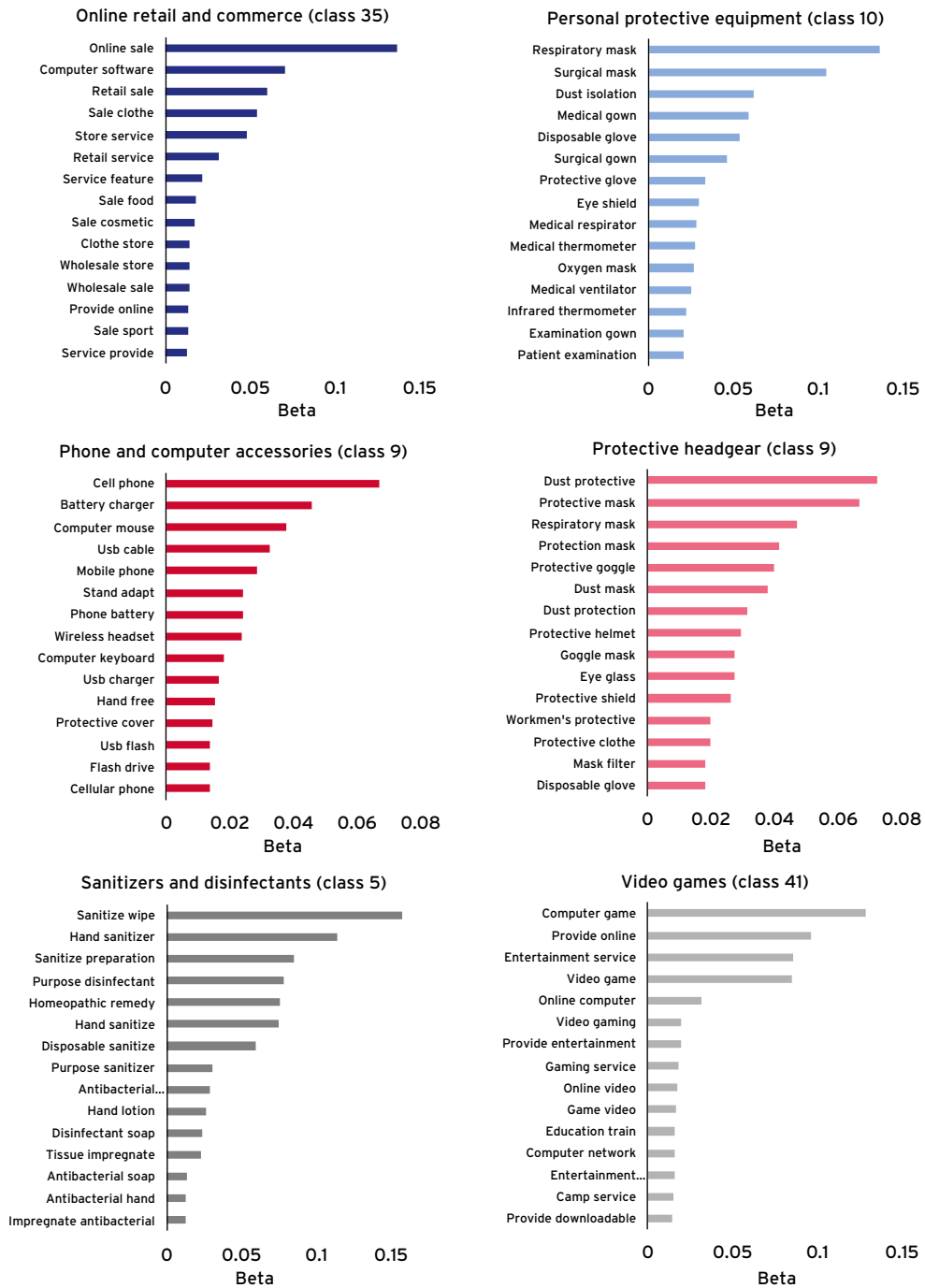


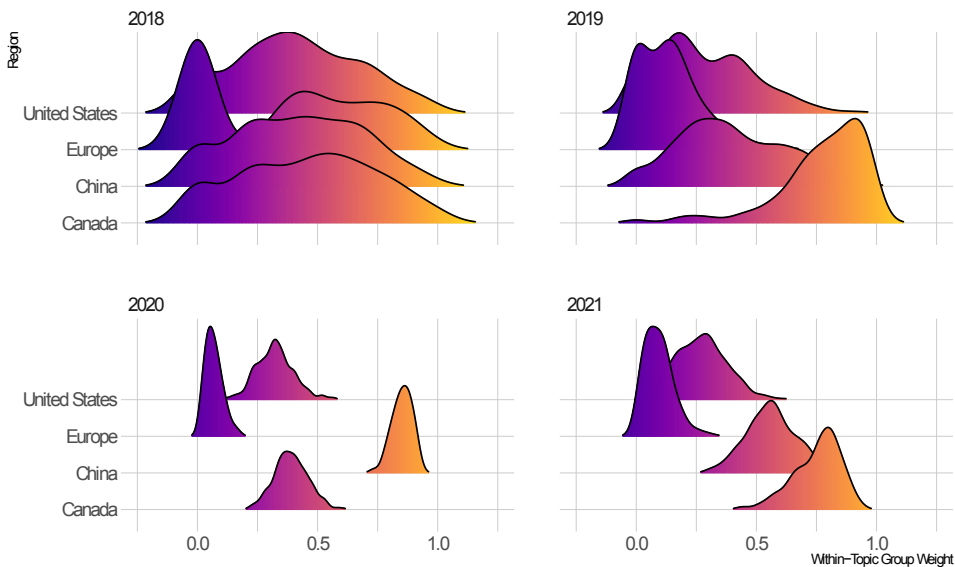
FIGURE 7 MOST PREVALENT WORDING WITH THE HIGHEST-GROWING TOPICS DURING THE FIRST PHASE



Topic popularity varied across time and geographical region

Geographical origins of the trademark applications also played a major role in pandemic effects on new brand activity. Four regions were considered in the analysis of these geographical effects: Canada, China, Europe, and the US. Both the magnitude and nature of changes to topic distribution varied for these regions. For example, Figure 8 shows the approximated distributions of topic emphasis for the “mask” topic in applications submitted under Nice class 10. In this figure, the horizontal axis (topic emphasis) refers to the strength of the relation that an application has towards a specific topic, computed by adding the frequency of words weighted by their importance to a topic, relative to how strongly related the application is when aggregated across all topics. Thus, the vertical axis can be interpreted as the probability that an application emphasises the topic to a specific degree. Comparing the region distributions in Figure 8 reveals which region would be more/less likely to emphasise the “mask” topic around a certain degree of strength.² Distributions largely captured in yellow depict countries where the application is more likely to place a stronger emphasis on a specific topic.

FIGURE 8 BOOTSTRAP DISTRIBUTIONS FOR RELATIVE WEIGHT OF “MASK” TOPIC IN TRADEMARK APPLICATIONS FILED UNDER NICE CLASS 10 FROM THE US, EUROPE, CHINA, AND CANADA, 2018-2021



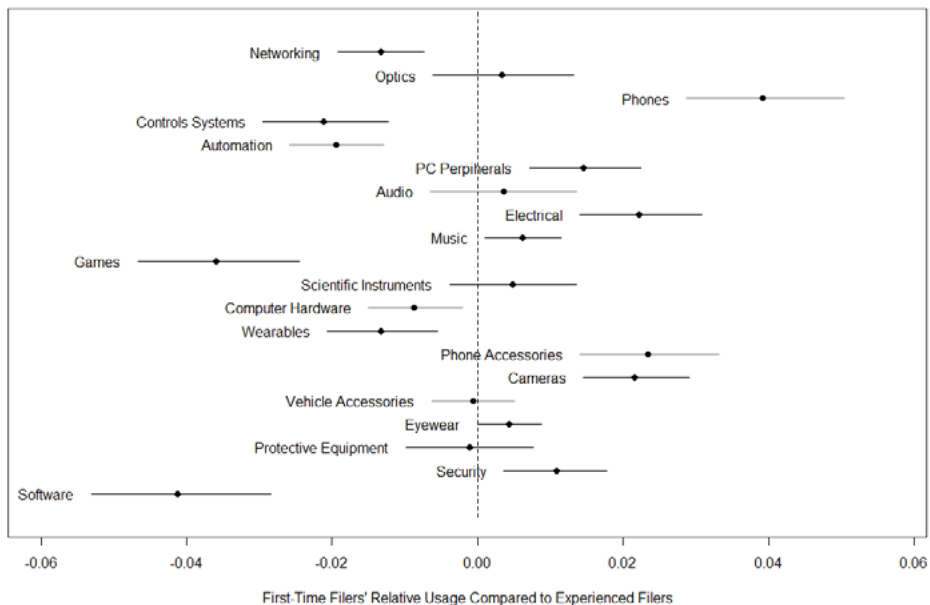
² This regional-effect variation was not limited to the data displayed in Figure 8 but observed for many other regions and topics; these are omitted for brevity.

In 2018, the relative emphasis levels were fairly uniform, suggesting that no single region had significantly higher or lower emphasis on masks than any other. However, by 2020 the emphasis levels have clearly polarised and shifted in position. This suggests that applicants in each region coalesced around the textual use of masks at different times, perhaps reflecting explicit national policies or strategic considerations. Europe is clearly the region with the least emphasis, while Canada and the US are fairly closely matched. China, however, displays a massive jump in mask-related trademark activity, even reversing a slight decline from 2018–2019. In 2021, though, Canada edged out China for the highest emphasis on masks in applications while the US and Europe remained stagnant.

The large increase in first-time Chinese trademark filers was driven by phones, phone and accessories, and PC peripherals

On the subject of regional influences on trademark activity, it should be noted that the increase in trademark activity at CIPO in 2020 and 2021 was driven by first-time applicants from China. A natural question regarding this activity relates to which lines of trade drove this boom. Figure 9 shows the relative topic usage of Chinese applications received by CIPO between April 2020 and March 2021; the right side of the figure indicates more commonly referenced topics by first-time filers, while the left side of the figure indicates those used most frequently by experienced filers.

FIGURE 9 RELATIVE TOPIC USAGE FOR FIRST-TIME VS. EXPERIENCED TRADEMARK APPLICANTS FROM CHINA IN NICE CLASS 9, APRIL 2020 TO MARCH 2021



Topics most associated with first-time filers are concentrated around phones, phone accessories, and PC peripherals. Given that first-time filers at CIPO are largely driving the increase in applications from China, it is likely that these lines of business are responsible for the bulk of the increased trademark application volume. The figure also reveals that software, games, and industrial controls and automation (among others) remain heavily tilted towards experienced filers. This may indicate that these lines of business had higher barriers to entry, which proved prohibitive to new firms.

CONCLUSION

The global changes brought on by the COVID-19 pandemic are difficult to overstate and proved even harder to predict. Despite the pandemic bringing a global economic recession, CIPO witnessed an unexpected increase in trademark activity as firms found opportunities in heavily disrupted markets. Significant evidence was found suggesting that these opportunities were not merely increased volume in firms' traditional segments, but a true shift in activity. The new, pandemic-era commercial landscape created business opportunities and many first-time trademark filers answered the call. These firms drove innovation on the backs of e-commerce, viral protection, and support for a stay-at-home society with careful adaptations for their local market conditions. Further research into the specific market conditions triggering these adaptations and the implications of these effects is ongoing.

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CHAPTER 4

COVID-19 and the analysis of patent, trademark and industrial design applications in Brazil

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The first cases of COVID-19 in Brazil were confirmed in the first quarter of 2020. The actions to control the pandemic involved the need for social isolation, which caused restrictions to business possibilities at local, regional and international levels. The impact of this across national activities differed. This chapter explores indicators of economic performance and patterns of patent, trademark and industrial design applications in Brazil, in order to shed light on the impacts of the COVID-19 pandemic on creativity and innovation. The indicators reveal how behaviour varied by economic activity, type of IP asset and applicant profile.

BACKGROUND AND THE NATURE OF COVID-19 CRISIS

The COVID-19 pandemic exposed productive and technological vulnerabilities in Brazil, the existence of asymmetries in relation to the production of scientific knowledge worldwide, and the dependence on imports of strategic inputs. Although with limitations, the Brazilian health infrastructure of public laboratories, research institutes and universities was well positioned to respond to the health emergency created by COVID-19 and showed its strategic importance in the organisation and coordination of science, technology and innovation activities related to the fight against the pandemic (IEDI 2018, Almeida et al. 2020, Cassiolato et al. 2021, Sabbatini e Fonseca 2021, Sarti et al. 2021, Vargas et al. 2021).

Thanks to this infrastructure, but after a long period of high numbers of cases and deaths, vaccination in Brazil started in January 2021 for the elderly population, medical staff and other at-risk groups. The campaign began with two vaccines: Coronavac, from the Chinese company Sinovac produced in partnership with the Butantan Institute of Brazil; and Covishield, an Oxford/AstraZeneca vaccine produced in partnership with

¹ The authors are thankful for the support of Leopoldo Coutinho. Special data treatment was provided by Leo Maranhão. Identification and categorisation of the patent documents related to the pandemic were provided by the ObTec-COVID-19 team. Translation was provided by Larissa Ormay and Érica de Holanda Leite. The opinions expressed are those of individual authors and do not necessarily reflect the official views of the Brazilian National Institute of Industrial Property.

Fiocruz/Brazil, including a technological transfer agreement.² In late April of 2021, Brazil also received the Pfizer/BioNTech vaccine and expanded its vaccination coverage. By September 2021, 50% of the adult Brazilian population had been immunised with two doses (Ministério da Saúde 2021). Thus, despite the arrival of the Delta variant in the country, which showed greater transmissibility, the lives of Brazilians have returned to certain normality.

Facing an extraordinary situation of exponential expansion in the demand for health goods and services, the Brazilian productive structure was at first unable to supply some essential products and services for the mitigation of the health crisis, even some products of low productive and technological complexity (Sarti et al. 2021). Imports were also partially constrained by the global supply shortage. Brazilian economic activity suffered, on the supply side, with the fall in production, higher production costs and a lack of raw materials. On the domestic demand side, higher consumer inflation added to the impacts felt in the labour market, which initially experienced an increase in unemployment followed by less job security in employment conditions and a drop in real income in 2021.

In the first year of the pandemic, some production lines were interrupted and Brazilian manufacturing production dropped by 4.6%. In the following year, manufacturing production grew by 4.3%, but this positive result is relative to 2020, which is a weak and insufficient comparison base. A lack of inputs was accompanied by a rise in producer prices, which reached a high of 29.3% in 2021 as measured by the Producer Price Index (*Índice de Preços ao Produtor*, or IPP), while inflation for the Brazilian consumer reached a high of 10% as measured by the Extended National Consumer Price Index (*Índice Nacional de Preços ao Consumidor Amplo*, or IPCA).

The job losses that led to rising unemployment in the Brazilian labour market were accompanied by a decrease in the number of self-employed workers. This was mainly the result of people leaving the job market either because of imposed isolation or reduced job security and wages. The change in the composition of employees led to increased real wages in the first year of the pandemic, as most job losses were among the more vulnerable.

In 2021, with the advances in vaccination and the resumption of economic activity, the labour market recovered, even reaching the same level as in 2019. This was accompanied, however, by an increase in insecure work (i.e. without a formal contract), an increase in self-employed workers and a fall in average income. Among the self-employed, the number of individual entrepreneurs with a National Registry of Legal Entities number (*Cadastro Nacional da Pessoa Jurídica*, or CNPJ) increased by 16.6%, while those without a CNPJ, who are in a situation of less job security, increased by 12%.

² For more information of these vaccines, see <https://portal.fiocruz.br/vacinasocovid19> and <https://butantan.gov.br/noticias/retrospectiva-2021-segundo-ano-da-pandemia-e-marcado-pelo-avanco-da-vacinacao-contra-covid-19-no-brasil> (both in Portuguese).

TABLE 1 SELECTED ECONOMIC INDICATORS, 2019-2021

| Indicators | 2019 | 2020 | 2021 |
|-----------------------------------------------------------------------------|--------|--------|--------|
| Physical production of manufacturing ¹ (accumulated in the year) | 0.20% | -4.60% | 4.30% |
| IPP manufacturing ² (accumulated in the year) | 4.83% | 18.14% | 29.30% |
| IPCA ³ (accumulated in the year) | 4.31% | 4.52% | 10.06% |
| Number of employees ⁴ | 95,515 | 87,225 | 95,747 |
| Unemployment rate ⁴ - 4Q | 11.10% | 14.20% | 11.10% |
| Number of self-employed ⁴ | 24,336 | 22,946 | 25,944 |
| with CNPJ ⁴ | 5,065 | 5,497 | 6,408 |
| without CNPJ ⁴ | 19,271 | 17,449 | 19,536 |
| Real average income ⁴ | 2,675 | 2,742 | 2,447 |

Source: Instituto Brasileiro de Geografia e Estatística, Dashboard of Indicators (www.ibge.gov.br/indicadores).

Notes: 1 Calculated using the Monthly Survey of Physical Production; 2 Producer Price Index; 3 Extended National Consumer Price Index; 4 Calculated using the Continuous National Household Sample Survey.

TRENDS IN INTELLECTUAL PROPERTY APPLICATIONS

In the context of an already fragile production structure, the COVID-19 pandemic also affected the demand for intellectual property protection. This section looks at patterns and trends of patent, trademark and industrial design applications.³ In part, it uses data from the Brazilian Industrial Property Statistical Database (*Base de Dados sobre Propriedade Intelectual*, or BADEPI) with information on the profiles of applicants.⁴ It also identifies the main economic activities of legal entities from a merging of BADEPI Federal Revenue's data.

Patents

The Brazilian patent system offers protection to inventions by considering two main types of applications: invention patents (around 90% of total) and utility models (almost 10%).⁵ In 2021, the cumulative number of patent applications was 26,921, a reduction of

³ For more information about the period pre-pandemic, see INPI (2020). All recent data are also available at www.gov.br/inpi/pt-br/central-de-conteudo/estatisticas

⁴ According to the information provided by applicants when filing applications. There are some pre-defined categories that are entitled to discounts: teaching and research institutions, public agency, individual micro-entrepreneur, micro-enterprise, small business, non-economic association, non-economic society, individual and cooperatives. Following the methodology of the Bulletins, this study considered as medium and large companies all other resident applicants that were not in previous categories. For more information, see www.gov.br/inpi/pt-br/central-de-conteudo/estatisticas/relatorios

⁵ There is also certificate of addition that represents fewer than 0.5% of applications.

-4.9% compared to 2019. The reduction was almost entirely observed in 2020, while in 2021 there was no significant change. The initial impact of COVID-19 was observed with a drop in the number of applications as early as the second quarter of 2020, compared to the same period of the previous year. The start of recovery was only noticed in the fourth quarter of 2021.

Among the types of applications, invention patents fell at the same level (-4.5%) in the period, while utility models showed a more accentuated decline of -8.9%. These differing trends are closely related to the origin of applicants. Non-resident applicants, who were responsible for 70% of all applications and concentrated in invention patents, initially fell by -4.4%, but in the second year they showed a slight recovery of +2.7%. Resident applicants, on the other hand, registered declines in both 2020 and 2021 that were more intense in invention patents (-3.3% and -11.6%, respectively) than in utility models (-4.7% and -4.1%, respectively). This seems to show that residents' invention patents are more closely related to long-term science and technology (S&T) investments and were therefore more impacted in the second year, while utility models – usually related to minor or incremental innovations – were already more impacted in first year and did not recover as the economic conditions were unfavourable in general.

During the pandemic, individuals and universities saw the largest reductions in patent and utility model filings. Individuals saw a -21% reduction in invention patents compared to 2019 and a -18% drop in utility models. This indicates that individuals were impacted substantially by the pandemic (consider, for instance, the fall in the average worker's income discussed above). Universities, teaching and research institutions and government showed a reduction of 24% in invention patents. In part, this reflects the continuous reduction of public S&T budgets, which have been essential in supporting research and innovation in Brazil since 2013 (De Negri and Koeller 2019), but it also reflects the suspension of face-to-face activities at federal universities from the beginning of the pandemic until their return in March 2022.

Medium-sized and large companies were the only ones to show an increase in invention patents (+7%). In contrast, individual micro-entrepreneurs, micro-enterprises and small businesses reduced their applications by -2%. However, this group exhibited exceptional behaviour in utility models, with an increase in applications of +20%. These results suggest that small companies rely more on utility models that are related to minor innovations.

For legal entity applicants for invention patents, we can look at the distribution by economic sector/activity.⁶ As COVID-19 highlighted the importance of science, Brazil faced a contradiction. Applicants from the 'education' sector – composed 88% of universities and 6% of technological institutes – have always been important contributors to Brazilian S&T. Although applications from this sector fell by -27%, it still managed to maintain

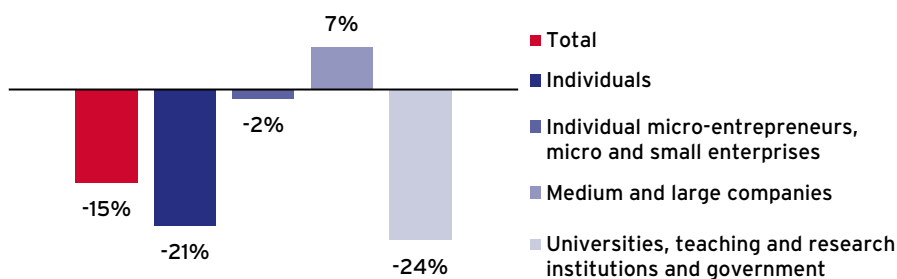
6 Here, applicants were classified according to their main economic activity using the ISIC classification.

an overall share of 35% of total applications in 2021. In contrast, applications from legal entities undertaking ‘professional, scientific and technical activities’ grew +31% in the same period, showing the growing importance of these institutes in producing technical solutions.⁷

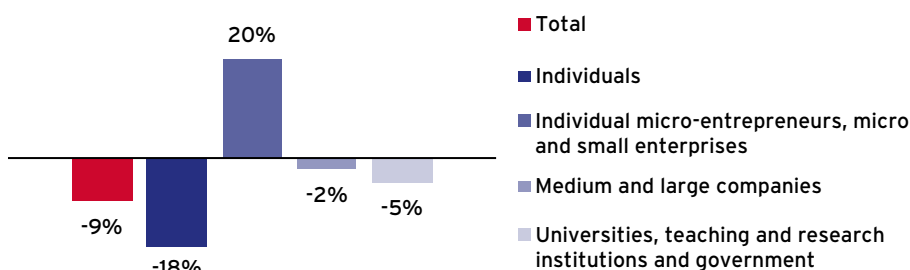
As the pandemic imposed isolation and remote work, it accelerated pre-existing trends for digitisation and fuelled demand among individuals to adapt their lives and upgrade their homes to be more comfortable for both living and working. Despite the increased demand for digitisation, however, the number of patent applications from the ‘information and communications’ sector actually decreased. This reflects the fragility of the Brazilian innovation system with regards to digital technologies. However, invention patent applications from ‘wholesale and retail trade’ entities increased, mainly related to household items. Their applications grew +5% during the period and their share increased to 6.4% of all applications from legal entities in 2021.

FIGURE 1 PATENT APPLICATIONS

a) Change in number of invention patent applications from 2019 to 2021 (%)

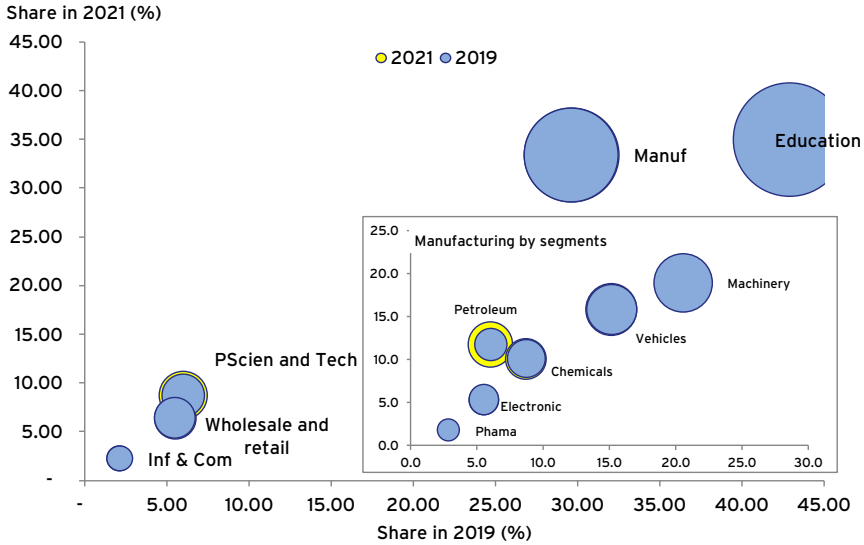


b) Change in number of utility model patent applications from 2019 to 2021 (%)

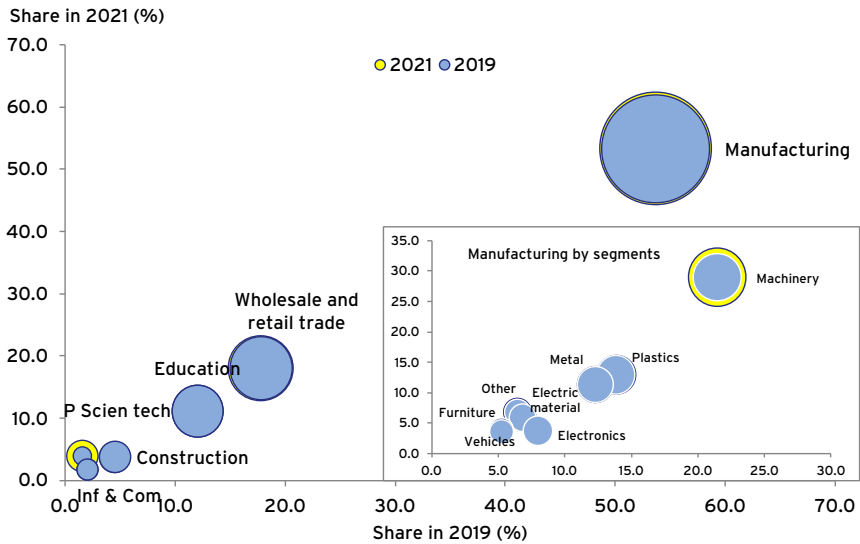


⁷ This refers to Section M, which includes activities that require a high degree of training, and make specialised knowledge and skills available to users. This can include private laboratories, public institutes and also enterprises once ‘professional, scientific and technical’ activities constitute their main economic activity. Among major applicants are private entities and also public research institutes.

c) Patent applications by economic activity



d) Utility model applications by economic activity



Source: Authors' elaboration based on data from INPI, BADEPI.

Legal entities in ‘manufacturing’ increased their applications by +2% compared to 2019 and accounted for 33.4% of all applications from legal entities in 2021. Among the segments in this sector, ‘machinery and equipment’ had the largest share of applications (19%), although the segment showed a decrease of -6% in filings. The ‘motor vehicles, trailers and car bodies’ segment remained in second place with 16% of applications in 2021, after showing an increase. The shares of ‘coke, petroleum-derived products and biofuels’ and ‘chemicals’ rose as a result of increases in applications of +98% and +18%,

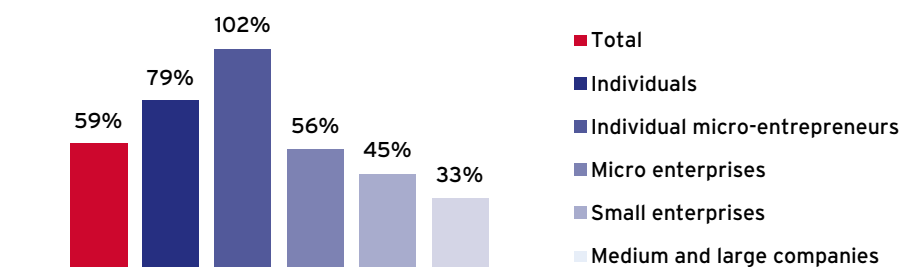
respectively. Contrary to expectations arising from the challenges imposed by the pandemic, applications related to ‘pharmaceutical’ and ‘electronic products’ decreased and lost share in total manufacturing. This result is in line with the theory that Brazil has productive and technological vulnerabilities.

Trademarks

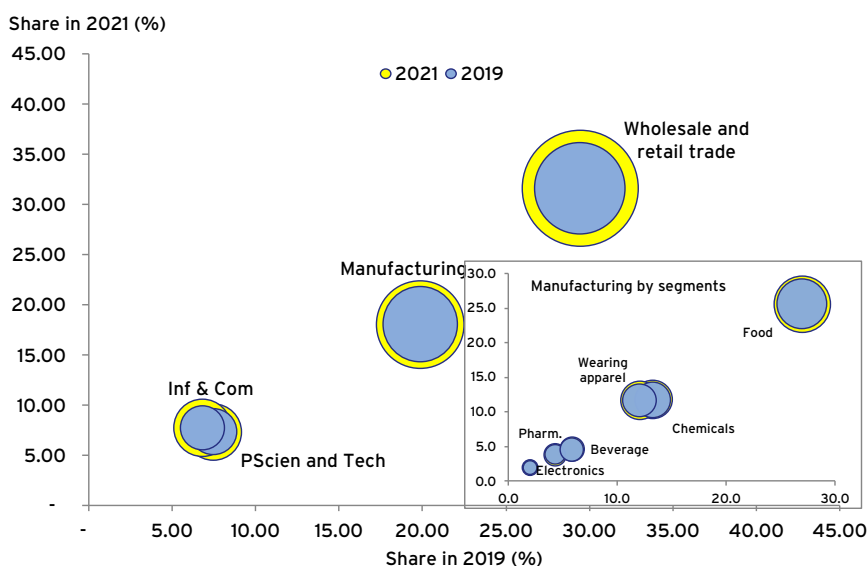
In 2021, the cumulative number of trademark applications was 386,845, up 58% from 2019. There was a temporary retraction in the second quarter of 2020, compared to the same period of the previous year. In general, resident applicants, who account for 90% of all applications, saw a greater increase than non-resident applicants. While non-residents increased their applications by +24% in 2020 and by +22% in 2021, resident increased filings by +19.2% and +33%, respectively.

FIGURE 2 TRADEMARK APPLICATIONS

a) Change in number of trademark applications from 2019 to 2021 (%)



b) Trademark applications by economic activity



Source: Authors' elaboration based on data from INPI, BADEPI.

The observed annual growth in non-resident applications may reflect the recovery of the global economy and also the entry into force of the Madrid Protocol in Brazil in October 2019, which facilitated international applications. Among residents, changes in the composition of the workforce during the pandemic seem to be the major driving force. Although in 2021 all applicant types exceeded their number of applications accumulated in 2019, the more relevant increments were related to individuals and individual micro-entrepreneurs. It seems that trademark registration has been used by the increasing number of self-employed in their new businesses, which do not have a track record of satisfied customers or successful products and are typically not known to the market. This is a very different behaviour from that observed for patents, since trademarks are an indicator related more to non-technological innovation and service activities (OECD 2011).

Turning to legal entity applicants, the ‘wholesale and retail trade’ sector increased its trademark filings by +63% compared to 2019 and accounted for 31.6% of the total in 2021, consolidating its position as the sector with the highest share. ‘Manufacturing’ remained in second place, with 18% of the total and a minor increase in filings.

It is worth mentioning the ‘construction’ sector, which saw the highest increase (+114%) despite accounting for only 3% of the total. This may reflect the need for social distancing, with more time at home and an increase in home-office work. As families changed their routines, they anticipated upgrades or adaptations to their home environment. Other growth sectors included ‘water supply, sewerage, waste management and remediation activities’; ‘agriculture, forestry and fishing’; and ‘professional, scientific and technical activities’.

Trademark applications related to ‘information and communication activities’, in general, do not stand out. Applications showed below-average growth during the pandemic and represented 7.3% of total applications from resident legal entities in 2021. When looking at trends in the sector’s individual segments, there is greater growth in ‘information technology services’, ‘data processing, internet hosting and other related activities’ and ‘publishing’. This attests to COVID-19 having accelerated the global trend towards a digital economy, forcing organisations to adopt new technologies and to adapt their communication services. However, below-average growth suggests that residents are not competitive in these activities.

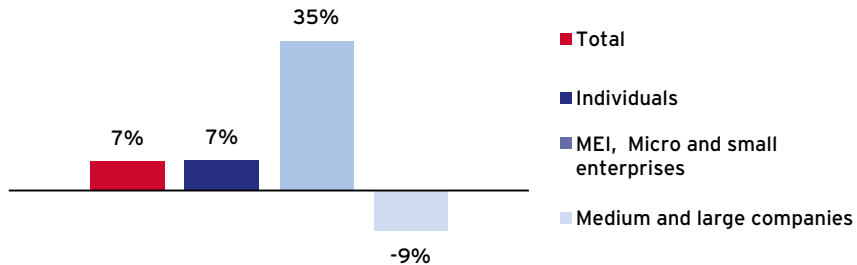
Among manufacturing, trademark activity in 2021 was highly concentrated in the top three segments: ‘food products’ (25.6%), ‘chemical products’ (11.8%) and ‘clothing and accessories’ (11.7%). These segments maintained their overall positions despite below-average increases. ‘Chemicals’ saw intense activity related to ‘soaps, detergents, cleaning products, cosmetics, perfumery and personal care products’ and strong growth related to ‘fertilisers and agricultural products’.

Industrial designs

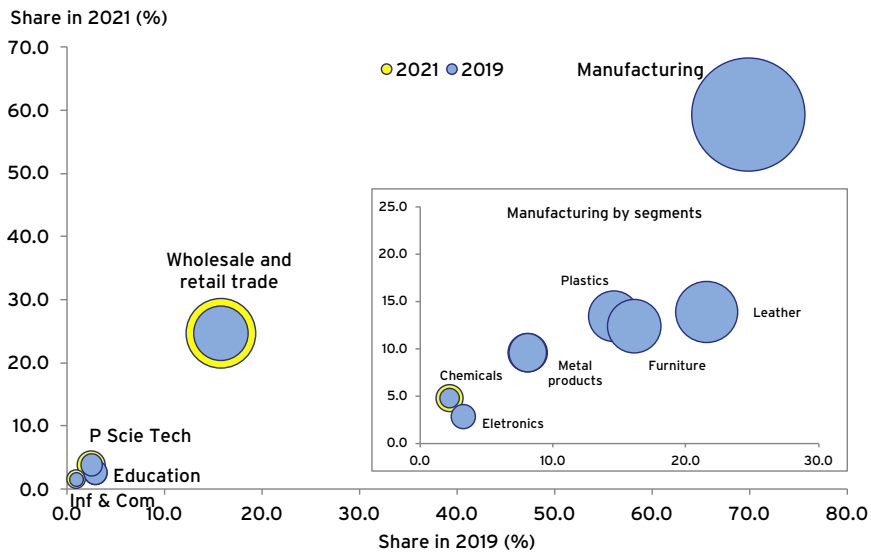
In 2021, the cumulative number of applications filed was 6,711, up +4.3% from 2019. There was a retraction of -2.6% in the first year of the pandemic, followed by an increase (+7.2%) in 2021. Industrial designs were used most often in the year when economic activity recovered, in line with the idea that they can be seen as a differentiating element in the competitive dynamics among sellers (Carvalho et al. 2007). When looking at quarterly growth compared to the same period of the previous year, no clear trend is observed.

FIGURE 3 INDUSTRIAL DESIGN APPLICATIONS

a) Change in number of industrial design applications from 2019 to 2021 (%)



b) Industrial design applications by economic activity



Source: Authors' elaboration based on data from INPI, BADEPI.

While non-residents reduced their applications by -0.7%, resident applicants increased by +6.9%. Among resident applicants, micro and small companies showed exceptional performance, while medium-sized and large companies reduced their applications. As industrial designs protect the 'ornamental' innovation of a product, they are usually associated with non-technological and marketing innovations and their trends are

closer to those of trademarks than patent filing activities, which are more related to technological inventions. The findings suggest that small companies rely more on non-technological innovations.

Turning to legal entities, ‘manufacturing’ continued to be the main applicant, despite a reduction in filings and in its relative participation. ‘Wholesale and retail trade’ deserves to be highlighted due to its impressive growth rate of +67% compared to 2019. This may be related to the increase in online sales, with several companies starting to sell products with their own design. Among ‘manufacturing’ segments, ‘preparation of leathers and the manufacture of leather articles, travel items and footwear’ maintained its lead, although with a reduction in applications.

COVID-19 PATENTS

The pandemic increased the demand for health care, generating an impact on different productive and technological subsystems of the Health Economic-Industrial Complex (CEIS), such as vaccines, medical instruments/equipment and pharmaceutical products.

The COVID-19 Technological Observatory (ObTec COVID-19) at the Instituto Nacional da Propriedade Industrial (INPI) was created to monitor the filling of patents related to COVID-19 in Brazil. The collection of patent documents from the INPI database was carried out in two stages. In August 2021, the first stage involved searching for applications filed from 2019 onwards through three search strategies: (i) using the most relevant IPC classifications in the areas of diagnostics, respirators and masks;⁸ (ii) using keywords related to COVID-19, severe acute respiratory syndrome and the SARS-CoV-2 Coronavirus; and (iii) the retrieval of applications that had requested priority processing at the INPI, through the modality established during the pandemic by INPI Ordinance No. 149/2020, published on 7 April 2020. The prioritisation of the exam in these cases can be requested by the applicant, holder, interested third parties (there were 119 requests from these kinds of applicants) or even by the Ministry of Health (63 requests). About 75% of the requests were approved for prioritisation based on that ordinance.

The second stage involved searching for weekly updates from publications in Brazil’s international property gazette (*Revista da Propriedade Industrial*, or RPI)⁹ in order to identify, in a continuous flow, new applications related to the pandemic.

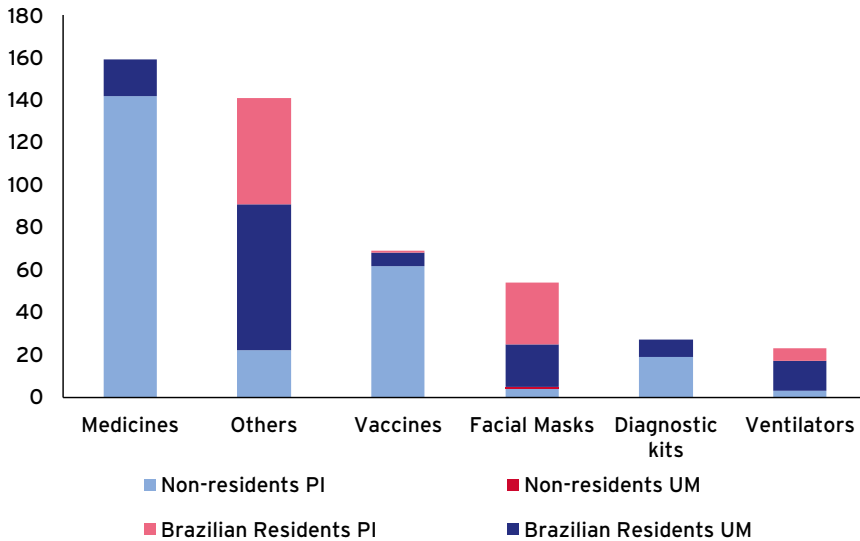
Considering that the epidemic began in December 2019 and a pandemic was only decreed in March 2020, the interest of the world’s scientific community in the subject is still recent. Furthermore, many applications may not have been filed in Brazil yet, since applications initiated abroad have up to 12 months (via CUP) or 30 months (via PCT) to enter the national phase in Brazil. Also, some applications may still be within the

8 <https://www.gov.br/inpi/pt-br/servicos/patentes/tecnologias-para-covid-19/Estudos>

9 <http://revistas.inpi.gov.br/rpi/>.

18-month period of confidentiality (except for those that applied for early publication). In other words, many of them will not yet be classified, which makes their recovery from the databases through the use of IPC codes unfeasible. ObTec COVID-19 is therefore continuing its monitoring, with the aim of bettering understanding the dynamics of the patenting profile in this area in Brazil.

FIGURE 4 DISTRIBUTION OF PATENT APPLICATIONS RELATED TO COVID-19 PANDEMIC, BY CATEGORY AND ORIGIN OF APPLICANT



Source: INPI, ObTec COVID-19.

According to data from the INPI's ObTec COVID-19, the 470 patent applications identified up to February 2022 were divided into six categories. Non-residents concentrated the largest number of patent applications in medicines, vaccines and diagnostic tests. Resident applicants, on the other hand, used both invention and utility model patents and were more highly represented in applications for masks, ventilators and others. Resident applications thus exhibit a profile of low technological complexity, mostly filed as utility model applications. While demonstrating that national companies and researchers took advantage of the opportunity to contribute solutions to combatting COVID-19, this also reflects the difficulty for actors in the national innovation system in developing products with greater economic value and technological complexity.

Considering only applications submitted during the pandemic period, the top five non-resident applicants for invention patents related to the new coronavirus were from the United States (89 patent applications), China (12), Germany (9), France (7), Japan and Russia (6 each). Among all applications, 249 (or 85%) listed only one applicant, with the

rest (43) listing more than one applicant ('co-holders'). Among applications with co-holders, only six indicated collaboration between countries, and two of the six involved cooperation with Brazilian residents.

CONCLUSION

Brazil's vaccination strategy, despite being late starting, was efficient and allowed the reduction of vulnerability, thus enabling economic recovery. This was possible thanks to the existence of the Brazilian public health system (*Sistema Único de Saúde*, or SUS) and the numerous public research institutions. However, it is worth noting that these institutions have lost some of their capacity for innovation due to continuous budget cuts. It is therefore necessary to ensure the proper functioning of the system, with trained professionals, adequate infrastructure and cooperation between its various actors.

Considering invention patent applications, non-resident applicants recovered better than residents, showing the asymmetry of capacity building in frontier technologies. Among resident applicants, both individuals and educational, research and government institutions saw a strong reduction in applications, although remaining the main applicants. Industrial designs showed growth in the period, driven by applications from residents. It is worth noting that micro and small companies showed more dynamism than medium-sized and large companies. Trademarks showed a significant increase in the period, with strong increases in applications from non-residents and, mainly, from residents. In this group, individuals and individual micro-entrepreneurs stood out.

Finally, the monitoring of the INPI's COVID-19 Technological Observatory (ObTec COVID-19) also highlighted asymmetries. Patent applications from non-residents with greater technological complexity are opposed to those from residents with a low technological complexity profile, which are often filed as utility model applications. This suggests it is necessary to guarantee investments in frontier technologies.

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CHAPTER 5

Impact of the COVID-19 pandemic on patent activity: Some evidence from patent filings at the European Patent Office

Bettina Reichl and Marc Nicolas

European Patent Office (EPO)

1 INTRODUCTION

In 2020, when COVID-19 hit societies around the world, it was expected that the pandemic and subsequent containment measures would severely impact economic activity.¹ As the nature of this crisis was unprecedented, the question of its impact on patent filings at the European Patent Office (EPO) was completely open.

Patents are typically meant to protect long-term investments in new technology, and as such they may be less sensitive than other activities to economic shocks. Patent applications are filed as a result of a long research and innovation process, thus any impact of the pandemic on research activity may not be immediately visible in patent data. Moreover, patent applications filed at the EPO are mainly 'second filings' (i.e. they follow a first application in a national patent office). Having previously undergone a pre-screening process in an office of first filing, they usually present a selection of high-potential inventions with a potential for exploitation beyond the period of economic shock.

Nevertheless, various transmission mechanisms and outcomes could be envisaged. For example, it was expected that, in specific sectors such as healthcare, the pandemic would stimulate both innovation and the propensity to patent. While this effect would probably be spread over time, disruption to operations caused by lockdowns and financial constraints could have an immediate negative impact on filings. If the impact of the pandemic was to mirror the experience of previous financial crises, total patent applications at the EPO would be strongly affected, possibly declining by as much as 10% compared to 2019 levels.

¹ In April 2020, the IMF projected the global economy would contract sharply by 3%, more than during the 2008/09 financial crisis (IMF 2020). Implications would differ significantly across countries. In 2021, the 'vaccine-powered' economic recovery began amid a resurging pandemic, with close to 6% global growth during 2020.

Using data published in the EPO's Patent Index² along with additional unpublished insights, in this chapter we provide an overview of how patent applications filed at the EPO developed during the pandemic and, whenever possible, analyse the extent to which the changes can be attributed to the pandemic. The analysis makes use of the existing structure of the data, which allows convenient breakdowns of applications by geographical origin and by technology.

The data show that despite disruption and uncertainty surrounding the pandemic, patent applications at the EPO in 2020 remained almost at pre-pandemic levels, and that the pre-pandemic trend was restored within a year. In 2021, the EPO even received a record number of applications. Breakdowns by geographical origin and technology show a more varied picture. However, even in this case the pandemic amplified some existing trends. So far, a 'disruptive' effect of the pandemic on patenting activity at the EPO cannot be observed.

2 IMPACT ON TOTAL PATENT APPLICATIONS AT THE EPO

Patent applications received during the pandemic

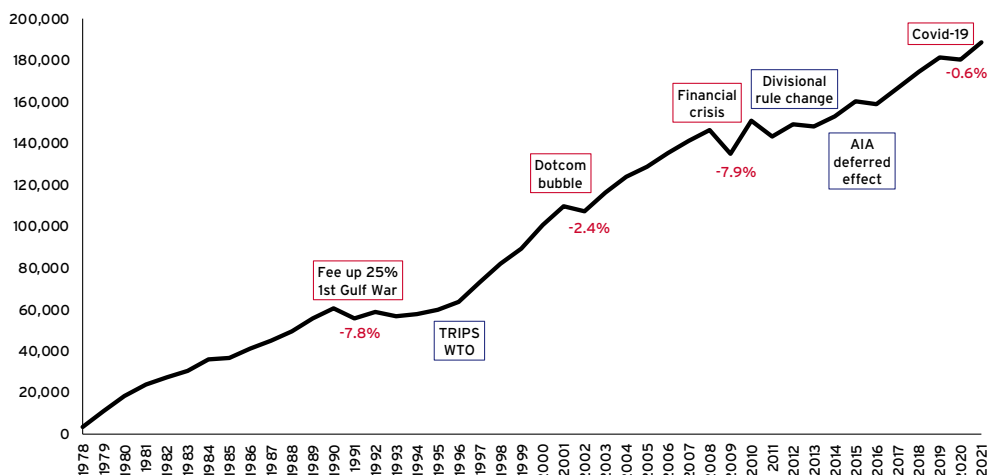
The first sign of an anomaly was observed in April 2020 when filings dropped by almost 7% compared to the level at the same point in the previous year. In the following period, a shortfall occurred almost every month. Despite the growth during the first quarter of the year, the cumulative effect eventually became negative in October 2020. By the end of the year, the EPO had received 180,400 patent applications, representing only a slight decrease of 0.6% compared to 2019. In 2021, the EPO received a record 188,600 new patent applications (+4.5%).

Medium- and long-term perspective

As yearly data reveal, the development of the number of applications has never been linear. In 2013 and 2016, the EPO observed similar short phases of stagnation followed by a quick recovery, both of which are comparable to that of 2020 in their magnitude (-0.4% and -0.6%, respectively). On those occasions, the effects were attributed to procedural changes within the patent system. Compared to the record drop of 8% in 2009 in connection with the great financial crisis, the decline in 2020 was modest.

2 The Patent Index is regularly published and updated on the EPO website in the section "Statistics and Trends" (<https://www.epo.org/about-us/annual-reports-statistics/statistics/2021.html>).

**FIGURE 1 PATENT APPLICATIONS AT THE EPO, 1978-2021
(EURO-DIRECT + PCT ENTERING THE REGIONAL PHASE)**



However, compared to the *average* annual growth since 2011 (+3%), the stagnation in 2020 still represents a significant fall. The positive growth trend was certainly suspended in the first year of the pandemic (2020) but the impact was modest, especially when compared to the depth of the recession which the pandemic induced.

The total number of patent applications received by the EPO includes both European applications filed directly at the EPO in accordance with the European Patent Convention (EPC) and Patent Cooperation Treaty (PCT) applications entering the European phase at the EPO (see Box 1). After four years of comparable growth, European direct applications in 2020 were more severely impacted by the crisis (-3%) than PCT regional phase entries (+1%). The subsequent rebound in 2021 was entirely driven by PCT applications.

Comparison to other offices

While similarities with other patent offices are limited by the specific nature of the EPO (see Box 1), it is still interesting to look at the changes in a broader context.

For 2020, the so-called IP₅ offices report an aggregated growth of 2% compared with 2019 (IP₅ 2020). However, differences between the offices were huge: while applications increased by 7% at the Chinese patent office and 4% at the Korean patent office, the patent offices of Japan and the US reported a decrease of 6% and 4%, respectively. An EPO internal survey among national patent offices in Europe also revealed heterogeneous developments, with a strong increase in first filings in some countries and sharp decreases elsewhere. While, for example, the UK and Italy noticed a significant increase, the patent offices in Germany and France reported a significant decrease in 2020. The German patent office recently published a further fall of some 6% in 2021 (German Patent and Trade Mark Office 2021).

The explanation of these significant differences lies to a large extent in the different economic impact of the pandemic between countries and between the sectors that compose their respective economies.

BOX 1 THE EUROPEAN PATENT OFFICE

The European Patent Office is the executive organ of the European Patent Organisation, an intergovernmental organisation set up in 1977 on the basis of the European Patent Convention (EPC). Its mission is to grant European patents in accordance with the EPC by a single procedure. The European patent grant procedure begins with a formalities examination and a search. The first stage ends with the publication of the patent application and the search report. The substantive examination, potentially leading to a grant, follows at the applicant's request. In each of the (currently) 38 EPC member states for which a patent is granted and validated, the European patent will then have the same effect as a national patent granted by the patent office of that state. It is important to bear in mind that in order to obtain patent protection in European countries, companies can also apply separately at selected national patent offices. However, one single examination and grant procedure before the EPO saves applicants interested in numerous markets financial and other resources.

The EPO is also a PCT Receiving Office, an International Searching Authority and an International Preliminary Examining Authority. In its role as Designated or Elected Office, the EPO examines international (PCT) applications entering the 'European phase' at the EPO (also named the 'regional phase') according to the rules established by the EPC.

The EPO is mainly an office of second filing for applications which claim priority of an earlier application.

The total number of patent applications at the EPO includes both European applications filed directly at the EPO in accordance with the EPC and PCT applications entering the European phase at the EPO during the reporting period. Over the last decade, the ratio between direct European applications and PCT European phase entries was about 40:60. The growth of both routes is not necessarily identical.

3 BREAKDOWN BY COUNTRY OF ORIGIN

As the pandemic did not unfold uniformly across the globe, an analysis of applications by geographical origin provides interesting insights.³

Overview

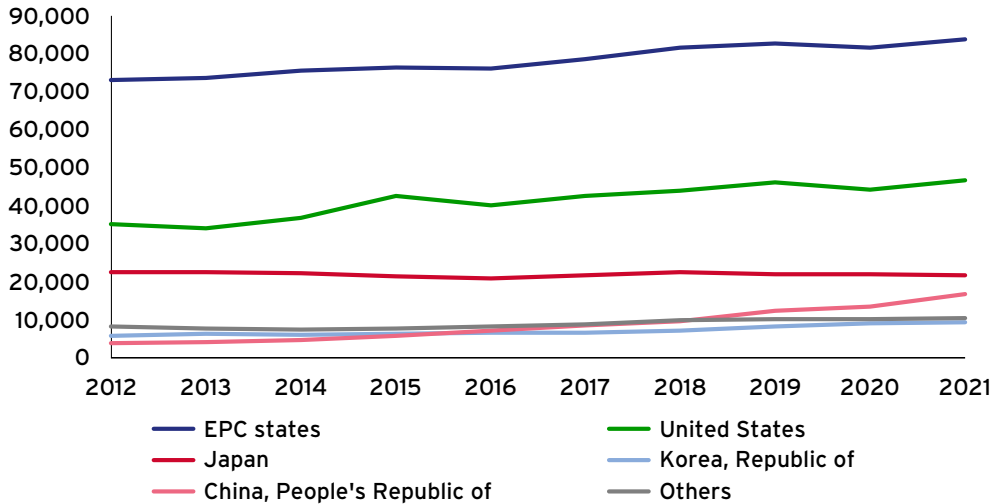
While the EPO receives patent applications from all over the world, their geographical origin is relatively concentrated: the top five applicant countries account for almost two-thirds of patent applications at the EPO, and the top 20 countries account for 95%. In 2020 and 2021, the top country of origin remained the US, accounting for 25%,

³ The origin of an application is determined by the country of residence of the first applicant listed on the application form.

followed by Germany (14%) and Japan (11%). The People’s Republic of China ranked fourth, followed by France. EPC countries as a bloc filed some 45% of all applications at the EPO, with Germany, France and Switzerland in the lead.

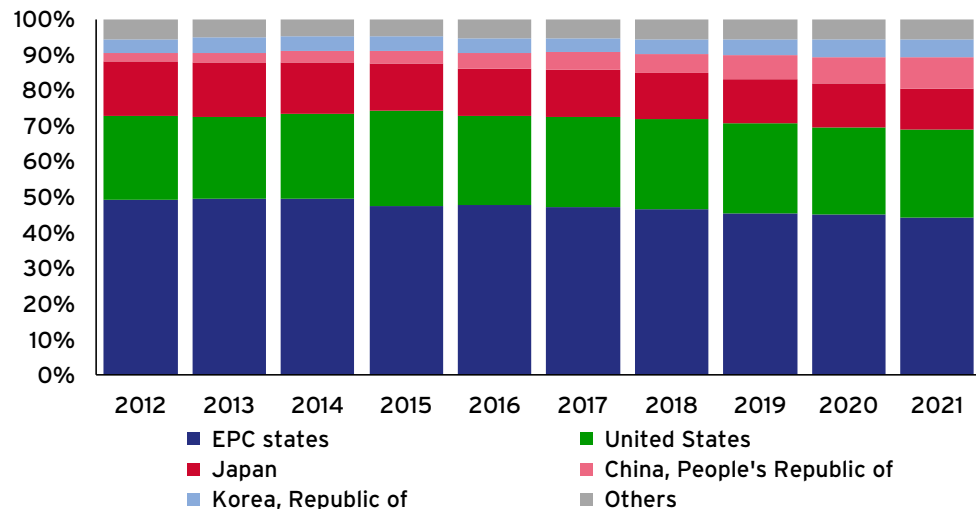
The overall ranking of the countries remained unchanged throughout the pandemic years 2020 and 2021, as did the geographical origin of the top applicants. As in 2019, four of the ten largest applicants were European, and there were two each from the US and the Republic of Korea, one from Japan and one from the People’s Republic of China.

FIGURE 2 GEOGRAPHICAL ORIGIN OF EPO APPLICATIONS 2012-2021



Looking at the relative proportions, a continuous shift is obvious: the proportion of Chinese applications continues to increase, mainly at the expense of European and Japanese applications.

FIGURE 3 GEOGRAPHICAL ORIGIN OF EPO APPLICATIONS 2012-2021



The absolute numbers for 2020 and 2021 indicate further interesting developments. In 2020, the People's Republic of China was the country with the greatest absolute growth. The continuation of a long upward trend results in filings having quadrupled in a decade. Filings from the Republic of Korea also continued to grow in 2020, while applications from Japan and the other countries remained fairly stable. Notably, applicants from the EPC states and even more so from the US filed considerably less.

TABLE 1 DELTA OF EPO APPLICATIONS IN 2019/2021 BY GEOGRAPHICAL ORIGIN

| Geographical origin | Change 2020/2019 | | Change 2021/2020 | |
|---------------------|------------------|------------|------------------|------------|
| | Applications | Percentage | Applications | Percentage |
| EPC states | -1 023 | -1.2% | +2 244 | +2.8% |
| United States | -1 927 | -4.2% | +2 283 | +5.2% |
| Japan | -132 | -0.6% | -273 | -1.2% |
| China | +1 209 | +9.9% | +3 229 | +24.0% |
| Rep. Korea | +745 | +8.9% | +310 | +3.4% |
| Others | +13 | +0.1% | +390 | +3.8% |
| All origins | -1 115 | -0.6% | +8 183 | +4.5% |

While the growth from Asia was strong, it only partly compensated for the decrease in applications coming from the two major blocs (the EPC states and the US), resulting in a net loss of some 1,100 filings. In 2021, applications from the US and the EPC states recovered from the decline in 2020 and contributed equally to the overall growth.

In the case of applicants from the US and the EPC states, information available strongly supports the assumption that the dip in 2020 was due to the conditions caused by the pandemic. The Patent Filings Survey carried out by the EPO of thousands of randomly selected applicants reports that in 2020, about 50% of respondents from the EPC bloc and the US indicated the pandemic would have a negative or significantly negative impact on their “patent-related business”. In 2021, significantly fewer respondents from those two blocs stated such a negative impact, while more respondents reported a positive impact, and the largest group, indicating “no impact”, also increased.⁴

While no such information is available for other countries, a more detailed analysis shows that during the first phase of the pandemic, the positive trend in Chinese applications also weakened when growth temporarily lost momentum (+30% in 2019, +10% in 2020, and +24% in 2021).

4 The recovery effect was more pronounced among European applicants.

Focus on the EPC area

The EPC countries are far from being a homogeneous bloc. In 2020, applications from Germany, Europe's top filing country, decreased by 3% and those from the UK by as much as 7%. Applications from France and Italy, on the other hand, each grew by 3% in 2020. There was a notable increase in filings from Finland (+11%), and significant differences were more generally observed in the group of smaller applicant countries. When the increase in the total number of applications resumed in 2021, growth from the EPC area (+3%) was below average, and it was not driven by the largest countries. German applications returned to a marginal positive growth of 0.3%, translating into fewer than 100 additional applications. Applications from France and the UK even declined. Spain and Italy contributed some hundred files to the rebound; big increases in patent filings were also observed from Sweden, Finland and Denmark, in addition to Switzerland and the Netherlands. The growth champions were among the countries with the smallest patenting volumes. Filings from Turkey, Portugal and Poland also grew at a rate above average.

As diverse as these observations are, so too are the potential explanations – some relate to long-term trends or the broader context, and others to the pandemic. The UK, for example, is one of several countries with large annual fluctuations over the last decade, and Brexit could play a role in directing more patent applications to the national office. German industry was traditionally strong in conventional mechanical engineering technologies, which have been losing relevance in recent years with the transition to electric vehicles. France, on the other hand, was a growth champion in pharmaceuticals in 2020, a field directly stimulated by the pandemic. In smaller countries with few but very active applicants, developments can even be traced back to one company. In 2020, for example, half of the increase in Finnish applications can be attributed to one company, which has for years been heavily engaged in a technology field that was not directly stimulated by the pandemic.

4 BREAKDOWN BY TECHNOLOGY

Asymmetric impact on innovation

While the pandemic forced profound changes in virtually all aspects of society and the economy, its impact on innovation was expected to be asymmetric across industry sectors. For example, innovations serving public health had to be fast-tracked, requiring immediate acceleration of critical innovations, with governments also waiving regulatory requirements to enable condensed trial periods and fast vaccine approvals. The pandemic was expected not only to stimulate the development of new vaccines, drugs and medical devices, but also to strengthen spillovers. Disrupted access to physical health services due to social distancing required the uptake of telehealth and remote care management, fostering digitalisation in the healthcare sector. In the fields of education, media and administration, the urgent need to minimise contact also encouraged digitalisation at an

unprecedented speed. In transportation, with an almost total collapse in demand leaving many companies fighting for survival, financial constraints led them to delay or cease investment in research and development. However, in view of a post-pandemic ‘new normal’, reduced human interaction would make innovation in the field of autonomous passenger transportation increasingly appealing. In the medium to long term, the pandemic would generally change consumer preferences and organisational culture, making them quicker to adopt new technologies.⁵

Patent statistics

Patent applications are filed at the end of a longer innovation process, and thus immediate visibility of the described developments in patent statistics is in most cases unlikely. In addition, unlike most economic analyses, patent statistics are not structured along branches of activity or products. The EPO data in the Patent Index build on the classification of technologies. The International Patent Classification (IPC) covers over 70,000 technological codes.⁶ The WIPO concordance table groups all codes into 35 distinct technology fields, and further into five broad technology sectors (electrical engineering, mechanical engineering, instruments, chemistry, and other fields).⁷

Overview

The breakdown by technology sector indicates two notable observations which deserve more detailed analysis. In the electrical engineering sector, growth slowed in 2020 but regained momentum in 2021. In the mechanical engineering sector, application numbers decreased in absolute terms in 2020 (-7%).

For three technology sectors – namely, instruments, chemistry and other fields – the positive trends continued, apparently unaffected by the pandemic.

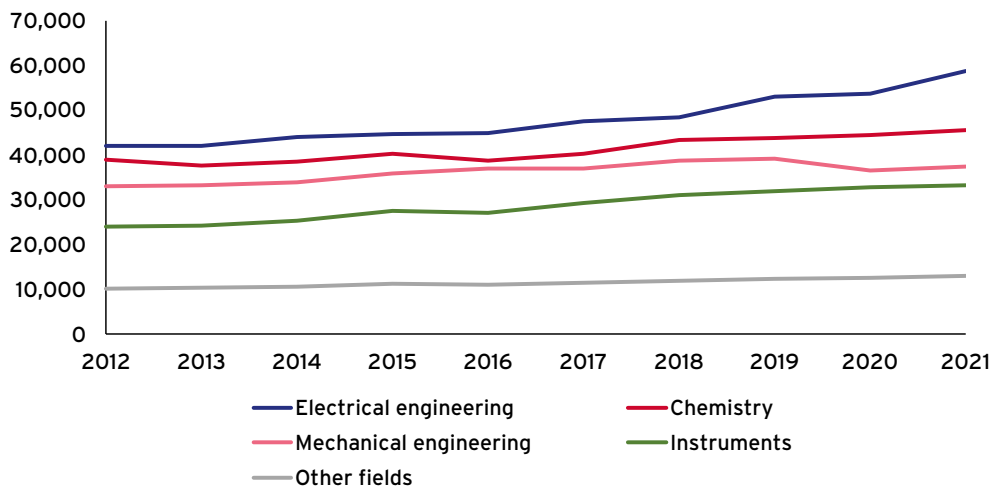
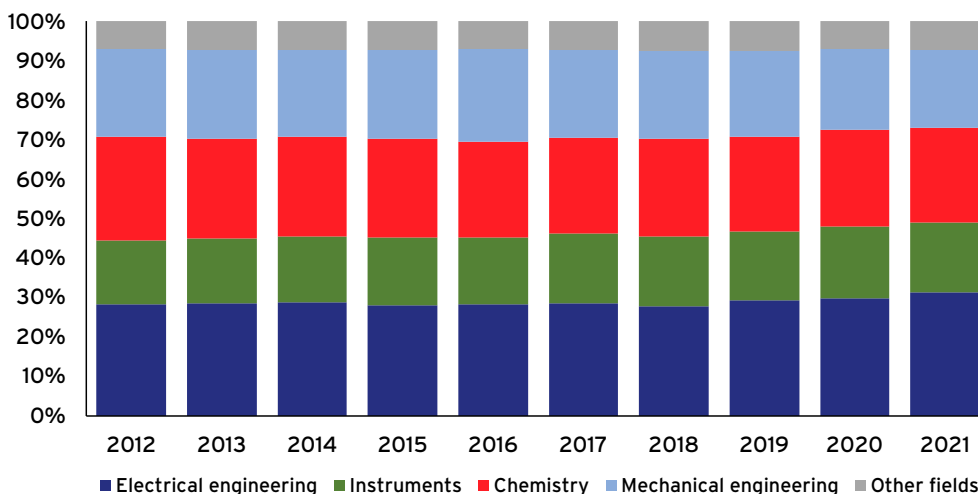
With regard to relative proportions, after two years of the pandemic, the reduction in the size of the mechanical engineering sector (minus 2 percentage points since 2019) was compensated for by an equivalent increase in the electrical engineering sector. However, in both sectors the trend had begun years earlier.

Looking at the technology fields in detail, diverging developments emerge more clearly. In 2020, over half of the 35 fields saw declining application numbers, of which only six recovered to pre-pandemic levels in 2021. In total, in 2021, 17 of the 35 fields saw filing numbers below 2019 levels.

⁵ An interesting report on this subject was published by The Economist Intelligence Unit in 2020.

⁶ <https://www.wipo.int/classifications/ipc/en/preface.html>

⁷ Regular updates of the WIPO Concordance Table are published on the WIPO website in the “Intellectual Property Statistics” section (<https://www.wipo.int/ipstats/en/index.html>).

FIGURE 4 DISTRIBUTION OF EPO APPLICATIONS BY TECHNOLOGY SECTOR, 2012 - 2021**FIGURE 5 DISTRIBUTION OF EPO APPLICATIONS BY TECHNOLOGY SECTOR, 2012-2021**

In 2021, the top ten technology fields⁸ were identical to those in pre-pandemic years. The number of patent applications increased in nine of the ten fields. In 2021, digital communication (+9%) narrowly overtook medical technology (+1%) as the field with the largest number of applications. Computer technology was the third strongest field, and the one with the steepest growth (+10%). Patent activity in the pharmaceuticals (+7%) and biotechnology (+7%) fields also continued to boom. The three fields which experienced a

⁸ In order of importance in 2021, these are: digital communication; medical technology; computer technology; electrical machinery, apparatus, energy; transport; measurement; pharmaceuticals; biotechnology; other special machines; organic fine chemistry.

decline in 2020 – namely, transport, measurement and other special machines – (almost) recovered to pre-pandemic levels in 2021. The only field that saw a decline in 2021 was organic fine chemistry.

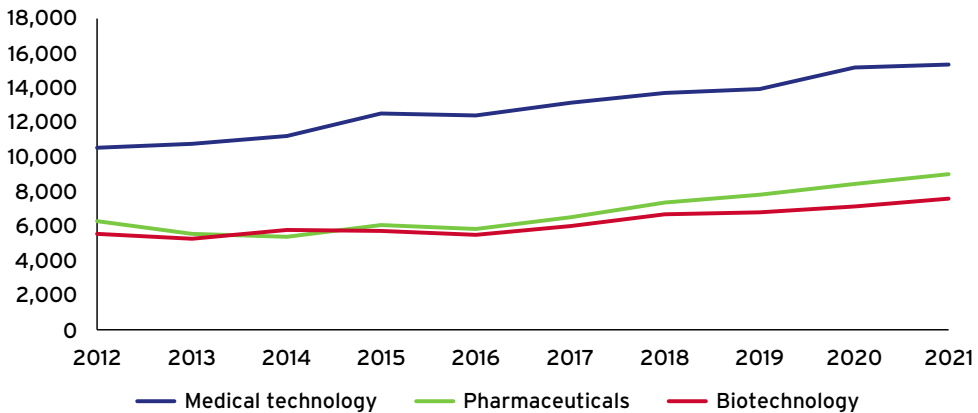
In seven of the ten fields, growth was disproportionately high, amplifying their dominance. The proportion accounted for by the top ten is increasing continuously: in 2021, they represented 57% of all applications at the EPO (compared to 54% in 2018).

Healthcare

Healthcare is not just about medicines and vaccines (i.e. the pharmaceutical sector). Genetic tests or therapies that ‘switch off’ genes known to trigger disease belong to the field of biotechnology. Both pharmaceuticals and biotechnology are part of the chemistry sector. The field of medical technology (instruments) covers medical instruments for diagnosis, the treatment of diseases and surgery. Examples of technologies in this field are surgical robots, computed tomography, pacemakers and smart wearables, as well as pandemic-related innovations such as vaccination instruments, respirators, ventilators or contactless infra-red thermometers.

Figure 6 compiles the filing trends in the medical technology, pharmacy and biotechnology fields. As expected, activity developed strongly in all three fields. In 2021, they contributed some 18% of all applications at the EPO.

FIGURE 6 DEVELOPMENT OF THE NUMBER OF HEALTHCARE APPLICATIONS AT THE EPO, 2012-2021



In 2020, applications in the medical technology field were up almost 9%, exceeding 15,000. However, it is important to note that the pandemic apparently offered a one-off boost, as in 2021 growth slowed significantly. Moreover, the magnitude of the surge in 2020 was not unprecedented. The medical technologies field was dominated almost

equally by US and European companies. Considerable growth, albeit from low bases, was also recently posted by the People's Republic of China and the Republic of Korea, while filings from Japan decreased.

The biotechnology and pharmaceuticals fields were also among the growth champions in 2020, increasing by 5% and 8%, respectively. These values exceeded the lower growth of 2019 but were in the range of the medium-term trend. In 2021, both fields grew by another 7%. The pandemic apparently had a stabilising effect on the dynamics of these two fields.

The field of biotechnology is quite diverse in its application domains, with the most active area directed towards medical uses ('red' biotech). Other important domains, such as agriculture ('green'), marine science ('blue') and industrial processes ('white'), were not directly affected by the pandemic, which might have obscured the impact on the growth rate.

Prior to the pandemic, innovative vaccines were already well represented amongst the pharmaceutical filings at the EPO, although they rose to over 240 in 2020 from 150 in 2016. This shows that researchers were able to quickly develop new vaccines against the coronavirus, but also that this field was already thriving with these ideas.⁹ Pharmaceuticals was one of the few large fields where applications from the People's Republic of China decreased.

Digital technologies

For more than a decade, digital communication,¹⁰ computer technology¹¹ and electrical machinery¹² have ranked among the top technology fields at the EPO. In 2019, 2020 and 2021, the three fields together accounted for more than 20% of all applications at the EPO.

As digital communication networks provided connectivity to sustain social and economic activity throughout the pandemic, these technologies became more crucial to daily life than ever before. The exploding demand did not necessarily require immediate major innovative steps, as mature digital tools that were already widely used could initially be scaled up for a quick roll-out.

Having soared in 2019 (+9%), the sector of electrical engineering made only modest gains in 2020 (+1%), with digital communication up 1%, computer technology up 4% and electrical machinery up 1%. Then, in 2021, the first two of these fields experienced

9 For detailed information and cases studies covering the topic, see the EPO Patent Index (<https://www.epo.org/about-us/annual-reports-statistics/statistics/2021/insight-into-vaccines.html>)

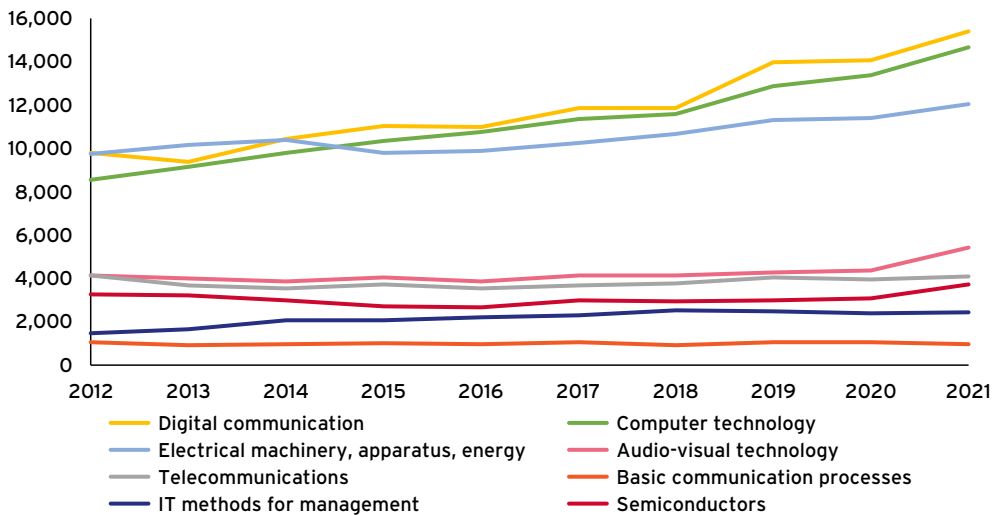
10 For example, basic electronic circuitry and electronic communication, transmitters, receivers, smartphones or wireless sensors.

11 For example, computing, calculating and counting devices, digital computers and data processing systems.

12 For example, lighting devices, power and electric energy supply systems, basic electric elements such as power cables, magnets, relays.

outstanding growth (+9%, +10%). In these fields, especially digital communication, waves of growth do not appear unusual. In the field of computer technology, the areas of artificial intelligence, machine learning and image data processing recorded steady growth above 10% during the pandemic. Another observation worth mentioning is the unprecedented growth, albeit from a smaller base, in the fields of audio-visual technology (+24%) and semiconductors (+21%). Taken as a whole, in 2021 the sector of electrical engineering accounted for over 31% of all applications at the EPO.

FIGURE 7 DEVELOPMENT OF THE NUMBER OF ELECTRICAL ENGINEERING APPLICATIONS AT THE EPO, 2012-2021

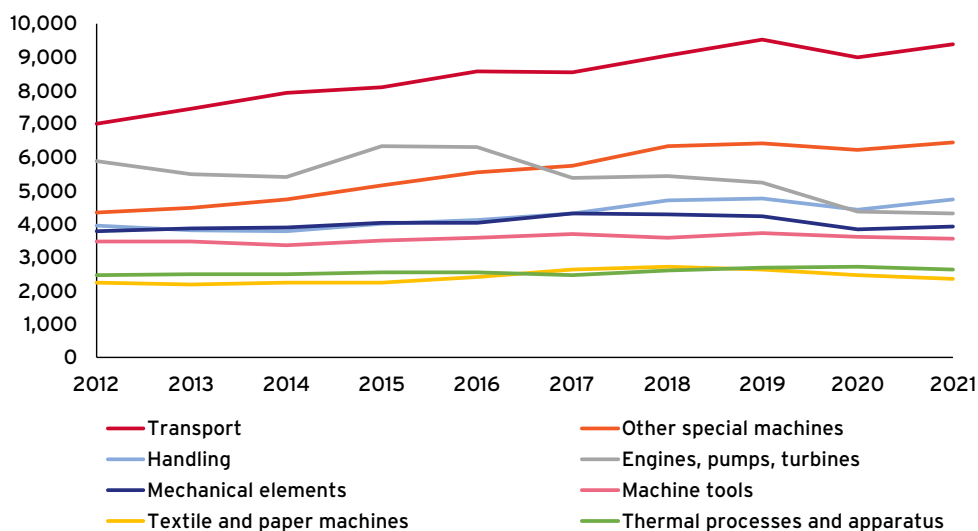


Mechanical engineering

A detailed view of the mechanical engineering fields reveals that a substantial part of the total decrease (-7% in 2020) occurred in engines, pumps and turbines, which finds itself in a longer-lasting phase of decline. Other mechanical engineering fields associated with so-called conventional technologies continued to stagnate or decline. After a dip in 2020, transport almost recovered in 2021.

Transport is a heterogeneous field covering air, water, road and rail vehicles, with divergent trends. The 2020 decrease and the 2021 rebound were mainly related to the aviation industry. In the area of passenger vehicles, recent trends tend to confirm the ongoing transformation of the sector. Electric propulsion, hybrid propulsion and drive control all recorded double-digit increases in 2021, while other fields such as vehicle equipment and brakes have been on a stagnating or declining trend since 2018.

FIGURE 8 DEVELOPMENT OF THE NUMBER OF MECHANICAL ENGINEERING APPLICATIONS AT THE EPO, 2012-2021



5 CONCLUSION

In 2020, patent applications at the EPO showed strong resilience (-0.6%), especially when compared to the depth of the economic recession caused by the pandemic. Though the uncertainty surrounding the pandemic continued in 2021, the stagnation of 2020 was overcome and followed by a quick rebound (+4.5%).

To a large extent, this reflects the longer-term development of applications at the EPO, with growth in demand for patents from some countries and in some technologies offsetting declines elsewhere.

- One constant over time is the continuous increase from Asia, mainly driven by the People's Republic of China and the Republic of Korea. In 2020, filings from these two countries compensated for the temporary drop in US and EPC applications, although not entirely. In 2021, applications from the US and Europe recovered from the decline presumably caused by the first shock of the pandemic and contributed equally to the overall growth.
- In 2020, disproportionate losses occurred in mechanical engineering, a technology sector which had begun to lose relevance long before the pandemic.
- Healthcare, on the other hand, saw a strong one-off boost in the field of medical technologies. Growth in the field of pharmaceuticals, which was also central to overcoming the pandemic, was almost equally strong but continued its established growth path thereafter.

- In the electrical engineering sector, growth was slightly above average in 2020 but still modest. In 2021, the scale of growth was outstanding in the ICT fields, in particular in audio-visual technology, digital communications and computer technology, certainly reflecting the growing demand for further digitalisation amplified by the pandemic.
- In 2021, the number of patent applications increased in nine of the ten most active fields of technology. In seven of these fields, growth was disproportionate, thus strengthening their dominance.

General conclusions about the impact of the pandemic are difficult. Some one-off effects can be observed, but so far it has not been possible to identify new sustainable trends triggered by the pandemic. The pandemic instead amplified some existing trends. The ‘disruptive’ nature of the pandemic on patenting activity at EPO seems much weaker than expected.

However, at this point in time further deferred effects should not be excluded. The delays between research, invention and patent filing can be significant, even more so for the EPO as it is an office of second filing. Trends at the EPO mainly reflect research outcomes generated months or years earlier, pre-filtered through the lenses of inventiveness and economic potential. This also means that the findings do not necessarily reflect one-to-one the impact of the pandemic on innovation as such.

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CHAPTER 6

The impact of COVID-19 and Singapore's response

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William Kwek, Ho Jia Yi, Thong Wei En, Tan Chor Kiang, Muhammad Bin Rahmat and Benjamin Mak¹

Intellectual Property Office of Singapore (IPOS); IPOS; Singapore Ministry of Trade and Industry (MTI); MTI; National Research Foundation Singapore (NRF); NRF

1 OVERALL IMPACT ON SINGAPORE'S ECONOMY

The global COVID-19 pandemic resulted in strong economic headwinds for Singapore. In 2020, Singapore's GDP contracted by 4.1% – the country's worst recession since independence. The impact of COVID-19 on the Singapore economy in 2020 was felt through five main transmission channels:

1. a fall in tourist arrivals and air travel;
2. a fall in domestic consumption;
3. a fall in external demand with supply chain disruptions;
4. manpower disruptions and the requirement to implement safe management measures (e.g. implementation of circuit-breaker² measures); and
5. negative spillovers from the slowdown in domestic economic activity.

Each of these channels affected the various sectors of Singapore's economy to varying degrees, resulting in variegated performance.

Since then, the Singapore economy has rebounded on the back of a recovery in global demand and a strong domestic vaccination programme. The country's GDP grew by 7.6% in 2021, recovering to above pre-pandemic levels in absolute terms.

While overall GDP rebounded in 2021, the recovery was uneven across sectors. For instance, while the real value-added of outward-oriented sectors such as manufacturing, wholesale trade, information and communications, and finance and insurance recovered

¹ The authors would like to thank the Registry of Patents, Designs & Plant Varieties, and the Registry of Trade Marks at the Intellectual Property Office of Singapore for their contributions to the chapter.

² The circuit-breaker measures included physical workplace closures, suspension of dining-in services and the stoppage of most construction works.

to above pre-pandemic levels, the real value-added of the other sectors remained lower. In particular, activity in the aviation- and tourism-related sectors, consumer-facing sectors, as well as the construction sector remained below pre-COVID levels.

The Singapore economy is projected to continue to recover in 2022, although growth will moderate from its 2021 level. This is barring the materialisation of downside risks, including those arising from the conflict in Ukraine and the ongoing pandemic.

2 SINGAPORE'S INNOVATION POLICY SUPPORT DURING COVID-19

The COVID-19 pandemic has accelerated structural shifts in Singapore's economy, such as digitalisation. In particular, businesses have taken steps to digitally transform their business operations, products, and services to seize new opportunities arising from the pandemic.

The S\$25 billion Research Innovation and Enterprise (RIE) 2025 plan was unveiled in December 2020 to build on earlier investments and enhance research to support areas of national priority, such as trade and connectivity, lifelong learning, sustainability, and digital innovation. In addition, time-limited funding support in the form of a S\$285 million Special Situation Fund for Startups was provided to help high-potential, Singapore-based startups sustain their growth momentum in the face of the pandemic. To catalyse public-private partnerships, a set of National Innovation Challenges (NICs) was introduced in the May 2020 Fortitude Budget. The NICs focused on partnerships to develop industry-led solutions for challenges that all businesses were grappling with amid COVID-19 – from reopening Singapore safely to achieving safe workplaces, homes, schools, and commutes. The NICs rode on the success of existing initiatives, such as Enterprise Singapore's Open Innovation Platforms and the Gov-PACT programme.

Internationalisation of startups was supported with enhancements to Enterprise Singapore's Global Innovation Alliance introduced in the February 2021 Budget. This includes (i) an expansion of the network from 15 to 25 city links over the next five years, and (ii) incorporation of the Co-Innovation Programme, which supports up to 70% of qualifying costs for cross-border innovation and partnership projects.

Under the Singapore Green Plan 2030,³ Singapore is working to build up the capabilities of its agri-food industry, with S\$144 million in RIE funding allocated to driving innovation in food tech. The pandemic further strengthened the case for food security innovations to enhance domestic resilience

At the same time, COVID-19 has led to a greater focus on securing supply chain resilience. For instance, disruptions in supply chains have alerted the government to the need to use technology to enhance the reliability of Singapore's logistics and transport networks. The government will support industries to harness their technological strengths more

3 www.greenplan.gov.sg

effectively to create new avenues of enterprise growth. For instance, the Maritime and Aviation Transformation Programmes were initiated to leverage technologies such as big data analytics and advanced sensors and communications to enhance connectivity capabilities and further Singapore's position as a maritime and aviation hub post-pandemic.

COVID-19 has also highlighted the importance of supporting epidemic preparedness and disease-specific research. Singapore was an important contributor during the pandemic, with A*STAR publishing 80 international papers on COVID-19 research to date. This, alongside other research from the Institutes of Higher Learning, has contributed to putting Singapore on the world map for COVID-19 research. According to Elsevier, a Dutch information analytics company, Singapore is ranked among the top 12 globally in terms of citation impact for COVID-19-related research. The Fortitude test kit and cPass were developed with the use of A*STAR⁴ and Duke-NUS⁵ patented technology, respectively, to detect the presence of the COVID-19 virus. The cPass was the first COVID-19 antibody test kit to obtain the approval of the U.S. Food and Drug Administration (FDA).

A National Programme for Research in Epidemic Preparedness and Response (PREPARE) was established to strengthen Singapore's diagnostics, therapeutics, and vaccine development platforms. There will also be development of regional infectious disease collaboration networks, as well as an exchange programmes for researchers, students, and public health experts to facilitate cross-border sharing of resources and capabilities, and efficient deployment of solutions during pandemics.

Although Singapore has provided a multitude of support schemes to support the country's economic interest, an empirical assessment of how R&D activities were affected will only be possible once aggregate R&D statistics for 2020 and 2021 become available.

3 INTELLECTUAL PROPERTY/INTANGIBLE ASSET FILING TRENDS DURING THE PANDEMIC

Overall trends

In 2020, intellectual property (IP) filings in Singapore for patents, trademarks, and registered designs dipped across the board in comparison with 2019. However, in 2021, Singapore witnessed an increase in IP filings across all forms of IP in tandem with the economic recovery.

⁴ "IPOS to roll out more initiatives to help businesses use IP to thrive amid COVID-19", IPOS press release, Intel 25 August (www.sgpc.gov.sg/media_releases/ipos/press_release/P-20200825-2).

⁵ "Duke-NUS and GenScript announce notice of allowance for U.S. patent application for SARS-CoV-2 surrogate virus neutralisation test", Duke-NUS press release, 22 June (www.duke-nus.edu.sg/allnews/u.s.-patent-application-for-sars-cov-2-surrogate-virus-neutralisation-test).

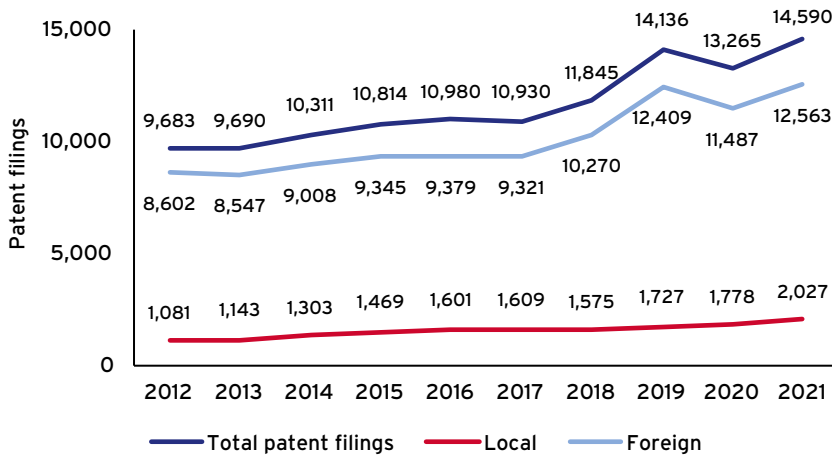
Technological innovation has played a critical role in Singapore's fight against COVID-19. There was an increase in IP filings for health-related innovations in 2020 as part of a larger response to the pandemic. Trademark filings in Pharmaceutical preparations and Medical apparatus saw substantial increases of +17.5% and +36%, respectively. For registered designs, filings in Medical and laboratory equipment increased by 77% in 2020. The IPOS also received patent applications relating to face masks, swabs for collecting of biological specimen, and contact tracing technology in 2020.

However, some sectors were not spared from the economic impact of the pandemic. Trademark filings in Food & beverages (F&B) and temporary accommodation services saw a sharp decline in 2020 by 22%, while filings in Fashion apparel goods and Education and entertainment services also observed declines of 12.9% and 8.7%, respectively. Registered design filings in the area of Articles of adornment was the most adversely impacted in 2020 with a 44% drop, followed by Travel goods and Furniture with declines of 38% and 13%, respectively.

Trends in patent filings

Singapore recorded almost 14,600 patent applications in 2021, representing a 10% year-on-year increase (Figure 1). In the ten-year period from 2012 to 2021, applications from foreign applicants made up 86.8% of total applications. Foreign applications also grew slower, at 46%, compared to local applications, at 87.5%.

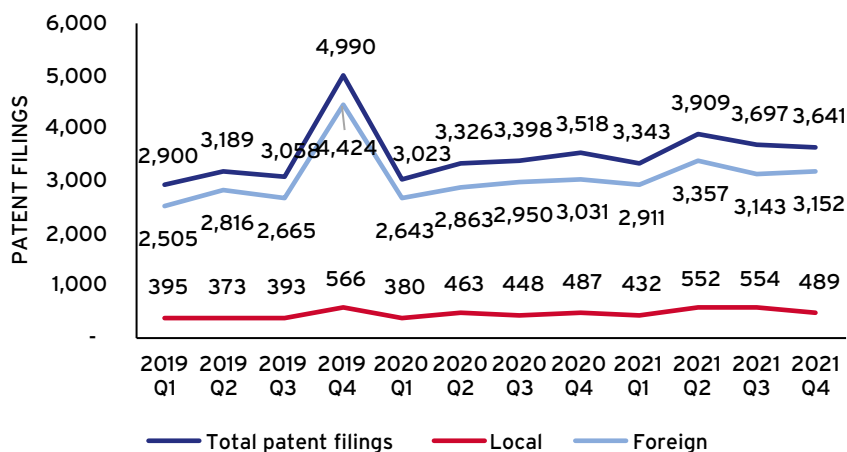
FIGURE 1 OVERVIEW OF PATENT FILINGS BY YEAR



Source: Intellectual Property Office of Singapore.

Focusing on quarterly filing numbers in the years 2019 to 2021, the main observation is the sharp increase in patent filings in 2019 Q4 and the steep drop thereafter (Figure 2). This was, however, not related to the pandemic but due to the closure of the 'foreign route' of patent search and examination at the beginning of 2020.⁶ This phenomenon was more apparent in foreign filings than local filings.

FIGURE 2 OVERVIEW OF PATENT FILINGS BY QUARTER



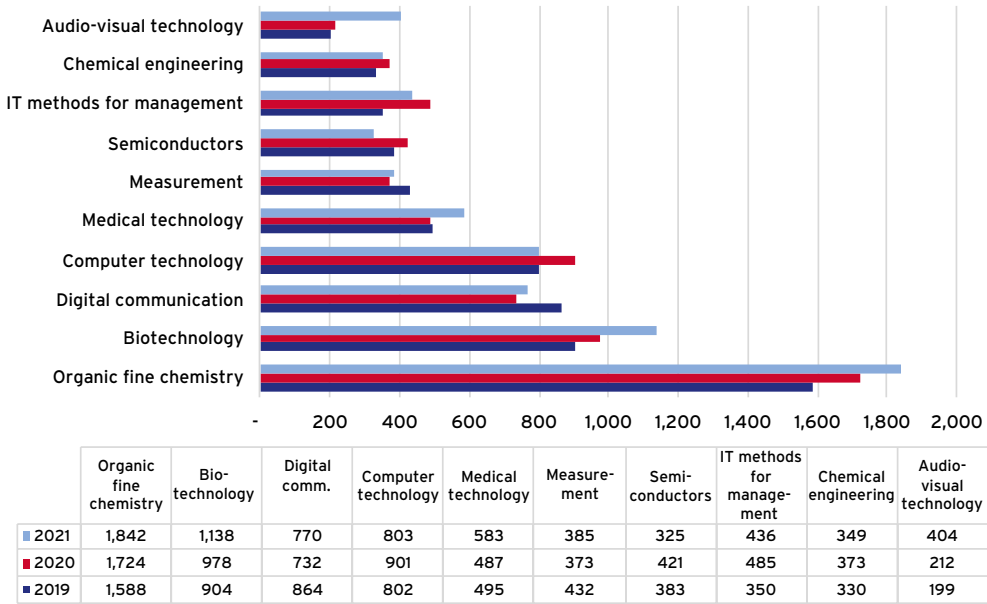
Source: Intellectual Property Office of Singapore.

In 2021, Singapore received the most patent filings from US applicants (4,771), with a 22% growth in volume from 2020. This was followed by Singapore (2,027), Japan (1,750), China (1,575), and Germany (579), maintaining the same top five rank order as in 2020. Together, these five countries accounted for 73.4% of total patent applications received in 2021.

A breakdown by technology field shows that Organic fine chemistry topped the list as the most frequently filed field of technology for patent applications in Singapore from 2019 to 2021, constituting about 17.6% of applications in 2021. This was followed by Biotechnology (10.9%), Computer technology (7.7%), Digital communication (7.4%), and Medical technology (5.6%). There were no shifts in the top five technology fields from 2019 to 2021 (Figure 3). However, strong growth was observed for Audio-visual technology (103.0%) and Biotechnology (25.9%) from 2019 to 2021, which could be attributed to changing consumer demands associated with the outbreak of the pandemic.

⁶ The 'foreign route' for search and examination entails an applicant relying on the search and examination report issued by a foreign patent office for the same invention to obtain a patent in Singapore.

FIGURE 3 OVERVIEW OF PATENT FILINGS BY TECHNOLOGY FIELD

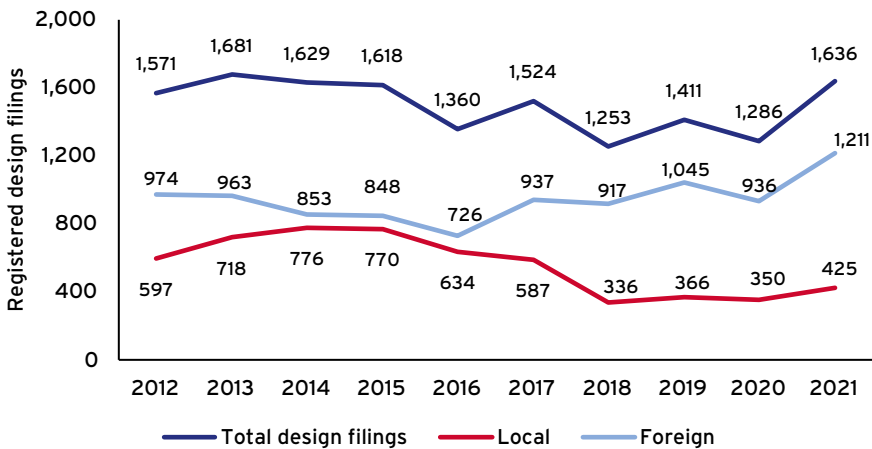


Note: Based on the top ten technology fields in 2021.
 Source: Intellectual Property Office of Singapore

Trends in registered design filings

Singapore recorded a total of 1,636 registered designs filed in 2021, representing a 27% year-on-year increase (Figure 4).

FIGURE 4 OVERVIEW OF REGISTERED DESIGN FILINGS BY YEAR

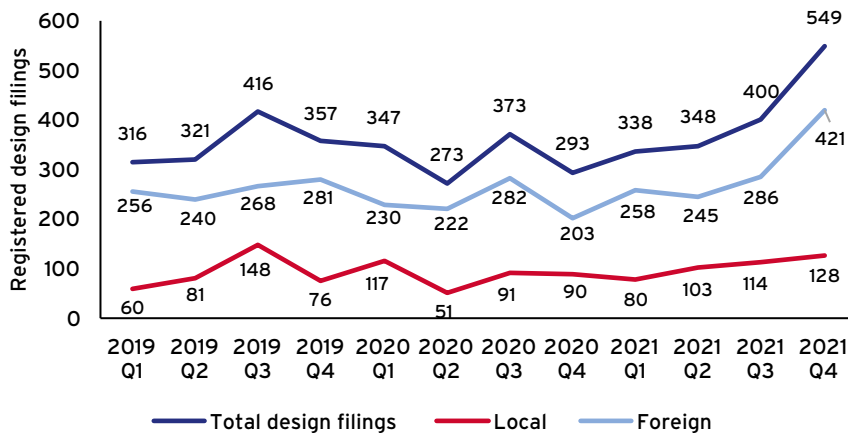


Source: Intellectual Property Office of Singapore.

Overall, there was an increase in the number of registered design filings in Singapore from 2012 to 2021, and this was driven by an increase in foreign filings. On the other hand, local filing numbers declined from 597 in 2012 to 425 in 2021, after experiencing an initial increase in the first half of the decade. In this ten-year period, foreign filings made up 62.9% of the total registered design filings.

The analysis of registered design filings by quarter from 2019 to 2021 shows that for foreign filings, there was a slight increase from 2019 Q1 to 2021 Q3, followed by a surge towards the end of 2021. For local filings, there was an overall increase, with slight fluctuations in 2019 and early 2020. Comparing the end of 2021 to the beginning of 2019, local filings more than doubled while foreign filings increased by 64.5%, although foreign filings saw a greater growth in absolute numbers (Figure 5). In 2021, there was an uptick in registered design filings as first-time and top filers such as Beijing Zitiao Network Technology Co., Ltd. and Beijing Kongming Technology Co., Ltd. contributed a huge volume of design filings, with most of their filings relating to recording and data-processing equipment. While it may not be possible to derive conclusive reasons for the sharp growth in registered design filings in 2021 Q3 and Q4, the increase shows continued investor/business confidence in Singapore even during the pandemic.

FIGURE 5 OVERVIEW OF REGISTERED DESIGN FILINGS BY QUARTER



Source: Intellectual Property Office of Singapore.

In 2021, the top registered designs filing origin was Singapore (425), with a 22% growth in volume from 2020. This was followed by China (394), the US (269), Japan (117), and the United Kingdom (76). Asian countries continued to lead in registered design filings in Singapore, accounting for 57.2% of all registered designs filed in 2021, up from 44.1% in 2020.

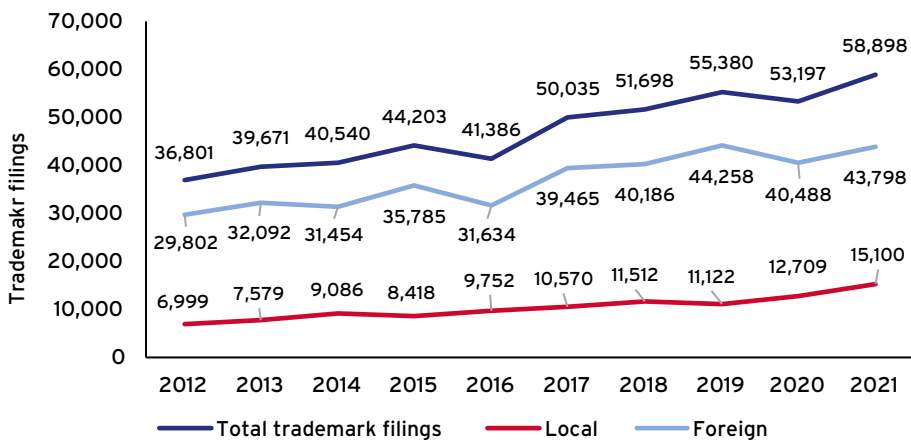
Similar to 2020, a breakdown by classification of articles shows that designs related to Recording, communication or information retrieval equipment (26.7%) accounted for the largest proportion of Singapore's registered design filing activity in 2021. This

was followed by Articles of adornment (8.3%), which has seen the largest decline in 2020; Medical and laboratory (7.7%); Fluid distribution equipment, sanitary, heating, ventilation and air-conditioning equipment, solid fuel (7.7%); and Packages and containers for the transport or handling of goods (5.6%).

Trends in trademark filings

Trademark filings in Singapore regained momentum in 2021. Singapore recorded close to 58,900 applications in 2021, up from 53,197 in 2020, representing a 10.7% year-on-year growth (Figure 6). Compared to 2020, trademark filings by local enterprises in 2021 remained resilient with a strong growth of 18.8%. Strong filings from foreign enterprises, which made up the bulk of Singapore's total trademark filings, also made a large contribution to the recovery in overall filings in 2021.

FIGURE 6 OVERVIEW OF TRADEMARK FILINGS BY YEAR (CLASS COUNT)



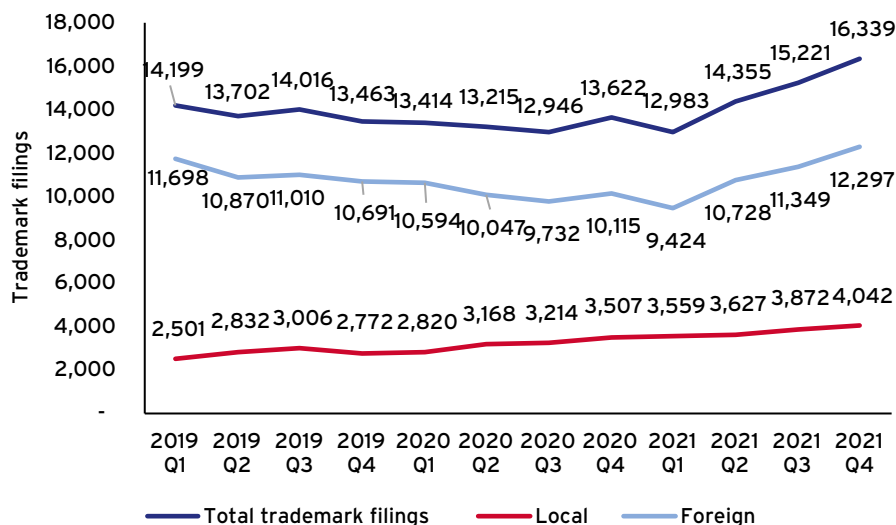
Source: Intellectual Property Office of Singapore.

Overall, there was an increase in trademark filings from 2012 to 2021. Similar to the other IP filings, foreign filings were higher than local filings.

The analysis of trademark filings by quarter shows that the total number of trademark filings were on a decline from 2019 Q1 to 2021 Q1, before rebounding for the rest of 2021. This trend is also observed for foreign filings. On the other hand, there was a consistent increase in local trademark filings from 2019 Q1 to 2021 Q4 (Figure 7).

There was no change in the ranking of the top six origins of Singapore's trademark filings in 2021 in comparison to the previous year. The top origins were Singapore (15,100), followed by the US (8,741), China (6,051), Japan (4,252), Germany (2,567), and the UK (2,315). These countries accounted for 66.3% of the total trademark filings in Singapore in 2021.

FIGURE 7 OVERVIEW OF TRADEMARK FILINGS BY QUARTER (CLASS COUNT)



Source: Intellectual Property Office of Singapore.

Trademark filings in 2021 improved across 36 out of the 45 classes of goods and services, in contrast to a decline in 31 out of 45 classes of goods and services in 2020. The most significant increase in filings were related to Technological goods such as Computers and scientific devices (Class 9) (+10.5%), Technological and scientific services (Class 42) (+19.6%), as well as Business and retail services (Class 35) (+15.1%). These three classes of goods and services were also the most popular among filers and accounted for 30.3% of the total 2021 trademark filings. On the other hand, trademark filings for Cosmetic goods (Class 3) saw the greatest fall (-4.6%).

Compared to 2020, there was a 16.2% increase in the number of first-time local filers⁷ seeking trademark protection in 2021. This group accounted for up to 69.1% of total local filers and contributed to 58.2% of the total filings by all local filers in 2021. Similar to 2020, the top two classes filed by first-time local trademark filers in 2021 were Business and retail services (Class 35) and Technological goods (Class 9) (Table 1). This is suggestive of an increase in new businesses being formed or existing businesses expanding their offerings, which is consistent with the message of economic recovery in 2021.

In 2020, the proportion of filings by first-time local filers in Business and retail services (Class 35), Technological and scientific services (Class 42), Education and entertainment services (Class 41), and F&B and temporary accommodation services (Class 43) were higher than that of filings by return local filers (Table 2). This could also be attributed to business trends associated with the outbreak of the pandemic – for example, the pivoting of small businesses online and corresponding increased recognition of the importance of branding on digital platforms.

⁷ First-time local trademark filers refers to filers based in Singapore who have filed trademark applications with IPoS for the first time within a particular year, but never before that.

TABLE 1 TOP CLASSES FILED BY FIRST-TIME LOCAL TRADEMARK FILERS

| Rank | 2020 | 2021 |
|------|-----------------------------------------------------------|-----------------------------------------------------------|
| 1 | Class 35: Business and retail services (15.2%) | Class 35: Business and retail services (15.0%) |
| 2 | Class 9: Technological goods (9.4%) | Class 9: Technological goods (9.4%) |
| 3 | Class 42: Technological and scientific services (9.0%) | Class 41: Education and entertainment services (8.7%) |
| 4 | Class 41: Education and entertainment services (7.8%) | Class 42: Technological and scientific services (8.3%) |
| 5 | Class 43: F&B and temporary accommodation services (6.7%) | Class 43: F&B and temporary accommodation services (7.2%) |

Source: Intellectual Property Office of Singapore.

TABLE 2 TOP CLASSES FILED BY FIRST-TIME AND RETURN LOCAL TRADEMARK FILERS IN 2020

| Rank | Class | Filings by first-time local filers (%of total filings by first-time local filers) | Filings by return local filers (% of total filings by return local filers) |
|------|----------------------------------------------------|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| 1 | Class 35: Business and retail services | 15.2% | 13.2% |
| 2 | Class 9: Technological goods | 9.4% | 9.7% |
| 3 | Class 42: Technological and scientific services | 9.0% | 5.6% |
| 4 | Class 41: Education and entertainment services | 7.8% | 7.1% |
| 5 | Class 43: F&B and temporary accommodation services | 6.7% | 5.8% |

Source: Intellectual Property Office of Singapore.

4 COVID-19 SUPPORT FROM IPOS

IPOS has also introduced new measures to support the IP and innovation ecosystem in Singapore during COVID-19.

COVID-19 accelerated IPOS' digitalisation efforts, and the office has since made its full suite of services available virtually. For example, it made available all IP Academy courses in an online/livestream format between April and June 2020. In addition, IPOS International and the Singapore University of Social Sciences (SUSS) jointly offered full complimentary access to the "IP Essentials for Business" online course on leveraging a company's IP assets for business. The course had equipped close to 3,000 learners with foundational IP competency to help them make better use of their IP for business growth.

IPOS also made its IP Business and Legal Clinics available virtually, and increased their frequency, to support businesses. In addition, it offered the option of fully virtual hearings and successfully conducted its first such hearing in June 2020, which resulted in time and cost savings.

To assist affected applicants during the circuit-breaker period, the Registrar issued Practice Directions to declare excluded days in respect of IPOS' stipulated deadlines falling within the period of 7 April 2020 to 4 June 2020. This automatically extended all filing deadlines to 5 June 2020. In parallel with the extension of filing deadlines, alternative filing modes and/or serving of documents on the Registrar were provided, with submissions able to be done electronically via FormSG, IP2SG, and IPOS Go.

New initiatives and support were also provided to help businesses with intangible assets/IP grow during COVID-19. Growing with Resilience through Intangibles (GRIT) is an inter-agency initiative to partner businesses and communities to better manage and monetise intangible assets/IP in the COVID-19 environment and beyond. Through GRIT, IPOS provides the community with the necessary information and resources, and access to related grants. Agencies across various sectors (in arts, culture, media, tourism, education, and sports) were engaged to develop industry-specific resources and tools, and improved access to government schemes. The National University Singapore's IP Students' Association contributed infopacks for the Arts and Technology sectors. IPOS also worked with the National Trades Union Congress (NTUC) and Law Society Pro Bono Services (LSPBS) on legal primers and clinics for freelancers, and collaborated with key industry partners (e.g. EduSpaze) to roll out IP education initiatives.⁸

With inventions conceived as a response to COVID-19 in dire need by the market, expedited patent grants were critical for businesses to secure protection in the challenging global economic landscape. The SG Patent Fast Track programme was a pilot scheme introduced in May 2020 to accelerate grants of patent applications during the pandemic, making it possible for companies to obtain a Singapore patent grant – in any technology

⁸ "Growing with Resilience Through Intangibles", IPOS (www.ipos.gov.sg/manage-ip/growing-with-resilience-through-intangibles).

field – within six months of filing.⁹ This is the world's fastest application-to-grant process of its kind. This was expanded to include related trademark and design applications, and renamed as the SG IP Fast Track programme (SG IP FAST) in September 2020.¹⁰ The programme was capped at five patent applications per month, and it was fully subscribed from 2020 to 2021.

5 CONCLUSION

In 2020, Singapore faced its worst recession since independence. Although GDP rebounded in 2021 with the recovery in global demand and a strong domestic vaccination programme, the rebound was uneven across sectors, especially in the tourism-related sectors. Singapore has focused on investing in the economy's innovation capabilities to continue its economic transformation, while building demand for domestic services.

In relation to IP, there was also a downturn in Singapore's IP filings for patents, trademarks, and registered designs in 2020. However, there was a strong recovery of IP filings in 2021. Throughout the pandemic, foreign IP filings continued to outnumber local IP filings. That said, trademark filings in Singapore have seen a rise in recent years, especially during 2021. This underscores the resilience of Singapore's economy and suggests that COVID-19 has encouraged individuals to be more innovative and start new business ventures.

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⁹ "Launch of the SG Patent Fast Track Programme on 4 May 2020", IPOS, 27 April ([www.ipos.gov.sg/docs/default-source/resources-library/patents/circulars/\(2020\)-circular-no-2-launch-of-sg-patent-fast-track-programme-on-4-may-2020-\(final\).pdf](http://www.ipos.gov.sg/docs/default-source/resources-library/patents/circulars/(2020)-circular-no-2-launch-of-sg-patent-fast-track-programme-on-4-may-2020-(final).pdf)).

¹⁰ Expansion of SG Patent Fast Track on 1 September 2020, IPOS ([www.ipos.gov.sg/docs/default-source/resources-library/patents/circulars/\(2020\)-circular-no-6---expansion-of-sg-patent-fast-track-programme-on-1-september-2020.pdf](http://www.ipos.gov.sg/docs/default-source/resources-library/patents/circulars/(2020)-circular-no-6---expansion-of-sg-patent-fast-track-programme-on-1-september-2020.pdf)).

CHAPTER 7

The COVID-19 impact on innovation in China

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Can Huang and Yurong Zhang¹

Zhejiang University; Shanghai University

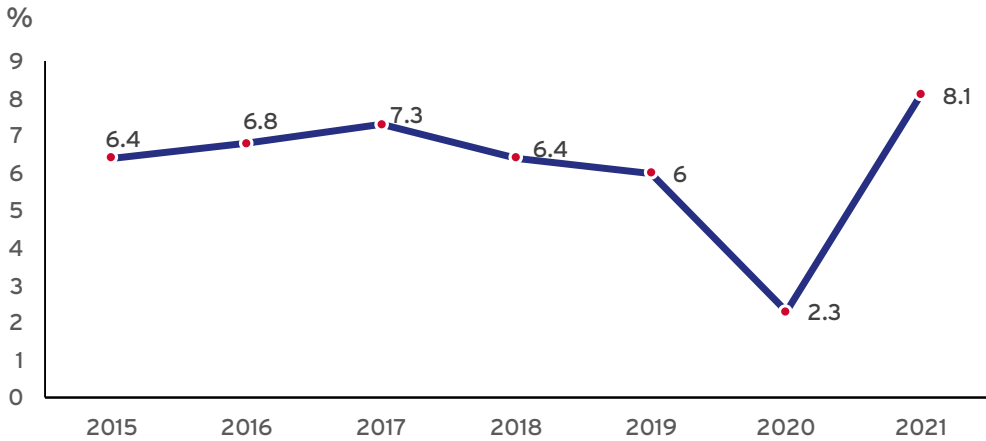
China was the first country to report a COVID-19 outbreak in December 2019. According to the Chinese government, the virus spread faster and wider than any other viruses since the founding of the People's Republic of China in 1949, and it has become the most difficult to control so far (State Council Information Office 2020). The COVID-19 pandemic has represented a major public health emergency and a serious test for China. Although facing extreme difficulties given the unknown nature of the virus at the beginning, China succeeded in controlling the outbreak in about three months after reporting the first case. By 31 May 2020, a total of 83,017 confirmed cases had been reported on the Chinese mainland, 78,307 infected people had been cured and discharged from hospital, and 4,634 people had died (State Council Information Office 2020). The last hospitalised COVID-19 patient from the first wave of the outbreak was discharged on 16 April 2020 in Wuhan city. Since then, only sporadic cases were reported in various cities and provinces until a major wave of infections occurred in March 2022.

Prior to the pandemic, the Chinese economy was already under downward pressure due to its own transformation and the sluggish growth of the world economy. In 2019, the annual Chinese GDP growth rate had dropped to 6%. Impacted by the COVID-19 pandemic, Chinese GDP growth in 2020 was only 2.3%, less than half of the rate in 2019, even though China was the only major economy in the world to achieve positive economic growth in 2020. The economy recovered better in 2021 with a GDP growth rate of 8.1%, which was the highest in the 2015–2021 period (Figure 1).

The quarterly data show that the quarterly Chinese GDP growth rate before the COVID-19 pandemic was stable, hovering around 6% (Figure 2). In the first quarter of 2020, the GDP growth fell by 6.8% year-on-year due to the nationwide lockdown for several weeks and severe restrictions on travel afterwards. That was the lowest quarterly growth rate and the only negative one in China since the reform and opening-up of the country began in 1978. However, due to the successful control of the pandemic in the second quarter of 2020, the quarterly GDP growth rate rebounded, reaching 3.2% year-on-year.

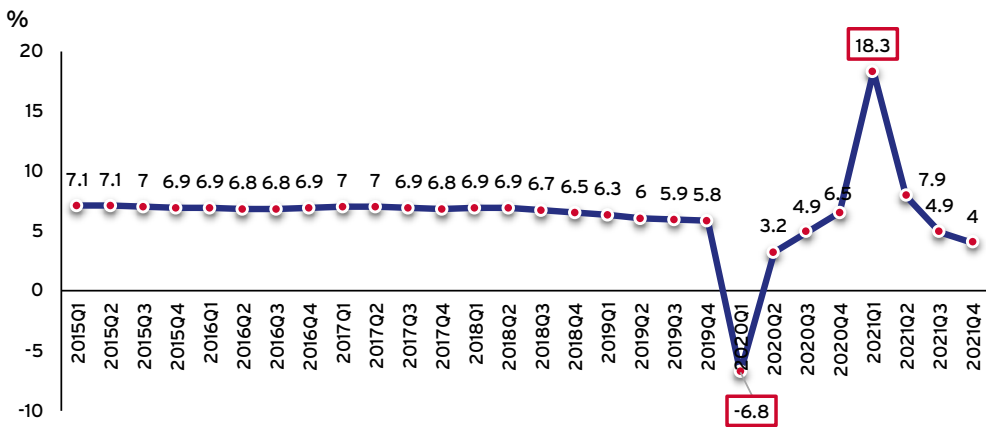
¹ The authors appreciate Ms. Zhenzhen Chen's excellent research assistance in preparing this chapter. Can Huang acknowledges financial support from the National Natural Science Foundation of China (Grant No. 71874152 and 71732008) and the National Office for Philosophy and Social Sciences (Grant No. 21AZD010, 21&ZD142 and 21BGL004). Yurong Zhang acknowledges financial support from the National Office for Philosophy and Social Sciences (Grant No. 20BGL043).

FIGURE 1 CHINESE ANNUAL GDP GROWTH RATE YEAR-ON-YEAR, 2015-2021



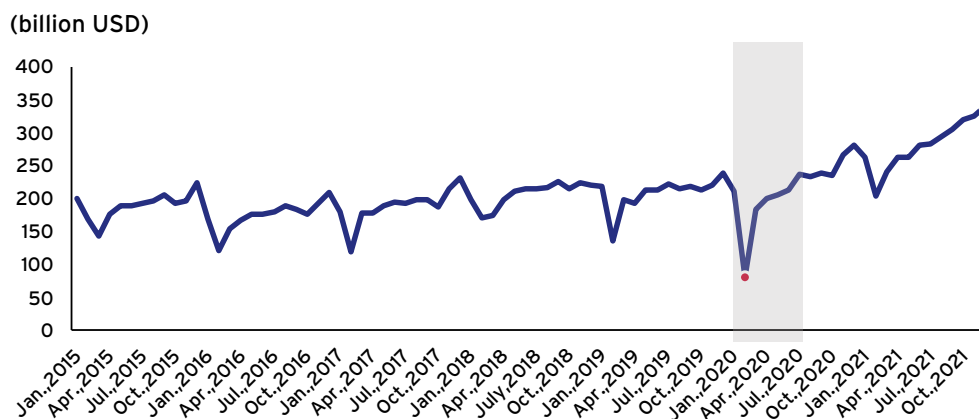
Source: National Bureau of Statistics (2016-2022).

FIGURE 2 CHINESE QUARTERLY GDP GROWTH RATE YEAR-ON-YEAR, 2015-2021



Source: National Bureau of Statistics (2016-2022).

While China was bringing its COVID-19 outbreak under control in April 2020, many other countries were adopting lockdown measures to fight the pandemic. To a certain extent, this increased foreign demand for China’s products because production elsewhere was severely affected. As seen in China’s export data (Figure 3), China’s export volume was reduced to US\$204 billion in February 2020 due to the pandemic impact, but it later recovered to the pre-epidemic level around June 2020 and has maintained a stable growth since then. Because of soaring demand, China’s export volume reached a new high in December 2021, exceeding \$340 billion. The annual export volume of China in 2021 was \$3363.9 billion, far exceeding the \$2055.6 billion of 2020. Substantial export growth contributed to the overall economic growth of China in 2020 and 2021.

FIGURE 3 MONTHLY CHINESE EXPORT VOLUME, 2015-2021

Note: The seasonal decrease of export volume in January or February is due to a spike before Christmas holidays in December and the Chinese New Year holidays around the period.

Source: Ministry of Commerce of the People's Republic of China (2021).

The rapid recovery of the Chinese economy has been made possible by a package of stimulus and relief policies introduced by the government to help enterprises, stabilise employment and expand domestic demand. As a result of the stabilisation and rapid recovery of Chinese economy, innovation activities and investment in China were not negatively impacted by the pandemic, but achieved steady growth instead. The overall innovation performance of China continued to improve. The ranking of China in the Global Innovation Index improved from the 17th in 2018 to 12th in 2021 (WIPO 2021).

Innovation in sectors related to the digital economy, such as information, telecommunications, online working and education and healthcare, flourished. For example, the number of people working online grew rapidly during the pandemic. In June 2020, there were 199 million people working online in China, but by 31 December 2021, the number had reached 469 million, accounting for 45% of the total internet users in China (Table 1). DingTalk, a software developed by Alibaba similar to Zoom with video conference call and online lecture functions, is widely used in China. The number of DingTalk users grew from 300 million at the end of March 2020 to 500 million at the end of August 2021 (Table 2).

TABLE 1 NUMBER OF PEOPLE WORKING ONLINE IN CHINA

| Date | Number of people (million) | Percentage of total internet users |
|---------------|----------------------------|------------------------------------|
| November 2021 | 469 | 45.4 |
| November 2020 | 346 | 34.9 |
| June 2020 | 199 | 21.2 |

Source: China Internet Network Information Center (2020-2022).

TABLE 2 NUMBER OF DINGTALK USERS

| Date | Number of users (million) |
|-----------------|---------------------------|
| 31 August 2021 | 500 |
| 14 January 2021 | 400 |
| 31 March 2020 | 300 |

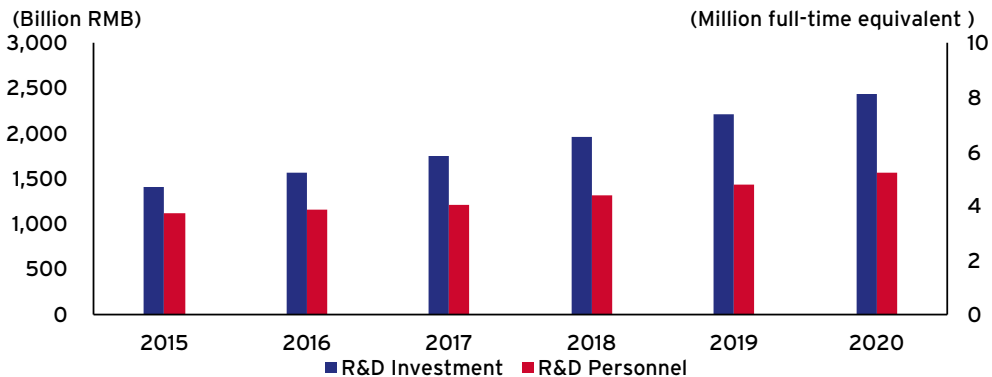
Source: Economic Daily (2020), Sina (2021), Tao (2021).

In what follows, we will present China's research and development (R&D) investment, personnel and output, newly listed companies, and venture capital investment before and after the outbreak of the pandemic, as well as China's scientific research relating to COVID-19, to demonstrate that the pandemic has not exerted a material impact on China's innovation activities.

R&D INPUT AND OUTPUT

R&D input and output are common indicators of the level of innovation. In the five years prior to the outbreak of COVID-19, China's R&D investment grew from RMB 1,417 billion in 2015 to RMB 2,214 billion in 2019, with an average annual growth rate of 11.8% (Figure 4). Despite the onset of COVID-19 pandemic, China spent RMB 2,439 billion on R&D in 2020, with a 10.2% year-on-year increase from 2019. In addition, 2020 saw a record number of R&D personnel in China, totalling nearly 5.24 million full-time equivalent. The average annual growth rate of R&D personnel in 2020 was over 9%, which roughly equals the growth rate in 2019.

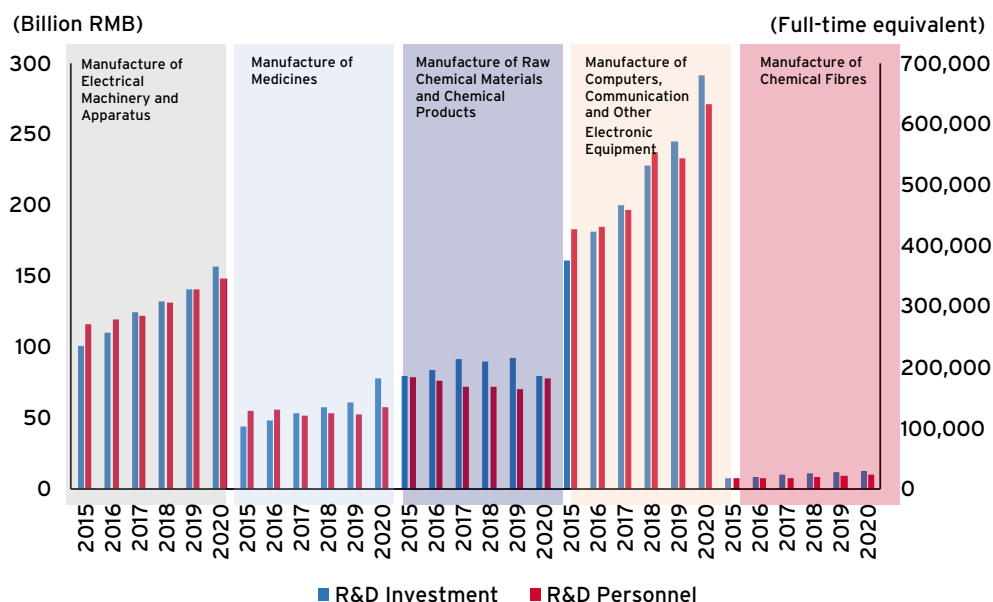
FIGURE 4 R&D INVESTMENT AND PERSONNEL IN CHINA, 2015-2020



Source: National Bureau of Statistics (2016-2021).

Analysing the data for the companies with annual revenue greater than RMB 20 million in five two-digit manufacturing sectors, we find that R&D investment and personnel in four out of five sectors – namely, manufacture of electrical machinery and apparatus, manufacture of chemical fibres, manufacture of computers, communication and other electronic equipment, and manufacture of medicines – increased between 2015 and 2020 (Figure 5). Even in sectors such as manufacture of electrical machinery and apparatus or manufacture of chemical fibres, which are not directly related to the pandemic prevention, we see a growth in R&D investment and personnel.

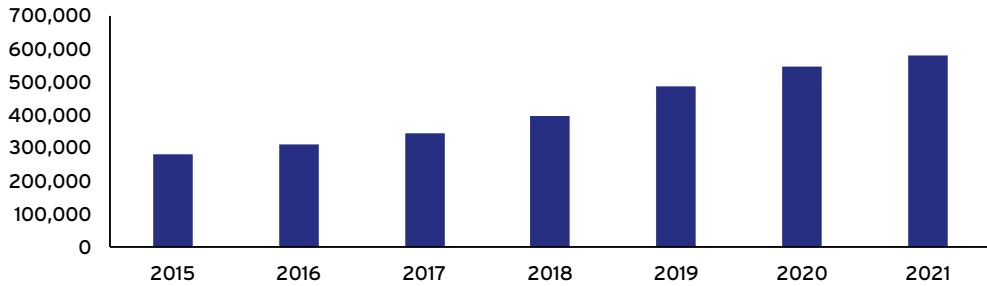
FIGURE 5 R&D INVESTMENT AND PERSONNEL OF COMPANIES ABOVE RMB 20 MILLION ANNUAL REVENUE IN FIVE MANUFACTURING SECTORS, 2015-2020



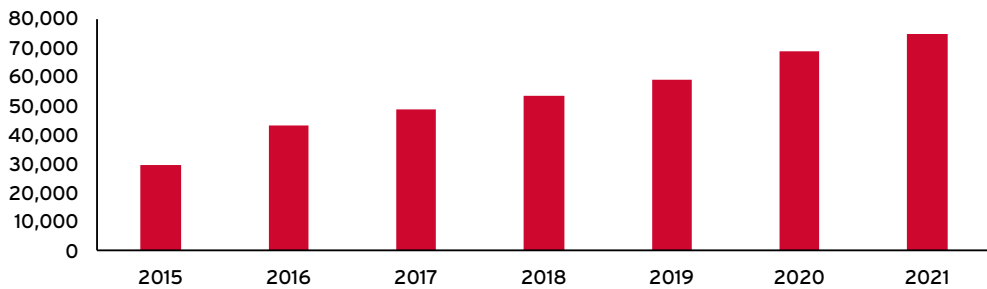
Source: National Bureau of Statistics (2016-2021).

Measured by the Science Citation Index (SCI) publications and Patent Cooperation Treaty (PCT) patent applications, China's innovation output was not affected by the pandemic. The number of SCI publications continued to grow from 282,529 in 2015 to 578,926 in 2021 (Figure 6). The number of PCT patent applications from China, which indicates the country's overseas patent filing, grew steadily from 29,837 in 2015 to 75,000 in 2021 (Figure 7).

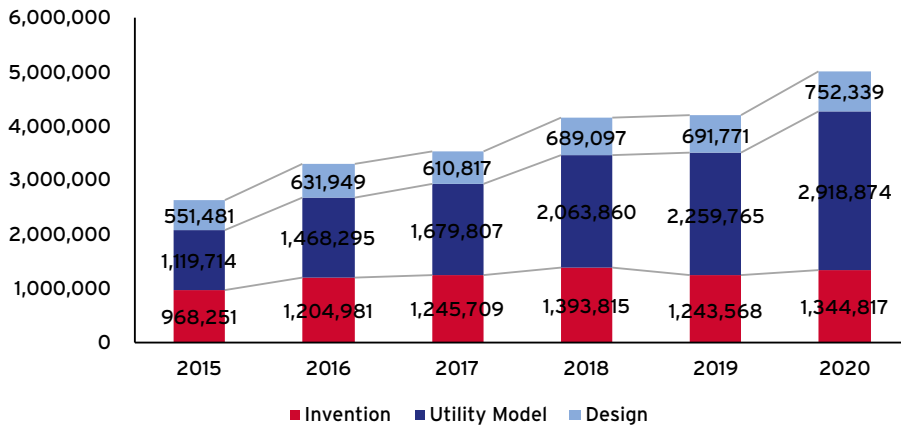
The total number of domestic patent applications in China grew steadily from 2,639,446 in 2015 to 5,016,030 in 2020. Applications of invention, utility model and design patents all increased between 2015 and 2020 (Figure 8). Among the companies with annual revenue above RMB 20 million in the five manufacturing sectors mentioned above, the numbers of their invention patent applications all increased between 2015 and 2020 (Figure 9).

FIGURE 6 NUMBER OF CHINESE SCI PUBLICATIONS, 2015-2021

Source: Web of Science; authors' own calculation.

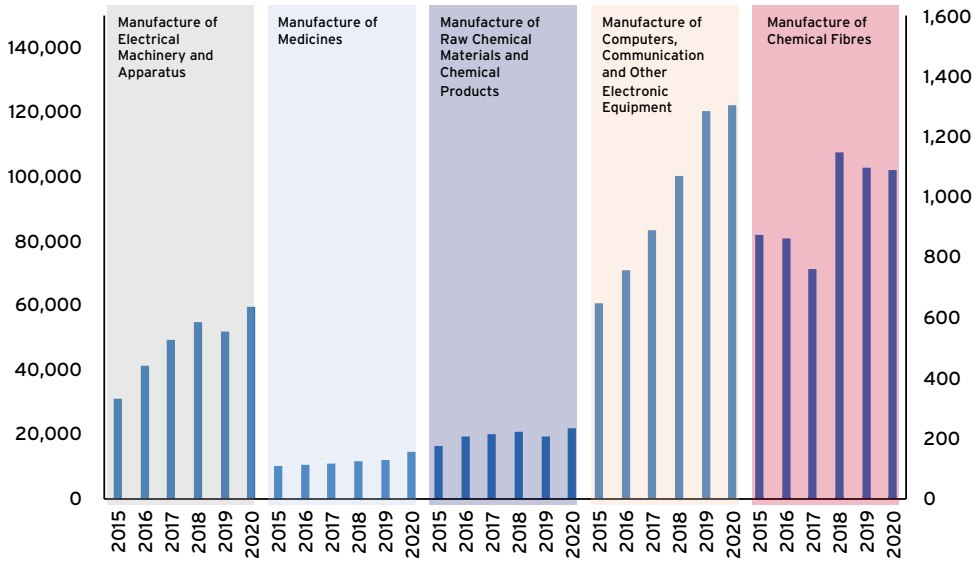
FIGURE 7 NUMBER OF CHINESE PCT PATENT APPLICATIONS, 2015-2021

Source: World Intellectual Property Organization (2016-2021).

FIGURE 8 NUMBER OF DOMESTIC PATENT APPLICATIONS IN CHINA, 2015-2020

Source: China National Intellectual Property Administration (2015-2020).

FIGURE 9 NUMBER OF INVENTION PATENT APPLICATIONS AMONG COMPANIES WITH ANNUAL REVENUE GREATER THAN RMB 20 MILLION, 2015-2020



Note: The units for the four left-most manufacturing sectors are on the left axis. The units for the manufacture of chemical fibres are on the right axis.

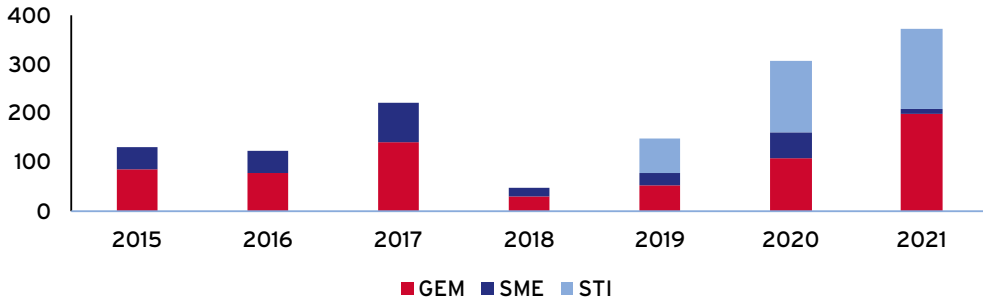
Source: National Bureau of Statistics (2016-2021).

COMPANY LISTINGS

Going public on a stock exchange is an important way to obtain financing for technology companies and startups. Accordingly, to some extent, the number of listed firms in a country can reflect the extent of financing for innovation in the country. In China, small and medium-sized enterprises (SMEs) can be listed on the Growth Enterprise Market (GEM) and SME boards of the Shenzhen Stock Exchange (SZSE), on the Science and Technology Innovation (STI) Board of the Shanghai Stock Exchange (SSE), the newly opened Beijing Stock Exchange (BeiSE) and the National Equities Exchange and Quotations (NEEQ).

The number of newly listed companies on the GEM board was 29 in 2018 and 52 in 2019. This increased to 107 in 2020, nearly four times the number of 2018, and further increased to 199 in 2021, doubling the number of 2020 (Figure 10). The number of new listings on the SME Board in 2020 was 54, a two-fold increase compared to that in 2019. The SME board was merged with the main board of the SZSE in April 2021, meaning the data for 2021 are not comparable to those in the previous years. The STI board was established in 2019. The number of companies listed there in 2020 was 145 and grew to 162 in 2021.

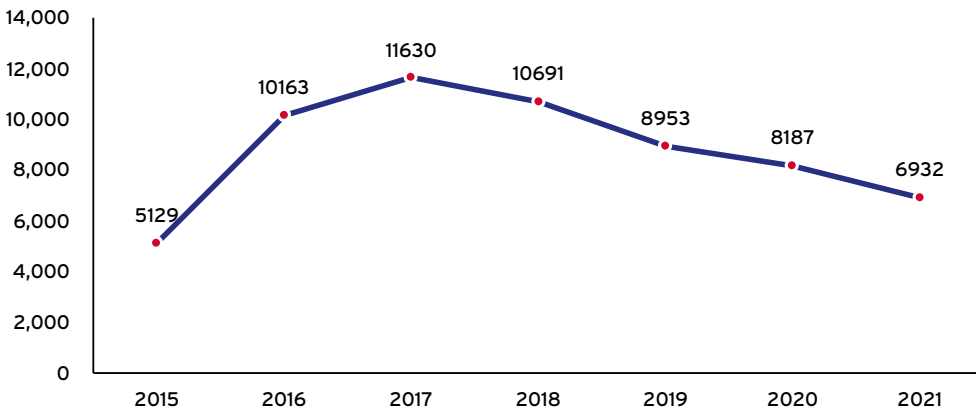
FIGURE 10 NUMBER OF COMPANIES NEWLY LISTED ON THE GEM, SME AND STI BOARDS IN CHINA, 2015-2021



Source: Shenzhen Stock Exchange (2015-2021); Shanghai Stock Exchange (2015-2021).

The requirements for listing on the NEEQ are not as strict as those for the other boards mentioned above, and it has therefore attracted a large number of companies to go public in NEEQ over the years. However, companies listed on the NEEQ are perceived by investors as less qualified than firms listed on the other boards. As a result, fewer investors bought and sold shares on the NEEQ in recent years, which in turn reduced its attraction to SMEs as a venue for obtaining financing. The number of listed companies on the NEEQ fell to 8,187 in 2020 from 8,953 in 2019, and continued to fall to 6,932 in 2021 (Figure 11). As explained above, the decrease in the number of firms going public on the NEEQ does not reflect the difficulty of SMEs in obtaining financing in the Chinese stock market, but rather reflects the declining popularity of the NEEQ as a forum for attracting SME listings.

FIGURE 11 NUMBER OF COMPANIES NEWLY LISTED ON THE NEEQ, 2015-2021



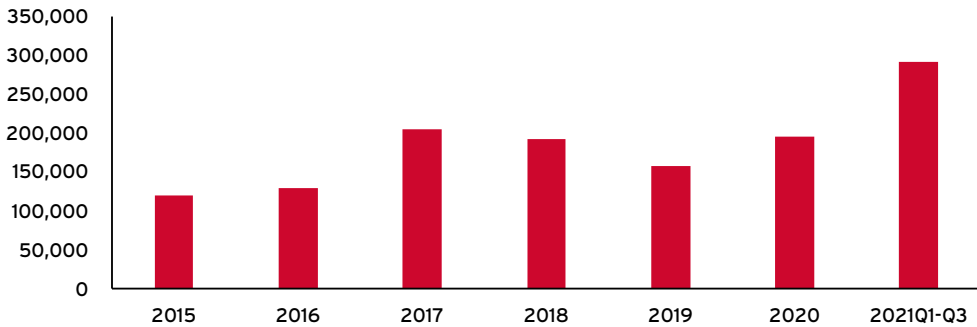
Source: National Equities Exchange and Quotation (2015-2021).

VENTURE CAPITAL INVESTMENT

Venture capital investment is another important channel for financing of technology firms and startups. Thanks to the positive growth of the Chinese economy in 2020, the total amount of Chinese venture capital investment in 2020 did not decrease but instead increased substantially in comparison to the figures in 2018 and 2019 (Figure 12). In the first three quarters of 2021 alone, the total amount of venture capital investment in China reached RMB 292.3 billion, setting a new record for total investment since 2015.

FIGURE 12 VALUE OF VENTURE CAPITAL INVESTMENT IN CHINA, 2015-2021

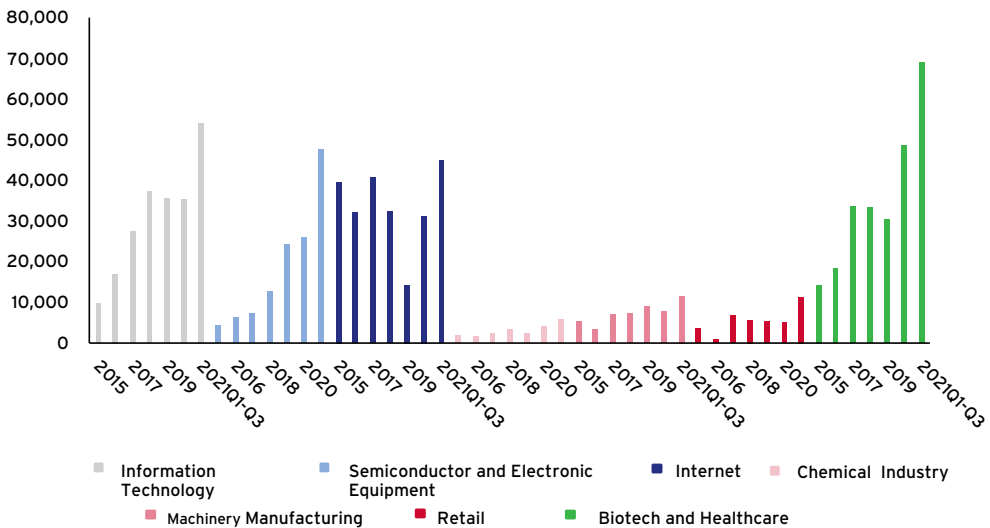
(million RMB)



Source: Zero2IPO Research (2015-2021).

FIGURE 13 VALUE OF VENTURE CAPITAL INVESTMENT IN SEVEN INDUSTRIES IN CHINA, 2015-2021

(million RMB)



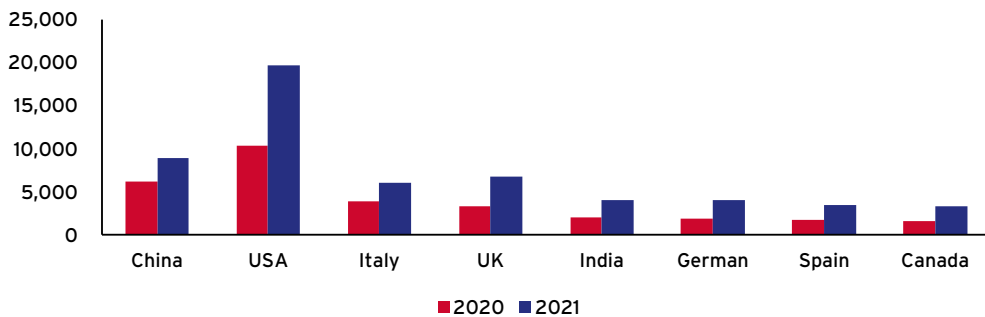
Source: Zero2IPO Research (2015-2021).

Venture capital investment grew in all seven of the industries featured in Figure 13 between 2015 and 2021. In particular, the growth in the biotech and healthcare sector, which is related to pandemic prevention, was substantial. This reflects the confidence of domestic and international investors in the Chinese economy and the prospect of its recovery.

SCIENTIFIC RESEARCH RELATED TO COVID-19

China has been very active in scientific research on methods to fight COVID-19 since the very beginning of the outbreak. China has developed seven vaccines, including the Sinopharm and Sinovac vaccines that were listed for emergency use by the World Health Organization. According to the science information and analytics company Airfinity, by November 2021 Sinopharm and Sinovac had produced more than 4.5 billion doses of COVID-19 vaccines, which accounted for 45% of the global total (Harries 2021). As of April 2022, the Sinopharm vaccine has been used in 94 countries and the Sinovac vaccine has been used in 52 countries (WHO 2022). To compare China's performance in scientific research on COVID-19 with other countries, we collected data on the number of Science Citation Index Expanded (SCIE) publications from the Web of Science database with search terms including "2019-nCoV", "COVID-19" or "SARS-CoV-2" and a publication date of 2020 and 2021 (He 2021, Pal 2021). We limited the types of publication to articles and reviews. The data show that China published 6,260 and 8,909 articles in 2020 and 2021, respectively, which makes it the second most prolific country after the United States (Figure 14).

FIGURE 14 NUMBER OF SCIE PUBLICATIONS ON COVID-19 RESEARCH FROM MAJOR COUNTRIES, 2020-2021



Source: Web of Science; authors' own calculation.

CONCLUSION

In summary, China was the first country in the world to report a COVID-19 outbreak. The Chinese economy was severely affected in the first quarter of 2020 due to the pandemic and the ensuing lockdown and travel restriction measures. However, following the rapid control of the pandemic in the second quarter of 2020, the Chinese economy bounced back. The quarterly GDP growth rate turned from -6.8% in the first quarter of 2020 to +3.2% in the second quarter of 2020. China was the only major economies in the world to achieve positive GDP growth in 2020. As China successfully controlled the pandemic in 2020 and the demand for Chinese goods from elsewhere in the world soared in 2020 and 2021, China's export volume reached a new high in 2021.

Innovation activities and investment in China were largely unaffected by the pandemic. Measured by R&D input indicators such as R&D investment and personnel, and R&D output indicators such as SCI publications and PCT and domestic patent applications, China's innovation performance continued to improve between 2015 and 2021. The upward trend demonstrated by these indicators can be observed not only in the sectors related to pandemic prevention and online work, such as manufacture of medicines and manufacture of computers, communication and other electronic equipment, but also in other sectors unrelated to the pandemic, such as manufacture of electrical machinery and apparatus. The number of SMEs listed on the Chinese stock exchanges and financing for startups (many of which are technology firms) have both seen continuous growth. China has published the second largest number of SCIE publications on the COVID-19 research, only trailing the United States. Two Chinese companies – Sinopharm and Sinovac – together had produced more than 4.5 billion doses of COVID-19 vaccines by November 2021, accounting for 45% of the global total by November 2021. As of April 2022, Sinopharm's vaccine has been used in 94 countries and Sinovac's vaccine has been used in 52 countries. China is thus making its contribution to the world's efforts to end the pandemic.

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CHAPTER 8

COVID-19: Crisis or opportunity? The case of South Korean innovation

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Korea Advanced Institute of Science and Technology

1 INTRODUCTION

The rapid spread of COVID-19 has taken millions of lives and disrupted most social and economic activities through movement restrictions and economic lockdowns. In response, the Korean economy dramatically contracted, similar to other countries (OECD 2020). With continuous social distancing orders and restrictions on daily life, the Korean economy experienced a substantial decline in employment, annual growth, and private consumption – the largest economic decline since the 1997 Asian financial crisis (KIET 2021).

Despite this sharp recession, the Korean economy has shown signs of recovery since the second quarter of 2020, where there have been significant differences in resilience among different countries. The IMF (2022) argued that South Korea has regained its economic ground from before the pandemic, and that the driving force for this recovery has been continuous efforts for new and sustainable innovation. In this chapter, we analyse these efforts by focusing on trends in patent applications and the number of new startups during the pandemic. We also examine how firms have responded to the pandemic.

Key takeaways from South Korean firms' pandemic responses are as follows:

1. Despite increased uncertainty in the business environment, patenting activities in South Korea showed a steady increase during the pandemic.
2. There has been a significant increase in technology-based new business creation, particularly within the information and communication (ICT) industry and science-based industries.
3. Industries reacted differently in terms of business and innovation during the pandemic; manufacturing firms tended to change their production methods, whereas service firms tended to redesign their organisational processes.
4. Prompt responses during the pandemic were more prominent among firms with risk-taking corporate cultures.

¹ This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) and funded by the Ministry of Education (2021R1A6A1A14045741).

Our findings suggest South Korean firms responded to the COVID-19 recession through continuous investments in new innovation (i.e. patents and new technology startups). To withstand prolonged social distancing restrictions, South Korean firms have tried to solve economic challenges (e.g. changing customer and business needs under social distancing) by relying on digital technologies, which is reflected in the increased number of digital-related patents and startups. At the same time, by viewing the pandemic as an opportunity and a driving force to achieve long-term competitiveness, South Korean players accelerated the development of emerging technologies, such as artificial intelligence (AI) and autonomous vehicles. Despite limited resources under a turbulent environment, this preemptive investment may turn into valuable technological assets for future growth.

Our chapter proceeds as follows. We first discuss innovation activities during the pandemic, focusing on patenting activities and new startup creation in South Korea. Then, we discuss how South Korean firms responded to the pandemic by analysing the measures they took to overcome uncertainty.

2 SOUTH KOREA'S COVID-19 EXPERIENCE

2.1 Knowledge creation: Patent applications

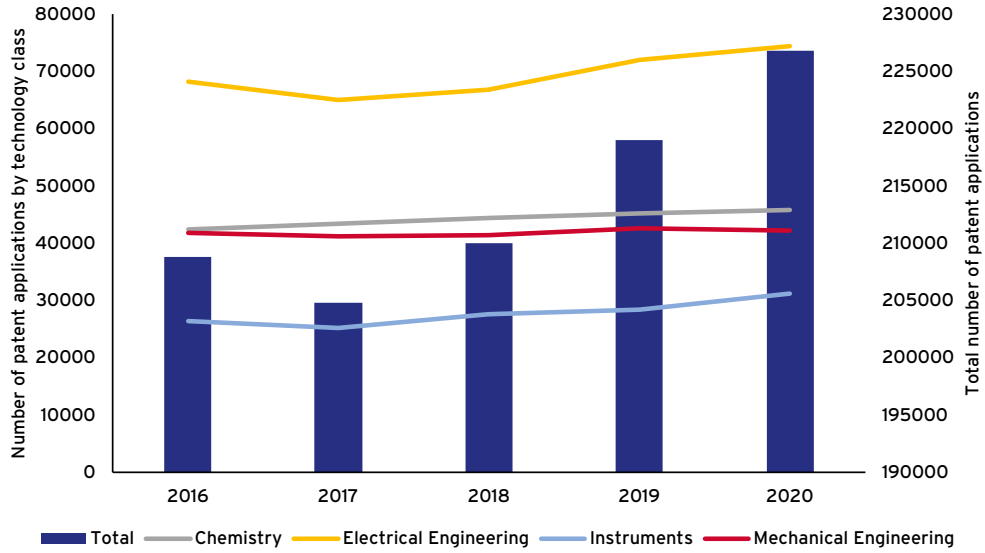
To explore the impact of COVID-19 on patenting activity in South Korea, we use databases from the Korean Intellectual Property Office (KIPO).² First, we investigate the changes in patent applications in Korea based on the World Intellectual Property Organization (WIPO) technology classification. According to Figure 1, patent applications related to mechanical engineering have not changed significantly over the past five years, but patent applications related to chemistry and electrical engineering have steadily increased. Further, during 2020, the increasing rate of patent applications related to electrical engineering was much steeper than other technology classifications. Overall in 2020, when COVID-19 broke out, although the numbers of patent applications were consistent without many changes, patent applications for the electrical engineering sector increased notably.

In the next step, we narrow our focus to the number of patents in emerging technologies, such as AI, big data, and industrial robots. Due to availability of the data provided by the KIPO, we limited the period up to 2020. Figure 2 shows the number of patent applications for each emerging technology in Korea. Despite the decrease in overall production activities, there has been a significant increase in the number of patent applications in emerging technologies. In particular, the emergence of the pandemic is associated with an acceleration in bio-related technologies, such as biomarkers and digital health care. Patent applications for these technologies showed a 30% increase compared with 2019.

2 The KIPO discloses patent application data up to 2020. Hence, we focused our investigation on patent activities between 2016 and 2020.

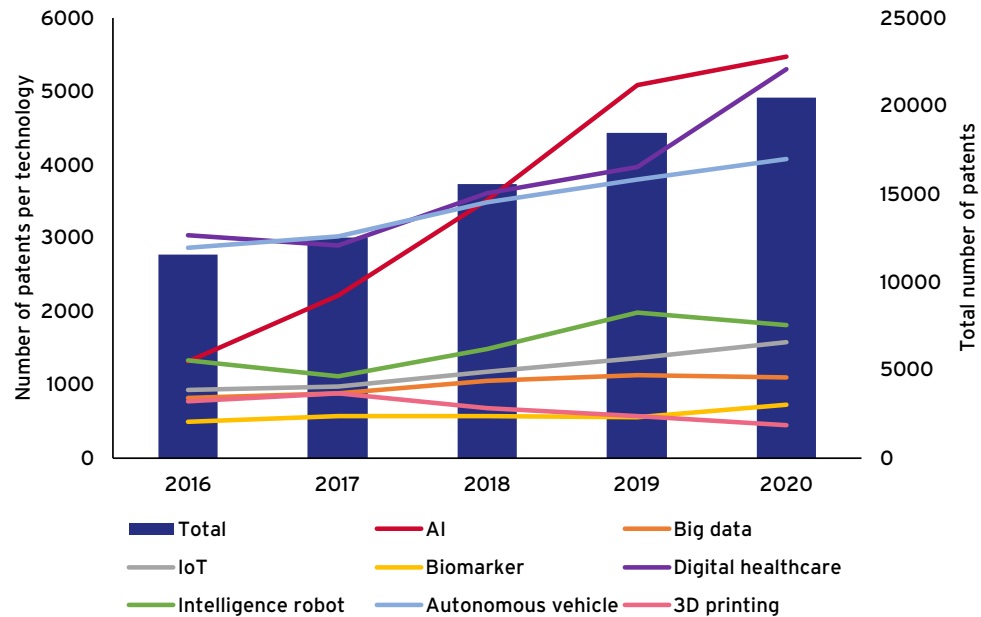
In addition to health technologies, we observe rises in other emerging technologies such as AI, autonomous vehicles, and the internet of things (IoT). This is direct evidence of the kinds of technology demand that have increased in Korea since COVID-19.

FIGURE 1 NUMBER OF PATENT APPLICATIONS BY TECHNOLOGY



Source: KIPO.

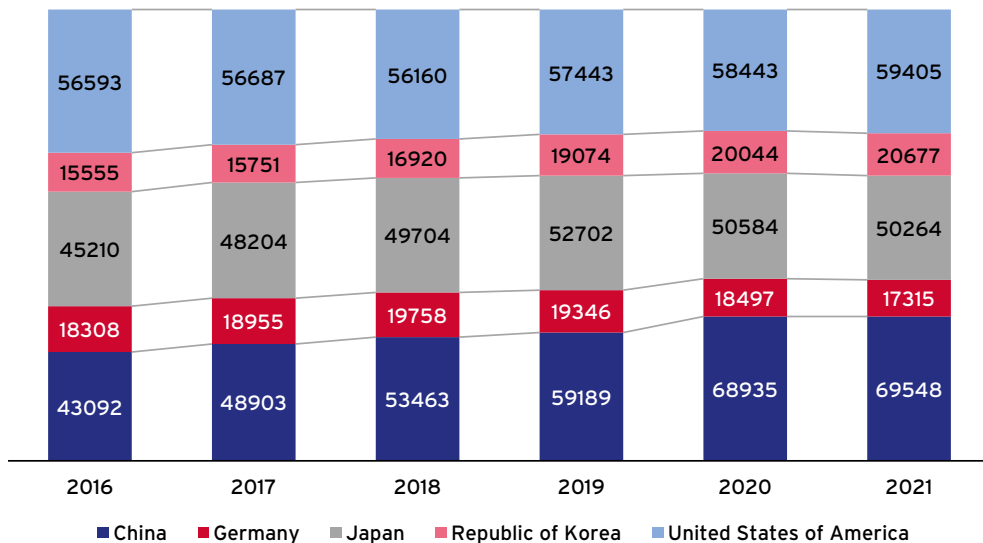
FIGURE 2 NUMBER OF PATENT APPLICATIONS BY EMERGING TECHNOLOGY



Source: KIPO.

Finally, to show overall global patenting activity, we analyse WIPO data to examine changes in international patent applications under the Patent Cooperation Treaty (PCT) over the past five years. In particular, we compare the changes in PCT patent applications of the Republic of Korea with four major countries (the US, Japan, China, and Germany). According to Figure 3, international patent applications under the PCT in Korea have been on a steady rise (15,555 in 2016; 15,751 in 2017; 16,920 in 2018; 19,074 in 2019; 20,044 in 2020; 20,677 in 2021). Korea had fewer PCT applications than the other four countries before 2020. However, after 2020, the number of PCT patent applications in Korea overtook that of Germany (20,677 in Korea versus 17,315 in Germany in 2021). This implies that, despite the global economic recession caused by COVID-19, Korean innovators are actively securing overseas intellectual property rights to strengthen their global competitiveness.

FIGURE 3 INTERNATIONAL PATENT APPLICATIONS UNDER THE PCT



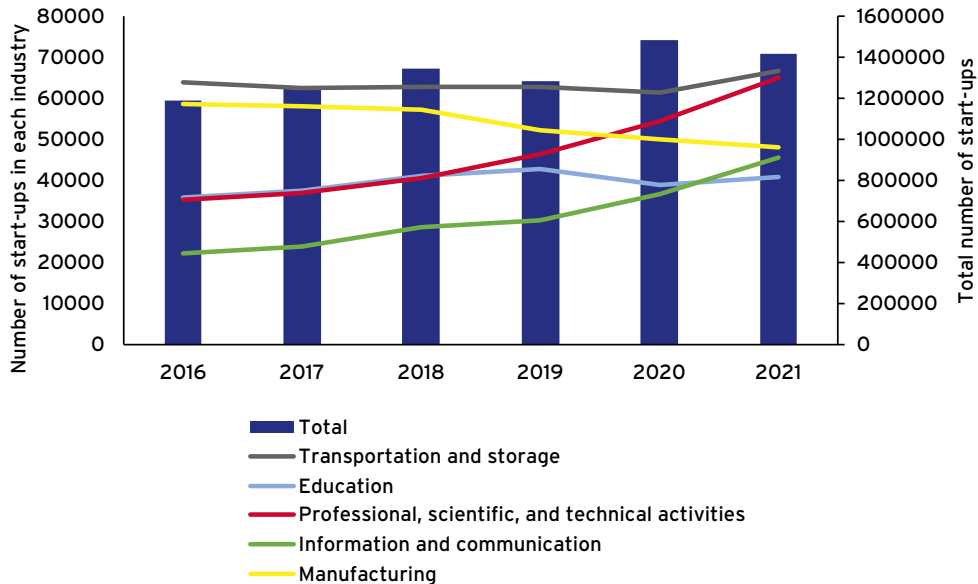
Source: WIPO IP Statistics Data Center.

2.2. Firm creation: Entrepreneurship

In this section, we analyse Korea's startup activities over the past five years using data from the Ministry of SMEs and Startups (MSS) of South Korea. When analysing the changes in number of new firms (Figure 4), we find that the number of new companies in the ICT industry has continuously increased, and that this increase accelerated after the outbreak of COVID-19. However, entrepreneurial activity in the manufacturing industry has continuously decreased since the COVID-19 outbreak. These results seem to suggest that the acceleration of the digital transformation (digital commerce, home schooling, online meetings, etc.) after the social distancing policy have created new business opportunities in the high-tech industry (Horii and Sakurai 2020). In other

words, the spread of COVID-19 and the social distancing policy implemented to prevent diffusion seem to be correlated with an increased demand for digital technologies such as telecommuting, teleworking, and online lectures, which may have played a major role in providing new business opportunities for potential entrepreneurs.

FIGURE 4 NUMBER OF STARTUPS BY INDUSTRY



Source: Ministry of SMEs and Startups of South Korea.

In contrast, the attractiveness of the manufacturing industry seems to have decreased since the COVID-19 outbreak. Given the high initial cost of starting a business in the manufacturing industry and the nature of the industry, which requires people to manufacture products through in-person interactions, the social distancing and economic recession caused by COVID-19 will have further reduced the attractiveness of the industry to potential entrepreneurs. In summary, social distancing caused by COVID-19 seems to be correlated with digitalisation (e.g. the spreading across society of online classes, telecommuting, and digital commerce), which has led to an increase in startup activity in industries such as ICT. However, traditional industries such as manufacturing seem to have become rather unattractive options for startups since the outbreak of the pandemic.

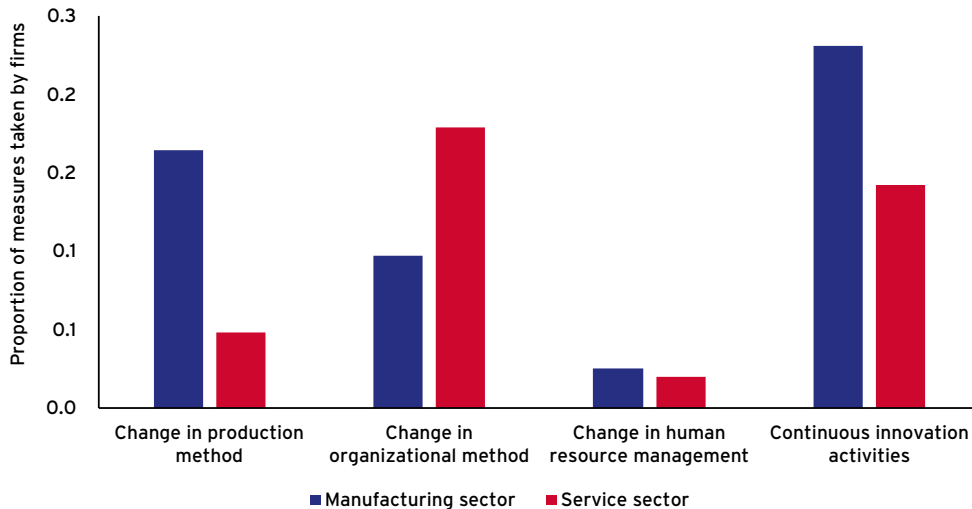
3 FIRMS' STRATEGIC RESPONSES TO THE PANDEMIC IN SOUTH KOREA

With such a substantial increase of uncertainty in the business environment, how did small and medium-sized enterprises (SMEs) in South Korea respond to the pandemic? To explore this question, we use the Korea Innovation Survey (KIS) for both the manufacturing and service industries in 2020. The population count for the survey was

4,000 firms in each industry, which covers firm innovation and management activities before and after the COVID-19 outbreak (2018–2020). One key value of the survey is that it asks respondents to mark or delineate specific measures they took in response to the pandemic, which allows us to understand the decisions firms made when faced with the crisis.

Figure 5 shows the measures firms have taken during the pandemic. Notably, firms within the manufacturing and service industries took different approaches to overcoming the pandemic. For example, manufacturing firms were more likely to dive into their innovation activities and change production methods. Despite the sudden decline in the economic environment, manufacturing firms indicated they would continue to conduct existing innovation activities.

FIGURE 5 MEASURES TAKEN BY FIRMS DURING THE PANDEMIC



Data source: Korea Innovation Survey (2021, 2022).

Concurrent with these ongoing innovation activities, manufacturing firms increasingly changed their production methods in response to the COVID shock. One prominent approach was to increase investment in operational technologies, such as operation intelligence and robotics. Approximately 68% of firms that responded changed their production processes by adopting or investing in these operational technologies during the crisis. The increase of patent applications involving IoT technologies shown in Figure 2 reflects these efforts by firms. Combined with IoT sensors, many SMEs tried to digitise their production lines, for which they predominantly resorted to human labour. However, in Figure 2 we observe a slight decrease of patent applications involving intelligent robots. We expect that there will be an increase in innovation outcomes in this field in the near future.

Based on their pandemic experience, firms prioritised agile responses to uncertain events and sustained their innovative production lines, which was also observed in the manufacturing industries of other countries (McKinsey & Company 2021). Using the pandemic as an opportunity for sustainable growth, manufacturing firms in South Korea have been transforming their organisations by orienting them toward digitisation.

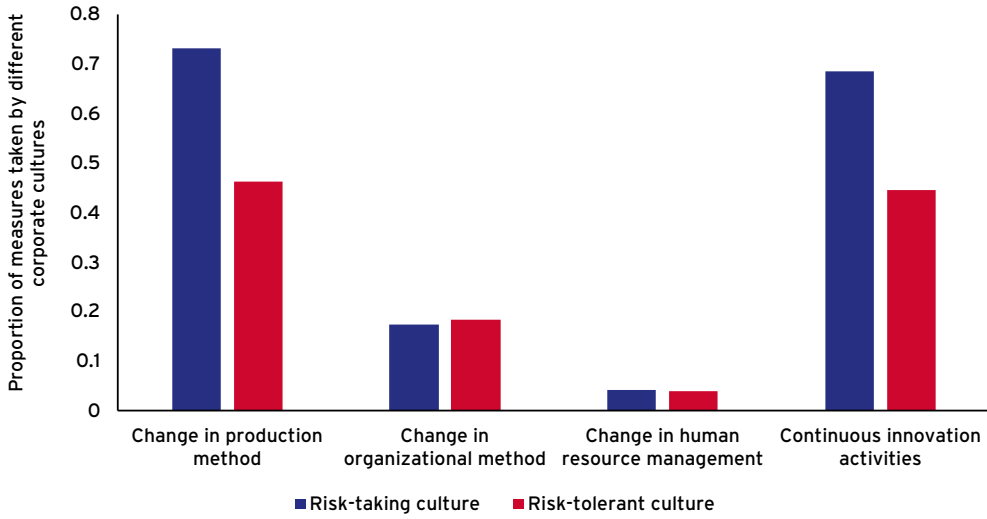
Similar to manufacturing firms, service firms have been more likely to focus on continuous innovation activities than to abandon innovation activities. One significant difference between the two industries is that service firms have been more interested in using organisational approaches (e.g. work-at-home policies) and increasing the use of platforms for internal communications as a solution to overcome the pandemic. Among the service firms that reported changing organisational approaches to adapt to the pandemic, 93% reported increasing 'smart work', which involves using information technology to perform tasks remotely and collaborate virtually, and expanding their use of flexible work hours, which were previously limited to a few large corporations. While experiencing the pandemic, service firms accelerated their adoption of this organisational change by recognising not only the importance of work efficiency but also other essential changes, such as flexibility in work, to survive the turbulent market conditions (Brynjolfsson et al. 2020).

One of the important similarities between the manufacturing and service industries is that firms have not necessarily changed their human resources-related strategies (e.g. firing current employees or limiting the number of new hires). Rather, firms seemed to emphasise either production improvement or organisational redesign while retaining their current employees during the pandemic.

Figures 6 and 7 show which corporate cultures were more likely to lead to prompt measures being taken during the pandemic. Corporate culture has been long recognised as an intangible asset, and includes cultural values and norms shared throughout an organisation to help employees understand how to behave appropriately (Kreps 1990, O'Reilly and Chatman 1996). Thus, different corporate cultures may have responded to the pandemic differently. Our analysis of corporate culture and COVID-19 measures reveals that firms that have pursued risk-taking activities³ were more likely to take measures in response to the pandemic. That is, manufacturing firms with a risk-taking culture were more likely to continue innovative activities and take preemptive actions to change production systems, while service firms with risk-taking cultures were more likely to maintain their current innovations and change their organisational structures during the pandemic. Thus, a risk-taking corporate culture may have been an important driving force for firm survival and innovation during the pandemic.

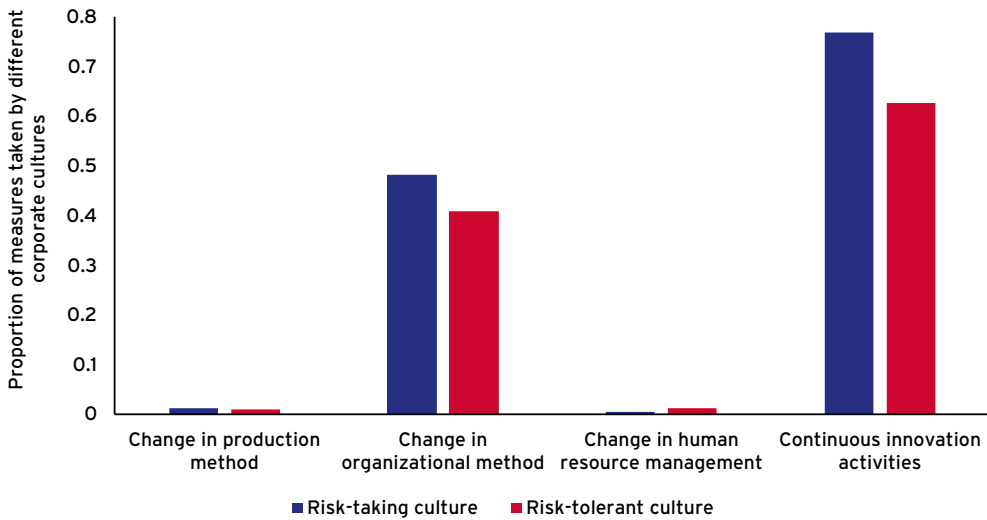
3 The KIS defines risk-taking behaviour as entailing exploration, the targeting of new markets, proactive moves, and a new and original way of doing business.

FIGURE 6 MEASURES TAKEN DURING THE PANDEMIC BY CORPORATE CULTURE: MANUFACTURING



Data source: Korea Innovation Survey (2021).

FIGURE 7 MEASURES TAKEN DURING THE PANDEMIC BY CORPORATE CULTURE: SERVICES



Data source: Korea Innovation Survey (2022).

4 CONCLUSION

In this chapter, we show how South Korean firms have recovered economic losses through efforts towards new innovation and technology-based startups, despite the challenges to the national economy caused by the pandemic. In contrast to decreased production activities, patenting activities in South Korea recorded the highest rates of applications in both ICT industry and more technology-based startups, albeit with heterogeneity among industries.

Although firms in both the manufacturing and service industries have responded to the pandemic by pushing existing innovations and keeping their current employees, there were differences in strategy between the industries. The manufacturing industry focused more on the renovation of production methods through digitisation, whereas service industries emphasised organisational redesign to create a more flexible working environment. Our findings showed these proactive moves have primarily been driven by firms with a risk-taking corporate culture.

Policy measures should be heterogeneous and customised to each industry. The pandemic accelerated innovation in some industries, but others have been negatively affected. In addition, depending on the type of industry, responses to pandemic challenges were heterogeneous. Therefore, considering the characteristics of each industry, policy measures such as research and development (R&D) subsidies and tax exemptions for hiring R&D labour should be further tailored to accelerate the innovation of the industry and bring economic benefits in the medium and long term. Although social distancing negatively affected the economy overall, this unique environment created opportunities for business and technological innovation. In other words, challenges became opportunities for some industries and firms.

In addition, the pandemic also accelerated the digital transformation of many industries, which suggests that proactive policy actions to promote innovation can be more beneficial than passive policies that focus on recovery from the crisis. 'Resilient growth' is the term we use to refer to situations where a company or government proactively accepts a crisis and related challenges and identifies the factors and dimensions necessary to change and transform the given business and technology systems. Leveraging the opportunity to substantially transform systems that have been in place for a long time, companies and nations can find new opportunities to recover and grow. Our findings seem to suggest resilient growth in some industries, and we need to evaluate national policies for resilient growth in the face of future challenges.

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CHAPTER 9

Impacts of COVID-19 on R&D and patenting activities in Japan: Demand shocks, application delay, and patent option value¹

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IMPACTS OF COVID-19 ON R&D AND PATENTING ACTIVITIES IN JAPAN | YAMAUCHI, NAGAOKA AND MIYAZAKI

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Meiji University and RIETI; Tokyo Keizai University and RIETI; Japan Patent Office

1 INTRODUCTION

Japan has experienced five waves of COVID-19 in terms of new positive cases by October 2021 (as shown in Figure 3 below). The first wave peaked on 11 April 2020, the second wave peaked on 7 August 2020, the third wave peaked on 8 January 2021, the fourth wave peaked on 12 May 2021, and the fifth wave peaked on 20 August 2021.

Although the number of positive cases was small in the first wave, the uncertainty about COVID-19 was so high that a state of emergency was declared for the first time on 7 April 2020. Each prefecture issued a request for closure in a wide range of industries. On the other hand, as of February 2022, though the number of new positive cases sometimes exceed 90,000 per day, the uncertainty about COVID-19 has considerably declined as vaccinations have spread and several drugs for treatments have become available. Therefore, a state of emergency has not been announced since the last emergency period under the fifth wave ended on 30 September 2021.

While the health impact of the COVID-19 pandemic on Japan has been the one of the lowest among the OECD economies, its economic impact has been no less severe in Japan. It caused significant downturns in the economy. Real GDP declined by 4.5% in the fiscal year 2020 (from April 2020 to March 2021). We know from the innovation economics literature that demand significantly affects the level and direction of inventions through incentives (Schmookler 1966, Scherer 1982, Geroski and Walters 1995) and it can also cause procyclicality in research and development (R&D) by affecting the level of liquidity constraints, even if the demand shock is temporary (Hall and Lerner 2010, Min 2011). Thus, we would expect the change in sales caused by COVID-19 to have significantly affected inventions. In addition, the COVID-19 pandemic generated significant economic

¹ We would like to thank Yusuke Naito for the compiling database for the recent application and examination requests to the Japan Patent Office and to Tokyo Keizai University for its grant for joint research.

uncertainty, including over how long it would last. While such economic uncertainty aggravates the demand constraint on R&D investment, patent rights would be able to soften the effect because the patent, being an option (Pakes 1986, Schankerman and Pakes 1986), provides the exclusive right to use an invention when the market recovers (Czarnitzki and Toole 2011). Therefore, we would expect the firms to make efforts to preserve such an option when the economic conditions deteriorate. Finally, COVID-19 may have directly constrained patent filing activities through its impacts on office work and meetings. If this effect were significant, we would observe a delay in applications.

This chapter analyses the impact of the COVID-19 pandemic on R&D and patenting in Japan from three perspectives: demand shocks, delays in applications, and the option value of patents. Section 2 provides an overview of the changes in R&D expenditures in relation to changes in sales during the first three waves of COVID-19, while Section 3 mainly examines changes in patent application behaviour and investigates application delays in the year 2020. Section 4 investigates the impact of the first wave on firms' decisions to make examination requests and to file foreign applications for inventions made before the onset of COVID-19 in order to assess the option values. Section 5 concludes.

2 R&D EXPENDITURE

This section reviews R&D expenditure in the first year of the COVID-19 pandemic, that is, in the fiscal year (FY) 2020 (from April 2020 to March 2021). We cover changes in aggregate R&D expenditures as well as by industrial sector, using data from the Survey of Research and Development (2021) by the Statistics Bureau of Japan.² In FY2020, R&D expenditure fell by around 2.4% in real terms.³ This decline was significantly less than those of GDP (-4.5%), private non-residential investment (-7.5%) and exports (-10.5%). The decline of R&D due to the COVID shock was modest compared to that brought on by the Lehman shock (-7.0% of R&D in real terms in 2009).

The decline of R&D was led by industry (-3.2% in real terms), which accounts for more than 70% of the R&D expenditure in Japan. The decline was largest for basic research (-5.7%), followed by applied research (-3.8%) and then development research (-2.8%).

The R&D response was highly heterogeneous across industries, as seen in the Table 1 and Figure 1. There were significant expansions of R&D in “electronic components, devices, and circuits” and “motor vehicles and related accessories”, with R&D increasing by 43% and 21%, respectively.⁴ The expansion of R&D in the electronic components industry likely reflects increased demand for semiconductors and the other electronic chips due to the demand shift towards online business, communications and games. In this

2 The data are available at <https://www.stat.go.jp/english/index.html>.

3 We use the GDP deflator to obtain a real value of R&D expenditure. The GDP deflator declined by 0.65% in the fiscal year 2020.

4 These numbers are in nominal terms.

industry, basic research significantly declined (as shown Table 1). The significant increase of R&D in “motor vehicles and related accessories” amid declining sales seems to have been driven by the long-term demand growth and opportunities for new technologies related to electric vehicles and automated driving.⁵ On the other hand, there were significant contractions of R&D in the capital goods industries such as “general-purpose machinery and equipment” and “electrical machinery and apparatus” (-28% and -43%, respectively), reflecting the decline in demand for capital goods and in their sales. In addition, the “textile” industry shows a significant decrease in R&D (-39%), reflecting the severe restraints on in-person contact. In these manufacturing industries, basic research declined more in percentage terms than did total R&D.

TABLE1 R&D BY INDUSTRY, FY2020

(Sectors with the largest increases versus those with the largest decreases)

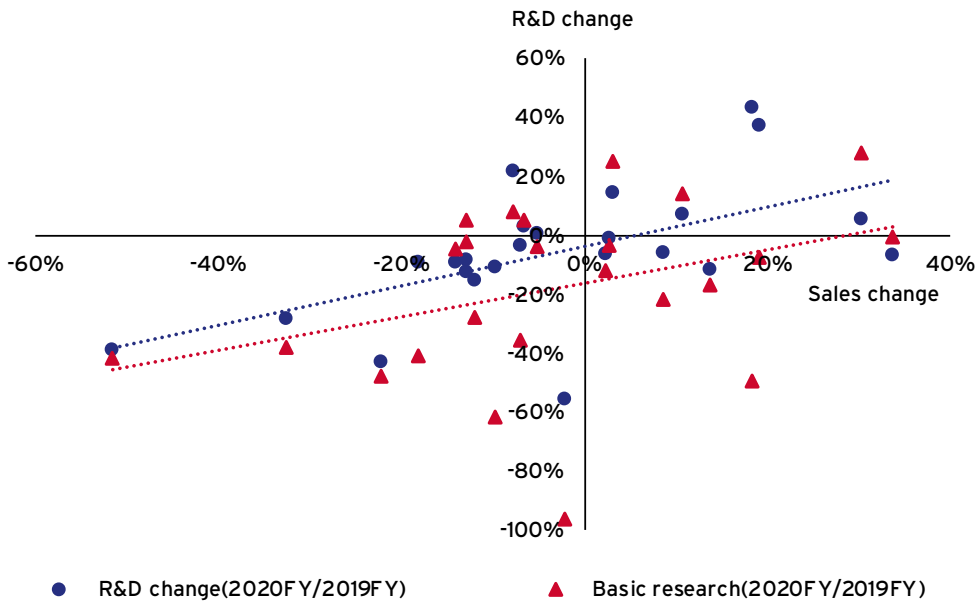
| | | Total R&D change (FY20/ FY19) | Basic research (FY20/ FY19) | Sales change (FY20/ FY19) | Size of R&D (share in the entire industry in FY19) |
|-----------|-------------------------------------------------------------|------------------------------------------------------|------------------------------------------------|----------------------------------------------|-----------------------------------------------------------------------------------|
| Expansion | Manufacture of electronic components, devices, and circuits | 43% | -50% | 18% | 6% |
| | Manufacture of motor vehicles and related accessories | 21% | 8% | -8% | 22% |
| Decrease | Manufacture of general-purpose machinery and equipment | -28% | -38% | -32% | 2% |
| | Other electrical machinery and apparatus | -43% | -48% | -22% | 8% |
| | Textile Industry | -39% | -42% | -52% | 1% |
| | Telecommunications | -56% | -97% | -2% | 2% |

A relatively close correlation between annual changes in sales and R&D in FY2020 is observed for the top 25 industries in terms of R&D performance, which accounted for around 91% of industrial R&D (as seen in Figure 1). This tight correlation between the two across industry sectors suggests the significance of demand-side shocks caused by COVID-19 for industrial R&D in FY2020. Based on cross-section estimations covering

⁵ According to a report by the Japan Patent Office (JPO 2021a), Japanese applicants filed the largest number of applications for technologies related to automated driving during the period between 2014 and 2018, and the number showed a rapid increase.

all 39 sectors, the change in sales was a much better predictor of the change in R&D in FY2020 than it was in FY2019 or FY2018.⁶ In addition, basic research decreased more (or increased less) than total R&D, as suggested by Figure 1. Since basic research is more patent-intensive, these results suggest that patenting activities can temporarily decline more than R&D.

FIGURE 1 R&D VERSUS SALES BY INDUSTRY, FY2020 OVER FY2019 (TOTAL R&D AND BASIC R&D)



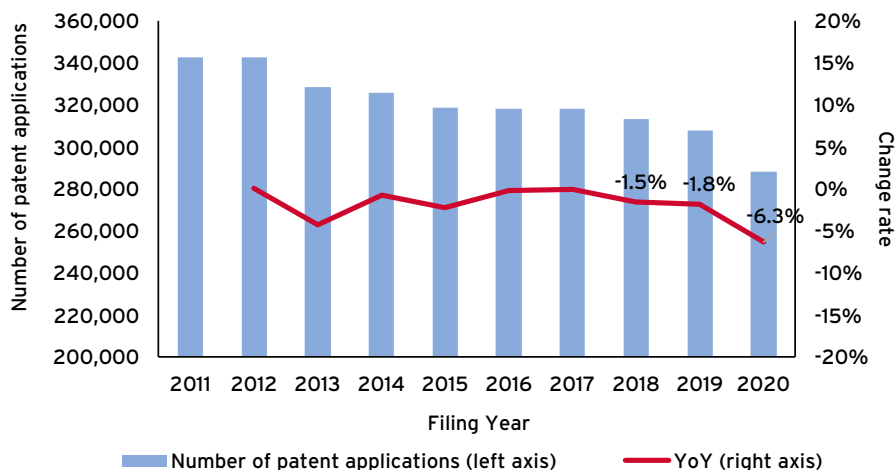
3 PATENT APPLICATIONS BEFORE AND DURING COVID-19

This section overviews the impact of COVID-19 on patent applications in Japan. Figure 2 shows the number of patent applications by calendar year, based on the statistics compiled by the Japan Patent Office (JPO).⁷ The line shows the percentage increase or decrease compared to the previous year. The bars show a gradual downward trend in the number of patent applications even before the pandemic (decreasing by about 1.5% from 2017 to 2018, and by 1.8% from 2018 to 2019). However, in 2020, the first year to be affected by COVID-19, the number of patent applications decreased significantly (by about 6.3% from 2019 to 2020). This large decrease suggests a significant impact of COVID-19 on firms' patenting activities.

⁶ The estimated coefficient is 0.81 for FY 2020 (1% significant), 0.27 for FY 2019 (10% significant) and 0.18 for FY 2018 (insignificant).

⁷ The statistics are available in the JPO Status Reports (<https://www.jpo.go.jp/e/resources/report/statusreport/index.html>) and Annual Reports (<https://www.jpo.go.jp/e/resources/report/nenji/>).

FIGURE 2 NUMBER OF PATENT APPLICATIONS BY CALENDAR YEAR



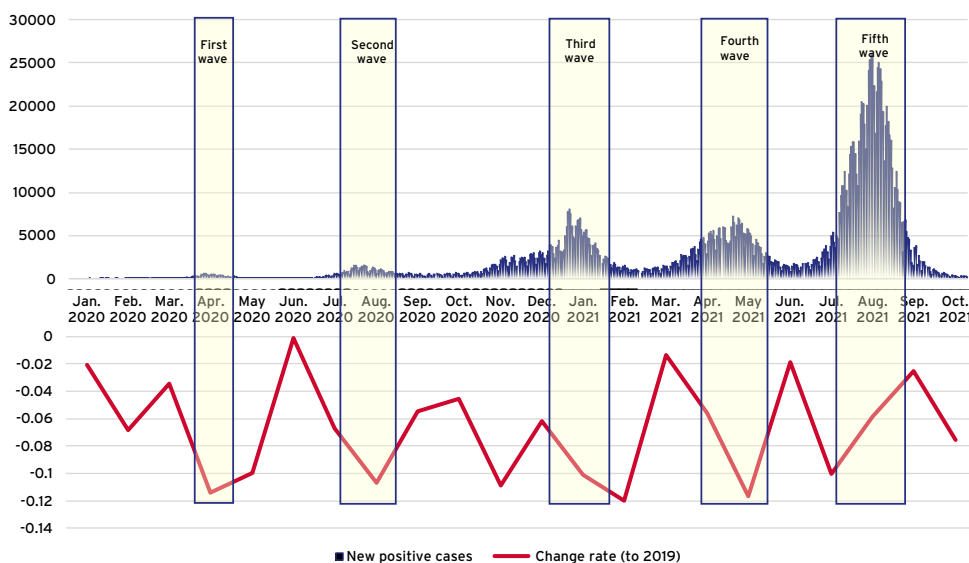
Data source: JPO annual report

As for 2021, although not shown in the figure, the number of patent applications has almost stopped decreasing. According to the provisional figures published by the JPO, the number of patent applications between January 2021 and May 2021 decreased by about 1.0% compared to the same period in 2020, and the number between June and October 2021 did not decrease (the rate of change was 0.0%).

In order to understand the potential impact of COVID-19 on application delays (i.e. time lost in terms of priority), we examine the monthly changes in the number of patent applications in relation to the waves of the pandemic. The line in the lower part of Figure 3 shows the rate of change in the monthly number of patent applications compared with the same month of the previous year (to 2019). The bars in the upper part show the number of new positive cases of COVID-19 based on daily data.

We find that most of the months in which patent applications significantly decreased roughly correspond to the waves of the pandemic highlighted by the yellow boxes. For example, in the period between April and May 2020 (the first wave), the number of patent applications decreased significantly (by 10–11%). Patent applications also show significant decreases in August 2020, November 2020, February 2021, May 2021, and July 2021. Most of these months occurred during the wave periods. There is little difference in the rate of decrease between the first wave (April 2020) and the subsequent waves, despite the waves getting bigger. This may partly be because Japanese society has been adapting to the COVID-19 pandemic, in particular through the rapid spread of telework in companies as well as through the spread of vaccinations and the increase of available drugs.

FIGURE 3 DECREASE IN PATENT APPLICATIONS CORRESPONDING TO WAVES OF THE COVID-19 PANDEMIC



COVID-19 may have caused the above-mentioned delays in the patenting process at the stages where direct contact between people is important, such as the drafting process within the organisation and consultation with the patent attorney.⁸ The shift to online work may have slowed the work of intellectual property (IP) department employees, who could not take invention documents home due to confidentiality concerns and did not have secure access to the firm's database.

To examine whether the COVID-19 pandemic was a significant driver of application delays, we compare the average month of application for FY2019 and FY2020. More specifically, we calculate $\sum_{m=1}^{12} m \times app_m / \sum_{m=1}^{12} app_m$, where app_m is the number of applications in the m th month of the fiscal year (April is the first month, May is the second month, ..., and March is the twelfth month of the fiscal year in Japan). We can assess whether the distribution of patent applications became more skewed towards the latter part of the year, due to the pandemic. The averages we obtain are 6.76 months in FY2019 and 6.83 months in FY2020. Thus, the timing of applications was delayed in FY2020 compared with FY2019. However, the difference was not very significant (only 1%). One of the reasons for this small gap may be that the Japanese applicants made significant efforts to accelerate their applications when COVID-19 did not constrain application activities. This could have offset the application delays due to the waves of the pandemic.

⁸ In the first wave, the Japanese government, under the declaration of a state of emergency, set a target of "reducing attendance by 70%" and strongly requested that firms promote telework and rotational work. Japan does not have a law that allows the government to impose a lockdown.

A nearly 100% online filing rate and the complementary digital processing of filing documents in Japan may have significantly reduced the disruptive impact of COVID-19 on the patent application process by containing the delay during the waves and accelerating applications outside of the waves. The JPO began accepting online applications for patents and utility models from personal computers in 1998. The online filing rate increased to 96% in 2000 and reached 98% in 2012; it then remained at that high level until 2020 (JPO 2010, JPO 2021b). This high online filing rate would have encouraged the preparatory work for filing within a firm or an attorney's office to become substantially digital.

4 IMPACT OF COVID-19 ON EXAMINATION REQUESTS AND ON FOREIGN APPLICATIONS FOR THE INVENTIONS MADE BEFORE THE PANDEMIC

This section investigates the impact of the COVID-19 pandemic on the examination request and foreign application behaviours for inventions that had (mainly) been made before the pandemic. In Japan, only those applications that are requested for examination are examined. Applicants can request examinations within three years of the filing date of the application. As for foreign applications, under the Paris route, a priority can be claimed within one year from the filing date of the first application. In addition, the PCT route provides a grace period of 30 months from the priority date to national entry. The fee for requesting examination is 138,000 yen plus 4,000 yen multiplied by the number of claims.⁹ This is far more expensive than the application fee, which is only 14,000 yen per application. Still, this is significantly less expensive than the costs for applications.

Given the patent application, the rate of 'eventual' examination requests (and the rate of foreign applications as well) would decrease if the opportunity to implement the invention decreased due to COVID-19. However, the option value of patenting can reduce this effect because the applicant can choose whether and when they will use the invention exclusively. In particular, they can wait to implement the invention until the market recovers. Moreover, if applicants perceive the risk that the pandemic might slow down the work of the IP department in the future, they would accelerate examination requests in order to acquire the option rights.

4.1 Changes in the eventual examination request rate

First, we look at the eventual examination request rate for patent applications filed between April 2016 and March 2018¹⁰ (i.e. well before onset of the COVID-19 pandemic). For these applications, the available periods for examination request ended between April 2019 and March 2021. Since the first wave of the COVID-19 pandemic in Japan began in April 2020, we can compare the rate of eventual examination requests before

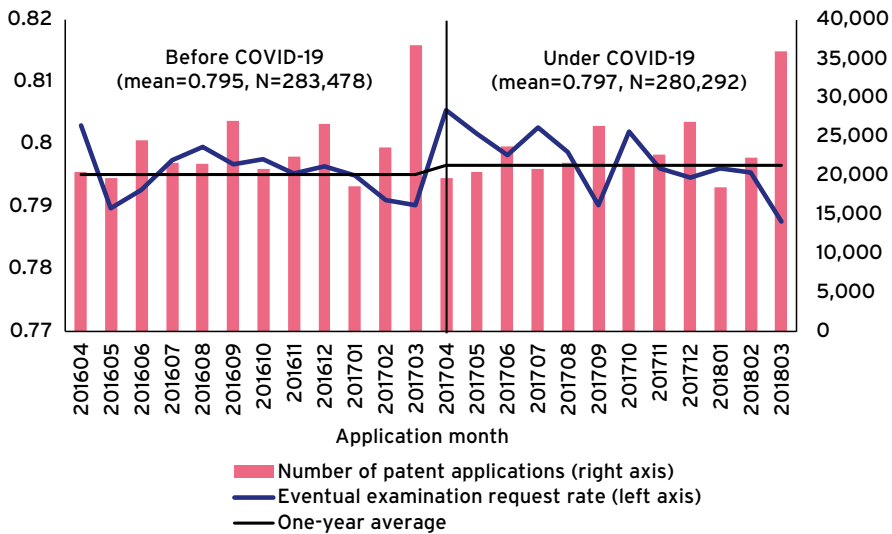
⁹ According to the Patent Administration Annual Report 2020, the average number of claims is 11.0 for all applications including via PCT in 2019. Therefore, the average examination request fee is 182,000 yen per patent application.

¹⁰ The applications filed by March 2018 were published by September 2019, and are free from truncation.

and during the pandemic in a twelve-month window by dividing the sample into two (the control, for which the allowable period had expired before the pandemic, versus the treatment, for which it had not).

Figure 4 shows the changes in the eventual examination request rate for the control and the treatment. The horizontal axis measures the application month, and the vertical axis measures the percentage of the applications eventually requested for examination for the applications filed in each month. Note that for the applications filed between April 2016 and March 2017 (the control sample), the allowable period for examination requests ended before the COVID-19 pandemic, while for the applications filed between April 2017 and March 2018 (the treatment sample) the allowable period ended during the pandemic. It is important to note that in Japan, examination requests are concentrated in the last year of the allowable period (Yamauchi and Nagaoka 2015).¹¹

FIGURE 4 EVENTUAL EXAMINATION REQUEST RATE FOR APPLICATIONS FILED BEFORE THE PANDEMIC



The figure shows that there was no significant change in the eventual examination request rate before and during COVID-19 pandemic for patent applications which had been filed before the COVID-19 pandemic. The average eventual examination request rate for the control (before the pandemic) is 79.5%, whereas the average for the treatment (during COVID-19) is 79.7%.

11 The percentage of the applications requested for examination in the last year of the allowable period for the examination requested applications filed in the FY 2016 was 63% (141,318 out of 224,294 examination-requested applications).

In other words, the pandemic had little effect on the eventual examination request rate. This result suggests COVID-19 did not affect firms' decision over how many of their inventions should be patented, even though, on average, firms cut R&D expenditure and patent applications. This gap can be explained by the option value of a patent. Even if the probability of using the invention in the future becomes lower, patenting an existing invention can be still worthwhile, since the cost of the examination request is low relative to the expected value of using the invention exclusively when such an opportunity arrives.

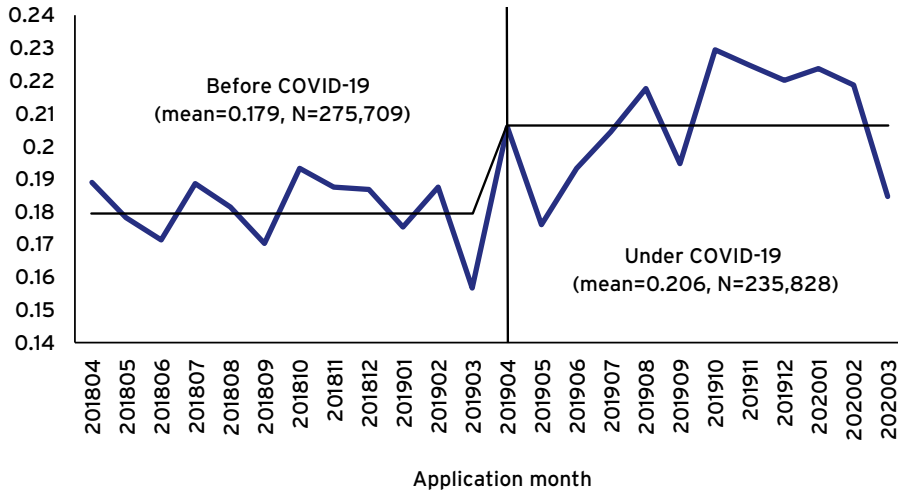
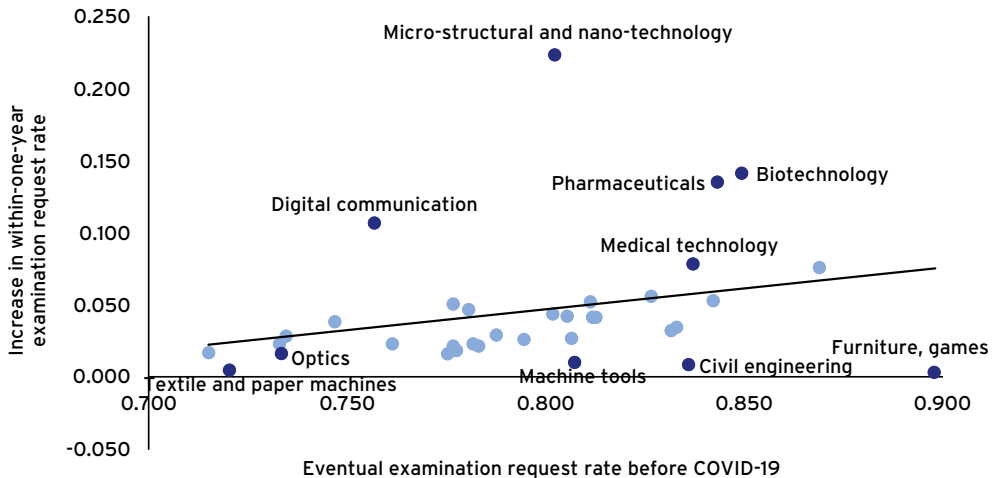
4.2 Acceleration of examination requests

This section investigates the impact of the COVID-19 pandemic on the rate of early examination requests (within one year of the application date) on a monthly basis in the framework of control and treatments. Note that this is the rate relative to all patent applications on a monthly basis. We focus on patent applications filed between April 2018 and March 2020 (all before the pandemic), which limits the sample to applications requested for examination by March 2021.

Figure 5 shows the monthly rate of examination requests made within one year. The horizontal axis shows the application month, and the vertical axis measures the rate of examination requests. For the applications filed during April 2018 to March 2019, the examination requests within one year are distributed over the period April 2019 to March 2020, prior to the COVID-19 pandemic (control group). In contrast, for the applications filed between April 2019 to March 2020, the examination requests within one year are submitted between April 2020 and March 2021, during the pandemic (treatment group).

Figure 5 shows that prior to the pandemic, the average rate of examination requests made within one year was 17.9%, while the rate during the pandemic increased to 20.6%. Since the sample is limited to applications filed prior to the pandemic, and the rate of eventual examination requests was almost stable, this result suggests that applicants accelerated their examination requests, probably in order to reduce the risk due to potential disruptions to IP processing within or outside of the firm.

We would expect that the acceleration of examination requests would be more important in those sectors where the demand for the innovations increased under the pandemic, controlling for the initial level of eventual examination requests. Figure 6 shows the positive correlation between the eventual examination request rate before the COVID-19 pandemic and the increase in early requests by the technology sectors. In sectors with high eventual examination request rates (low incidence of low patenting values), examination requests were more accelerated due to the pandemic.

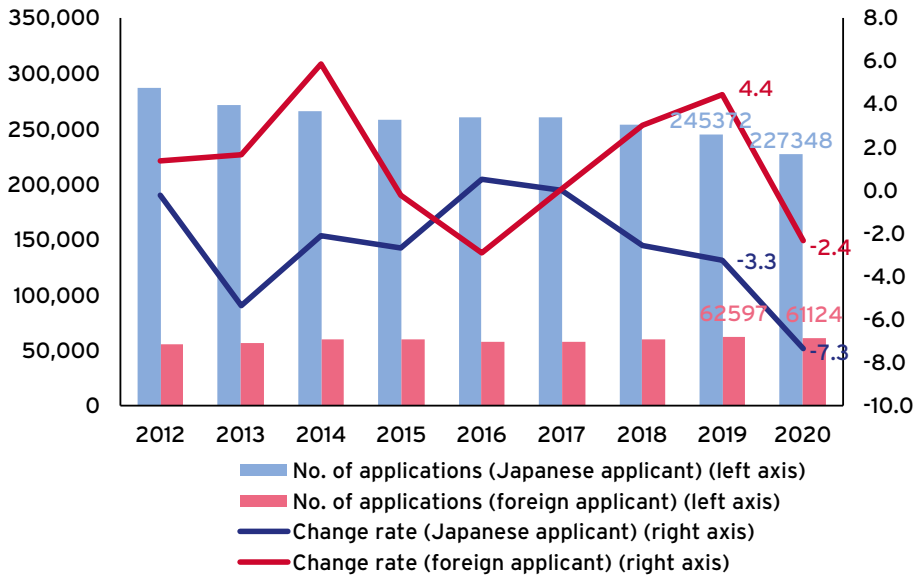
FIGURE 5 CHANGES IN THE RATE OF EXAMINATION REQUESTS MADE WITHIN ONE YEAR**FIGURE 6 RELATIONSHIP BETWEEN THE EVENTUAL EXAMINATION REQUEST RATE AND THE RATE OF EXAMINATION REQUESTS MADE WITHIN ONE YEAR**

Controlling for this correlation (the trend line in Figure 6), three sectors showed a significant increase in early examination request rates beyond the trend line: “micro-structural and nano-technology” (22.3 percentage points), “biotechnology” (14.1 percentage points) and “pharmaceuticals” (13.5 percentage points). These are the top three out of the 35 WIPO technology sectors in terms of their increase in early examination request rates. These three sectors are closely related to medical treatment, which faced increased demand for accelerated innovations during the pandemic.

4.3 Foreign applications

Figure 7 shows the number of patent applications filed with the Japan Patent Office and its annual change by domestic and foreign applicants.

FIGURE 7 PATENT APPLICATIONS BY JAPANESE AND FOREIGN APPLICANTS



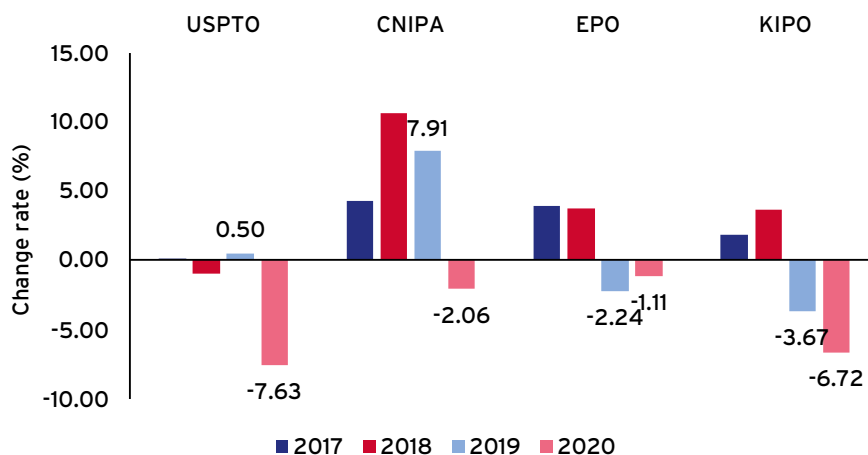
We find that the number of applications by both Japanese and foreign applicants decreased in 2020. We also find that patent applications by foreign applicants had shown an increasing trend before COVID-19 but decreased after the onset of the pandemic. The annual growth rate for applications by foreign applicants was 4.4% in 2019, and it decreased to -2.4%. This change was more significant than the change in applications by Japanese applicants. Note that we can see this relationship despite of the fact that, in many cases, the foreign applications had already been filed in the home country in 2020, since they can claim priority within 12 months of the initial application through the Paris route and within 30 months through the PCT route. One potential reason is that foreign applications require additional processes, involving local agents, translators and a foreign patent office, so the influence of the stagnation of activities due to COVID-19 would be greater than for domestic applications. Another reason could be the high cost of foreign applications. These reasons could partially explain the difference from the impact on eventual examination requests.

Figure 8 compares the rate of change in the number of applications filed by Japanese applicants to foreign patent offices. We can see a decrease in patent applications by Japanese applicants in all patent offices in 2020. Patent applications to the United States Patent and Trademark Office (USPTO) declined by 7.63% in 2020, whereas they

were almost flat in 2019. We can also see that patent applications to the China National Intellectual Property Administration (CNIPA) had significantly increased before the first wave (+7.91% YoY in 2019), but declined in 2020 (-2.06%).

Given the one-year grace period for foreign applications through the Paris route for these countries, the impact here is mainly driven by changes in foreign application behaviour. That is, even if the R&D were completed and the inventions existed, COVID-19 seems to have significantly reduced foreign applications. This finding again suggests the significance of the additional processes and costs required for foreign applications.

FIGURE 8 CHANGES IN PATENT APPLICATIONS BY JAPANESE APPLICANTS TO FOREIGN PATENT OFFICES



5 CONCLUSION

The chapter has analysed the impacts of the COVID-19 pandemic on R&D and patenting activities in Japan from the perspective of demand shocks, application delays, and the option value of patents.

We found that the change in sales significantly explains the change in R&D across industries for FY2020 (up to March 2021), suggesting the importance of demand shocks as a driver of R&D during the pandemic. We also found that basic research declined more, which may have caused the larger decline in patent applications than that in R&D expenditure.

In contrast, the level of ultimate examination requests for inventions made before the pandemic did not decline, and requests were accelerated on average. These findings indicate the significant option value of patenting, which could help protect the R&D investment from the negative demand-side shock.

Furthermore, we found no significant delay in patent applications despite the fact that the waves of the pandemic significantly affected the monthly number of applications, suggesting that the patent application system functioned with no major disruptions. The nearly 100% online filing rate in Japan may have helped in this regard.

However, foreign applications from and to Japan based on priority filings (mostly inventions made before the pandemic) declined significantly, probably due to the additional processes and costs required for these applications.

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CHAPTER 10

The COVID-19 impact in Australia

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Michael Falk, Haiyang Zhang, Brodie Dobson-Keeffe, Catriona Bruce and Pushpika Wijesinghe

IP Australia

Australia reported its 100th case of COVID-19 on 10 March 2020, the day before the World Health Organization declared COVID-19 a pandemic. Within a fortnight, the Formula 1 Grand Prix in Melbourne was cancelled, non-essential businesses stopped trading, and Australia's international border was closed to all non-citizens and non-residents. Australia's GDP fell 6.8% in the second quarter of 2020, the largest quarterly drop on record. Unemployment increased from 5.4% at the start of the pandemic to a 20-year high of 7.4% by June 2020. Already subdued by one of Australia's worst bushfire seasons, the Australian economy entered recession for the first time in nearly 30 years.

Despite its sharp economic contraction in 2020, Australia saw an 8% increase in trademark applications relative to 2019. This strong growth was unexpected – trademark activity tends to be procyclical, increasing during periods of economic expansion and decreasing in recession. Trademark filing activity continued to surge, growing 9% in 2021 relative to 2020. That same year, patent and design right applications in Australia also reached record highs after falling 2% and 4%, respectively, in the pandemic's first year.

Though it is difficult to isolate drivers of this growth in intellectual property (IP) activity, prior research shows that trademark filings are highly responsive at the country level to entrepreneurship activity (Lyalkov et al. 2019) and to changes in average household income (Jensen and Webster 2011), both of which increased markedly in Australia during the pandemic period. In this chapter, we consider how Australia's response to the pandemic shaped IP activity and how IP trends in Australia have reflected its economic adaptation to the pandemic environment.

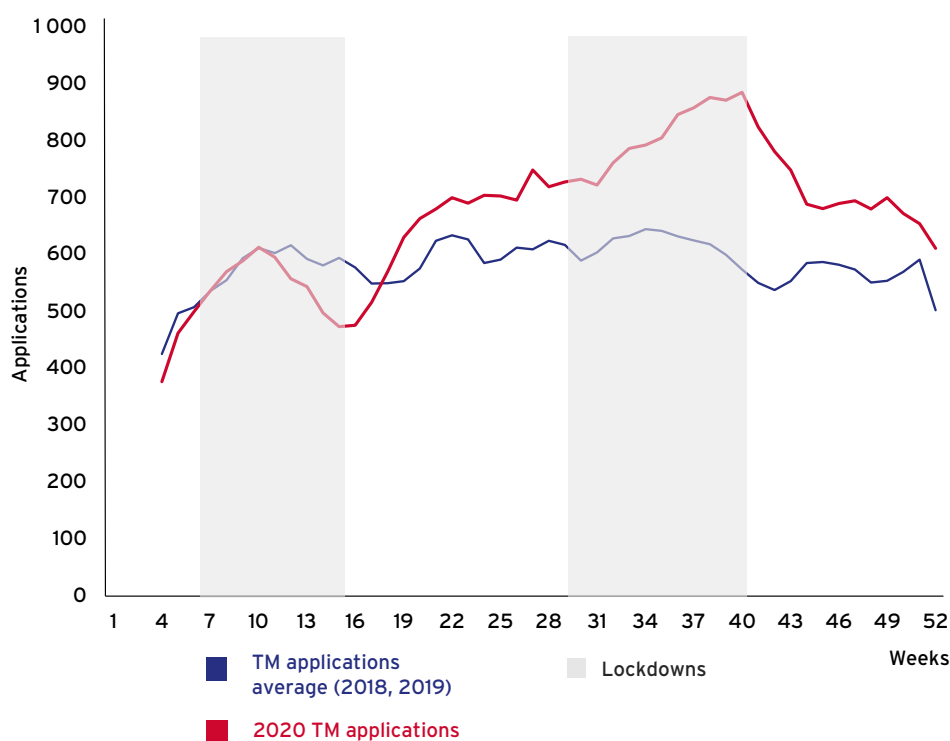
CRISIS AND RESPONSE THROUGH THE LENS OF IP DATA

Trademarks and entrepreneurship

Australia's 2020 growth in trademark activity was entirely due to increased applications by Australian residents. Typically, residents account for 60% of trademark applications filed in Australia. In 2020, resident applications increased 17% while non-resident applications fell 4% from their levels in 2019.

Figure 1 illustrates how trademark filing activity from New South Wales and Victoria – Australia’s two most populous states – deviated sharply in 2020 from its past average, set over 2018 and 2019. First, applications from the two states fell sharply below trend in early March (week 10 on the horizontal axis), coinciding with the initial outbreak of COVID-19 cases in Australia and the introduction of extended lockdowns across the country. Applications then rose above trend as restrictions eased. In early August 2020 (week 32), as Victoria entered its second extended lockdown, application numbers increased further to a peak mid-lockdown. Applications then fell sharply below trend in early August 2020 (week 32), as Victoria entered its second extended lockdown, application numbers increased further to a peak mid-lockdown.

FIGURE 1 IN NEW SOUTH WALES AND VICTORIA - AUSTRALIA'S TWO MOST POPULOUS STATES - TRADEMARK FILING ACTIVITY DEVIATED SIGNIFICANTLY FROM ITS PAST TREND



Source: Intellectual Property Government Open Dataset (IPGOD), IP Australia (2021)

Companies file trademarks to announce new offerings, provided that there is demand for different and higher quality products (Castaldi et al. 2020). Over the pandemic period, a market correction occurred in the Nice class orientation of trademarks in Australia. First, there was a structural shift in applications toward product and service classes that helped mitigate the health impacts of the pandemic. Second, trademark applications grew strongly for discretionary categories of products as household income increased, and for digital technologies as Australian social and economic life adapted to the pandemic environment.

In 2020, the strongest relative growth in trademark filings was in Surgical and medical apparatus (Class 10) and Pharmaceutical and veterinary preparations (Class 5). Applications in each class rose 23% on their 2019 levels. Strong growth was also observed for pharmaceutical patent filings, which grew 18% in 2020 and then a further 27% in 2021, well above their historic growth rate of the past decade.

Recent empirical research shows that at the country level, trademark registrations are positively related to entrepreneurship activity. For example, using data on 33 European countries, Lyalkov et al. (2019) find a positive and significant relationship between trademark registrations and the share of a country's self-employed workforce identified as opportunity-alert entrepreneurs, focused on discovery and prompt exploitation of profit opportunities. These actors can be distinguished from necessity entrepreneurs, considered self-employed as a last resort.

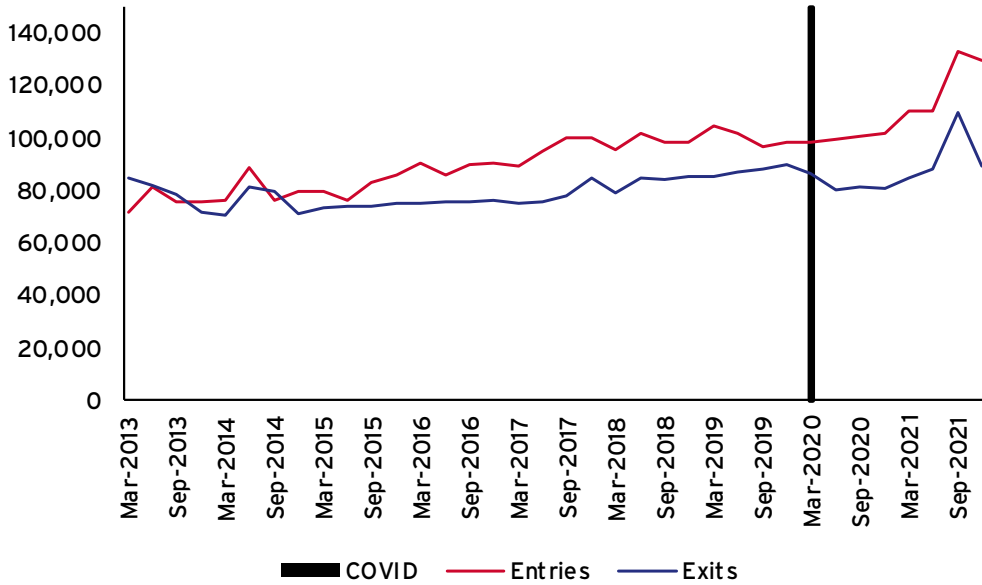
With unemployment at a 20-year high in Australia by June 2020, amidst an unprecedented business shutdown, a rise in necessity entrepreneurship could be expected. However, entrepreneurship in Australia as measured by the rate of new business entries remained stable in 2020 while the firm exit rate actually decreased – for example, when compared to December 2019, around 10,000 fewer firms exited in December 2020 (ABS 2022).

Over the pandemic period, Australia was among the leading countries for new business registrations per capita (World Bank 2022). Many other OECD countries experienced large drops in entries (OECD 2021). However, firm dynamism in Australia only surged in 2021, with the latter half of the year seeing some of the highest rates of business entry and exit in nearly a decade (Figure 2). Based on startup activity as an indicator, entrepreneurship is unlikely to explain the counter-cyclical increase in trademark applications observed in the first year of the pandemic.

Anecdotally, a notable form of pandemic-era entrepreneurship in Australia involved established businesses diversifying into supply of essential products. Australian local whiskey and gin distillers reallocated their spirits production capacity to manufacture hand sanitizer. The Australian government called for and worked with consumer goods manufacturers to produce medical products such as surgical gowns and masks.

Analysis of Australian trademark data shows that in 2020 there was no significant increase in the share of trademark applicants who were 'first filers' (i.e. identified as applicants in 2020 that had not filed any previous trademark applications in Australia at least since 2005). First filers accounted for 54% of trademark applicants in 2020, close to the five-year moving average share of 53%. However, 2020 saw a marked increase in the proportion of trademark applications accounted for by 'repeat filers' in certain Nice classes (repeat filers are identified here as applicants that had filed at least one trademark prior to the current year since 2005). Figure 3 shows a high level of diversification by repeat filers into Surgical and medical equipment (Class 10) in 2020. From 2019 to 2020, the share of total applications in that class accounted for by repeat filers who had not previously filed in that class rose from 29% to 41%.

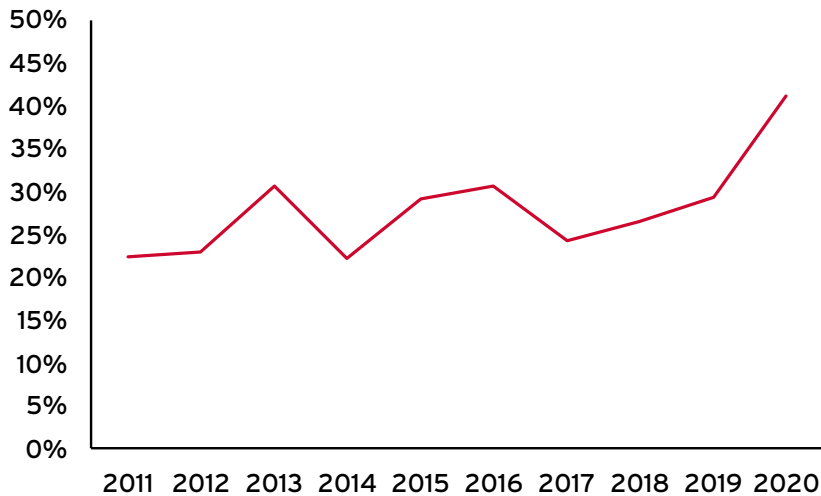
FIGURE 2 QUARTERLY BUSINESS ENTRIES AND EXITS, SEASONALLY ADJUSTED



Source: Counts of Australian Businesses, including entries and exits, Australian Bureau of Statistics (2021)

FIGURE 3 REPEAT TRADEMARK FILERS DIVERSIFIED INTO SURGICAL AND MEDICAL EQUIPMENT IN 2020

Focused on repeat filers, share of total filings in Surgical and medical equipment (Class 10) by diversifying entrants into the class



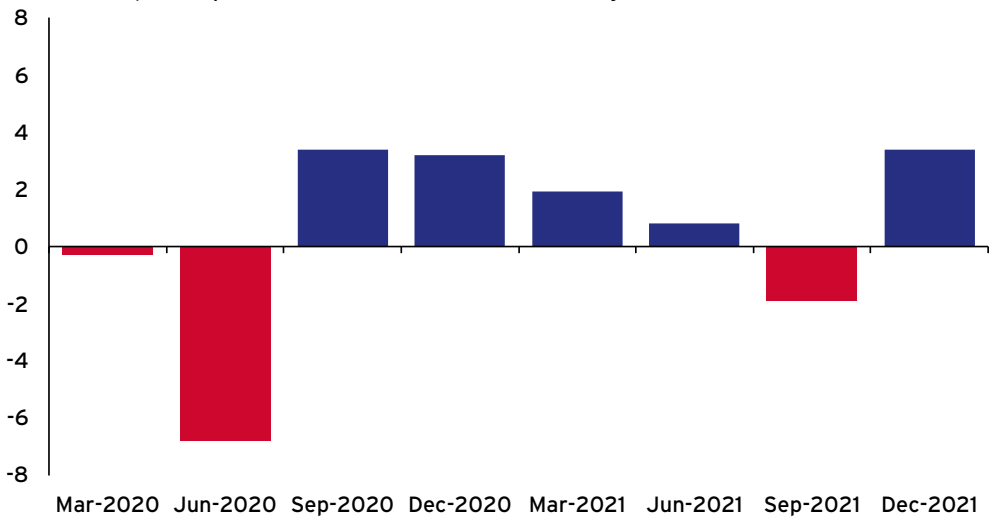
Source: Intellectual Property Government Open Dataset (IPGOD), IP Australia (2022).

Trademarks, income and adaptation

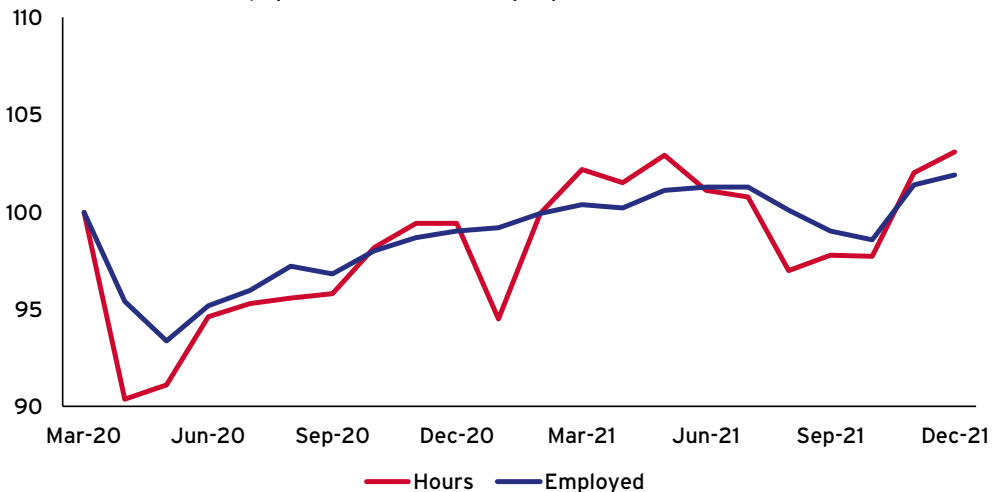
In early 2021, Australian employment and GDP recovered and then passed their pre-COVID levels. However, periodic lockdowns to contain new viral variants continued throughout the year. The impact of ongoing social restrictions was evident in steep swings in employment and total hours worked (see panel B of Figure 4). Despite this, trademark filings continued to surge and grew 9% in the second year of the pandemic. In 2021, patent and design right applications in Australia also reached record highs, up 11% and 13%, respectively, from their levels in 2020.

FIGURE 4 AUSTRALIAN ECONOMIC INDICATORS OVER THE PANDEMIC PERIOD

a) Australia quarterly GDP, chain volume measures (% changes)



b) Hours worked and employment, index, seasonally adjusted (March 2020=100)

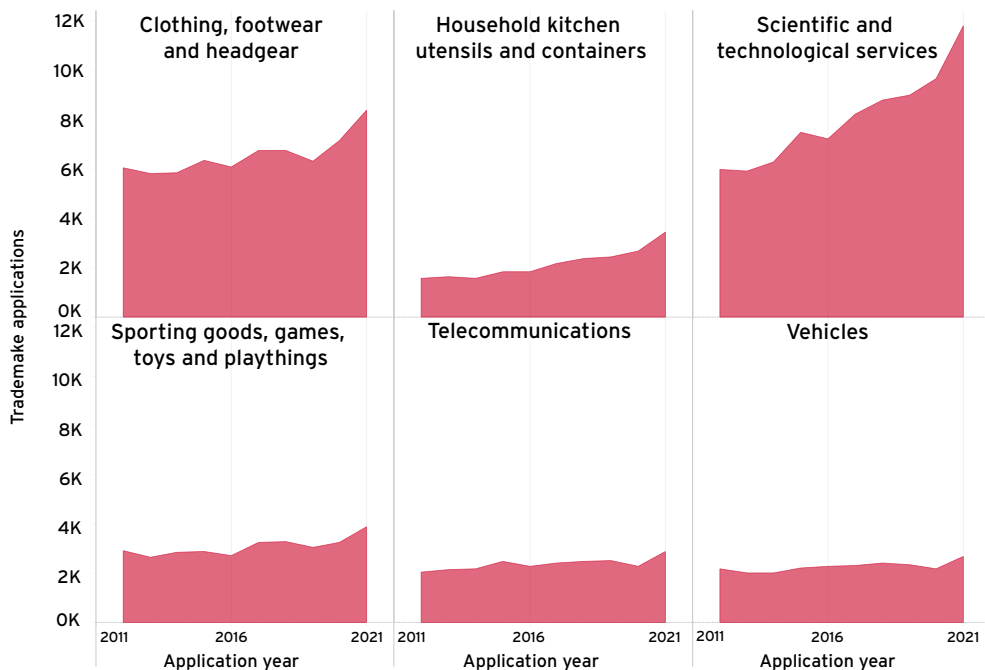


Sources: ABS (2021a, 2022).

In 2020, the Australian government initiated a broad programme of economic stimulus including JobKeeper, a wage subsidy designed to keep workers attached to a job while temporarily stood down. Additionally, the Reserve Bank of Australia twice lowered the Official Cash Rate, and later conducted further rate cuts. In 2020, real household discretionary income grew 11%, most evident for low-income households, largely due to the wage subsidy (Li et al. 2021). In 2021, gross disposable income in Australia reached its highest level on record (ABS 2021a). While expenditure in discretionary categories (like furnishings, household equipment, transport, clothing and footwear) declined significantly when restrictions were in place, it rebounded sharply when they eased, especially after the shorter lockdowns from late 2020 (ABS 2021b).

Trademark activity is highly responsive to changes in average household income (Jensen and Webster 2004). In 2021, the strongest growth in trademark applications occurred in Household or kitchen utensils and containers (Class 21), up 28% from 2020. Demand for homeware and kitchenware products is positively related to income and capital expenditure on private dwellings. Remote work arrangements have prompted many Australian households to upgrade their homes to create comfortable living and workspaces.

FIGURE 5 THE LEADING CLASSES FOR GROWTH IN TRADEMARK APPLICATIONS IN 2021, EXCLUDING 'LOW VOLUME' CLASSES, BELOW THE MEAN FOR TOTAL APPLICATIONS IN 2021



Source: Intellectual Property Government Open Dataset (IPGOD), IP Australia (2022).

As the global economy has moved to a digital model, organisations have been required to adapt and digitise overnight and adopt new communication services. In 2021 the second highest growth class for trademarks was Telecommunications (Class 38), applications for which were up 25% relative to 2020. This class includes telephone and voice mail services and services that provide virtual conferencing, video-on-demand, data sharing and email, internet chatrooms and forums, radio, television and user access to global computer networks. Patent applications for audiovisual technology grew 85%. COVID-19 has accelerated pre-existing trends towards digitalisation of the economy (Iansiti and Lakhani 2020), an adaptive process reflected in the technologies and services that have been the focus of IP filings.

CONCLUSION

The COVID-19 pandemic upended the world economy, and in Australia stopped much of daily public life, causing the sharpest economic recession in at least 30 years. Government support for households and businesses was of a magnitude not seen before in our lifetime. As a result, the pandemic has impacted innovation and IP in ways that deviated from the experiences of previous major economic crises. Change in the rate and direction of innovation has been a crucial factor in enabling new ways of living and working.

Early effects came in the form of trademark growth related to generally increased consumer demand. The rapid and widespread government support resulted in record-high levels of retail spending and, with social restrictions in place, Australians turned to online shopping and home improvements. The classes with the strongest growth in applications reflect this trend.

The other more immediate shift was growth in filings related to more specific consumer demand in classes that posed solutions to the new problems of the pandemic, namely remote work and widespread mask-wearing and testing. In surgical and medical equipment – the lead growth class for trademark applications in 2020 – opportunistic domestic applicants who already held registered trademarks diversified into the class. More generally, the share of first time trademark applicants increased little in 2020, consistent with limited growth in new business startups over the calendar year. New entrepreneurial activity in the form of startups took until 2021 to develop then reached a decadal high.

Through its relationship to entrepreneurial activity, innovation and changing priorities and needs of the population, trademark activity in Australia has traced the crisis and its response. Looking forward, the easing of social restrictions and tapering of government support may return trademark activity to its usual procyclical pattern. Alternatively, the recent boom in firm dynamism may have long-run effects on trademark behaviour that are yet to play out. Early growth patterns in patent filings suggest that COVID-19 has influenced the direction of innovation, with a notable shift toward technologies that support remote work and interaction. While patenting typically occurs early in the life

of a research project, R&D also tends to produce lagged effects on firm patenting (Wang and Hagedoorn 2014). The pandemic's impact on IP activity in Australia, and the role of innovation and IP in shaping the post-pandemic environment, remain twin areas of focus for observation and research.

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PART II

Responses in the innovation ecosystem

CHAPTER 11

Impact of COVID-19 on investments in digital technologies by SMEs in the EU and the US

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Julie Delanote, Ilja Rudyk and Désirée Rückert¹

European Investment Bank; European Patent Office; European Investment Bank

1 INTRODUCTION

Already before the COVID-19 pandemic, digital firms were recognised as performing better than non-digital firms. They were more productive, exported more, invested more, were more innovative, grew faster and paid higher wages on average (e.g. Veugelers et al. 2019, Revoltella et al. 2020). Nevertheless, European small and medium-sized enterprises (SMEs), in particular, lagged their US counterparts in both the creation of new inventions for the digital transformation and the adoption of these technologies in their business, products or services (EIB 2021, EIB and EPO 2022).

The COVID-19 shock accelerated the digital transformation, especially remote work, e-commerce and automation (EIB 2022). Recent evidence indicates that 46% of EU firms took action to become more digital as a response to the pandemic (EIB 2022) – for example, by organising work remotely, improving digital communication with customers, suppliers and employees, and selling products and services online. Firms that adopted advanced digital technologies in their business were better able than non-digital firms to cope with the disruption unleashed by the pandemic and they were less likely to experience a strong decrease in sales since the beginning of 2020. Patent data likewise shows that the rate of innovation in digital technologies has accelerated, if anything, during the pandemic (EPO 2022).

This chapter assesses the impact of the COVID-19 pandemic on investments made by European and US small businesses in the digital transition. It uses the results of two recent surveys – the EIB Investment Survey (EIBIS) and 4IR survey² – to analyse SMEs' investments in both the adoption of digital technologies and the development of new advanced digital technologies (see the Appendix for a definition of digital adopters and innovators).

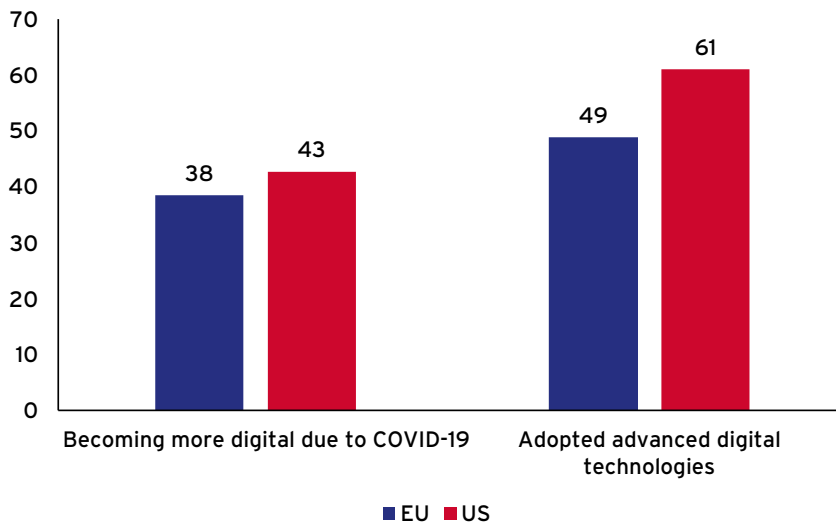
1 The views expressed are those of the authors and do not necessarily reflect the position of the EIB and EPO.

2 The results of both surveys can be compared to each other since both are based on questions that are phrased in the exact same way. The fieldwork of both surveys took place in 2021.

2 THE COVID-19 PANDEMIC DID NOT LEAD TO A CATCH-UP IN ADOPTION OF DIGITAL TECHNOLOGIES BY EUROPEAN SMEs

The pandemic seems to have encouraged the digital transition of small businesses in both the EU and US. The most recent EIBIS (2021) shows that 38% of EU SMEs invested to become more digital as a response to COVID-19 (Figure 1). However, only 49% of EU SMEs adopted advanced digital technologies – such as the internet of things (IoT), cloud computing, 5G, 3D printing and artificial intelligence (AI) – in 2021, a share that is somewhat smaller than in 2020 (52%) and only slightly higher than in 2019 (48%). Adopting advanced digital technologies, such as new AI algorithms or IoT solutions is, often a complex process, requiring a reorganisation of the company's business, acquisition of staff with new skills, and re-training of existing staff. It is likely that, against the backdrop of the pandemic, firms have been delaying the most complex investment projects, focusing on their immediate needs. Advanced digital technologies appear to have been less of a priority for many SMEs during the COVID-19 crisis. The adoption rates were higher for large European companies and the drop less severe than for SMEs (from 75% in 2020 to 74% in 2021).

FIGURE 1 ADOPTION OF DIGITAL TECHNOLOGIES OF SMEs IN 2021, BY REGION



Notes: Base: Firms with fewer than 250 employees. A firm is identified as having “implemented” advanced digital technology if at least one of four digital technology specific to its sector was implemented in parts of the business and/or if the entire business is organised around at least one digital technology. Question: “As a response to the COVID-19 pandemic, have you taken any actions or made investments to become more digital (e.g. moving to online service provision)?”

Source: EIBIS (2021).

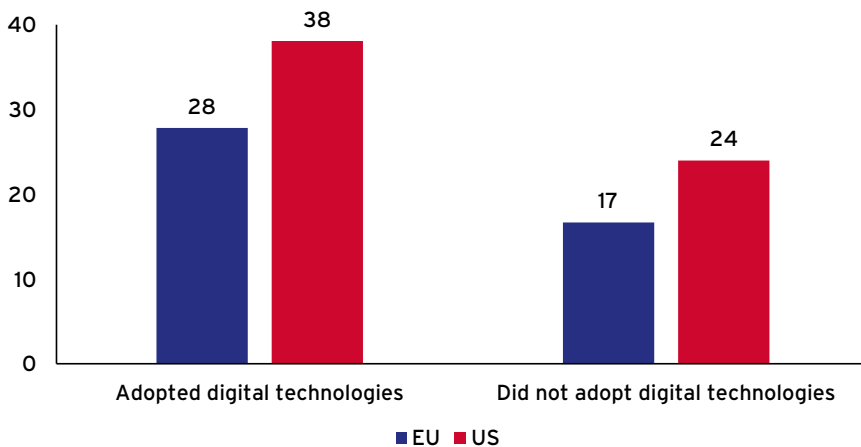
SMEs in the US responded more actively than their EU counterparts, with 43% of US SMEs digitally investing as a response to COVID and 61% having adopted advanced digital technologies in 2021. The proportion of SMEs that invested in the digital transition in response to the pandemic is 5 percentage points lower in the EU than in the US, and

the gap reaches 12 percentage points in the case of the adoption of advanced digital technologies during that period. This suggests that the lead of US small businesses over EU ones in their digitalisation journeys has not been closing but has widened instead during the pandemic.

3 THE IMPACT ON INNOVATION MAY SUBSTANTIATE THE US LEADERSHIP

SMEs that adopted advanced digital technologies (digital adopters) are more likely to develop new products and services as a response to COVID-19, compared to those SMEs that did not. However, this holds more for US SMEs than for EU SMEs, as shown in Figure 2.

FIGURE 2 DEVELOPMENT OF NEW PRODUCTS AS A RESPONSE TO COVID-19, BY DIGITAL STATUS AND REGION (% OF FIRMS)



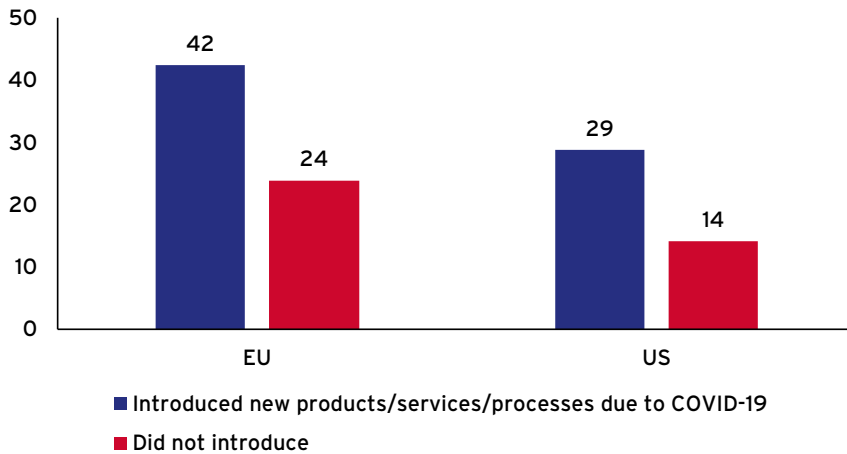
Base: Firms with fewer than 250 employees that adopted advanced digital technologies in EIBIS (don't know/refused not shown). Question: "And as a response to the COVID-19 pandemic, have you taken any actions or made investments to develop new products, services or processes?"

Sources: EIBIS (2021).

Interestingly, 42% of those EU digital adopters that did innovate as a response to COVID-19 report that their investment priority for the coming three years is to develop or introduce further new products or services, compared to 29% of their US peers (Figure 3).

The 4IR survey data further show that the innovation response to the COVID shock was also stronger in US small businesses. US SMEs with patenting activities in advanced digital technologies ('digital innovators') are forging ahead and surpass their European peers. About 75% of US digital innovators indicate that they expect to invest more in innovation in advanced digital technologies in the coming five years, compared to 61% of EU digital innovators (Figure 4).

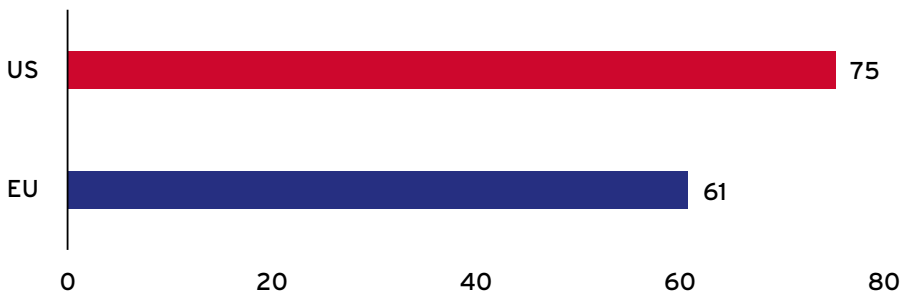
FIGURE 3 INVESTMENT PRIORITY OF DIGITAL ADOPTERS TO DEVELOP OR INTRODUCE NEW PRODUCT OR SERVICES OVER THE NEXT THREE YEARS (% OF FIRMS)



Notes: Base: Firms with fewer than 250 employees that implemented advanced digital technologies in EIBIS (don't know/refused not shown). Questions: "And as a response to the Covid-19 pandemic, have you taken any actions or made investments to develop new products, services or processes? Looking ahead to the next three years, which of the following is your investment priority? Replacing capacity, capacity expansion, developing or introducing products or services, no plans."

Sources: EIBIS (2021).

FIGURE 4 MORE INVESTMENT IN ADVANCED DIGITAL INNOVATION EXPECTED IN THE COMING FIVE YEARS (% OF FIRMS)

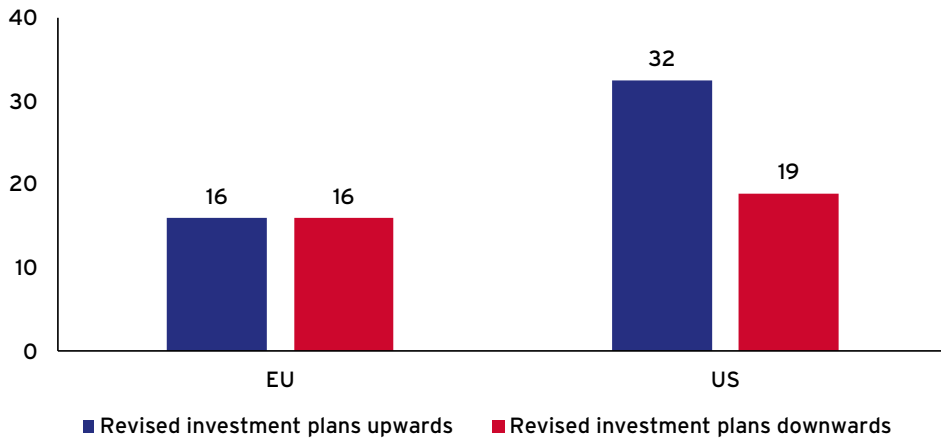


Notes: Base: 4IR innovators (don't know/refused not shown). Question: "Looking ahead to the next five years, do you expect your company to invest in 4IR-related innovation more, less or about the same?"

Sources: 4IR Survey (2021).

Although most digital innovators expected their future investments in 4IR technologies to increase, their general future innovation investment plans, not limited to those in 4IR technologies, were more likely to be revised because of COVID-19. However, there is a significant difference between US and EU SMEs in this respect (Figure 5). A higher share of US digital innovators revised their future investment plans upwards than EU digital innovators (32% versus 16%), while the share of digital innovators that revised their investment plans downwards is relatively similar (19% versus 16%).

FIGURE 5 REVISION OF FUTURE INVESTMENT PLANS FOR INNOVATION RELATED TO ADVANCED DIGITAL TECHNOLOGIES DUE TO COVID-19 (% OF FIRMS)



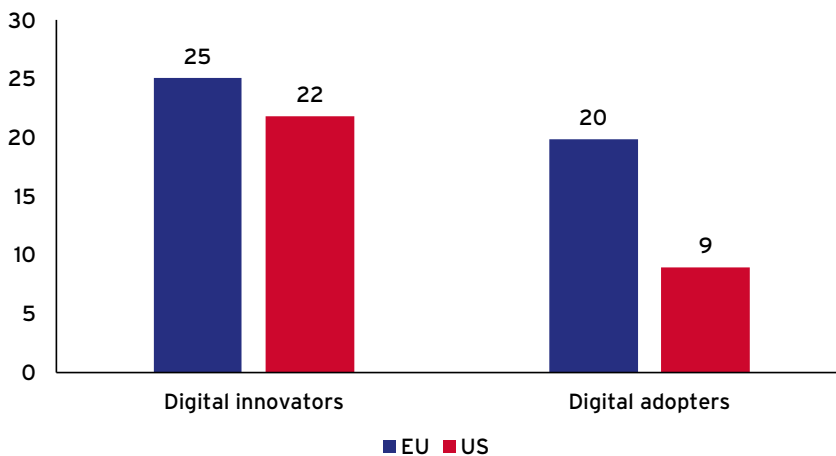
Notes: Base: 4IR innovators (don't know/refused not shown). Question: "Has the COVID-19 pandemic caused your company to revise future investment plans for 4IR-related innovation?"

Sources: 4IR Survey (2021).

4 ACCESS TO FINANCE IS A MAJOR BARRIER

Why are EU SMEs lagging behind and what could turn the tide? European digital adopters complain more than their US peers about access to finance. Figure 6 shows that EU SMEs in particular report it as a major impediment (20% versus 9% in the US).

FIGURE 6 AVAILABILITY OF FINANCE AS MAJOR OBSTACLE TO INVESTMENT (% OF FIRMS) REVISION OF FUTURE INVESTMENT PLANS FOR INNOVATION RELATED TO ADVANCED DIGITAL TECHNOLOGIES DUE TO COVID-19 (% OF FIRMS)



Notes: Base: Firms with less than 250 employees that implemented advanced digital technologies in EIBIS, 4IR innovators in 4IR survey (don't know/refused not shown). Question: "To what extent is the availability of finance an obstacle to the success of your business? Is it an obstacle, a major obstacle or not an obstacle at all?"

Sources: EIBIS (2021); 4IR Survey (2021).

For digital innovators, the lack of availability of finance is an even higher impediment to investment. Interestingly, digital innovators in both the EU and US seem to suffer at a similar rate. Nevertheless, the share of digital innovators that state having developed new products due to COVID-19 is substantially lower for SMEs for whom the availability of finance is a major barrier to their investment activities, and this difference is particularly pronounced for digital innovators in the EU. This suggests that even if the shares of digital innovators in the EU and the US complaining about access to finance are similar, the consequences seem to be more severe for EU SMEs.

5 CONCLUSION AND IMPLICATIONS FOR EUROPEAN POLICY

Although the COVID-19 pandemic accelerated the uptake of and investment in basic digitalisation, the pre-pandemic gap in adoption rates and innovation efforts between the EU and the US still remains and is likely to widen even further. If European policymakers want to counteract this trend, they have to address some profound barriers to the adoption of digital technologies.

Survey data confirm that the financial system as it is, with its strong focus on bank finance, may put European firms at a funding disadvantage. This is true in particular for SMEs, which are much more likely to report problems accessing finance than their larger peers. An important explanation for this is the difference in access to growth capital, being more widespread in the US.

Targeted financial incentives prove very relevant in promoting transformative investment with regards to digitalisation. European firms that received such incentives for digitalisation in the last three years were almost twice as likely to invest more in digitalisation as a response to the pandemic (Revoltella et al. 2021).

Intellectual property (IP) rights can also play a role in helping SMEs finance the commercialisation of new technology in Europe. According to the 4IR survey, 80% of EU SMEs report that their IP strategy is of relevance to their investors, and 49% consider patents as very important in securing finance. In this context, the introduction of the unitary patent will be a welcome development to help SMEs secure patent protection on the EU scale.

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APPENDIX

The 4IR survey

The main goal of the survey was to collect information on small and medium-sized enterprises (SMEs) in Europe and the US that are developing and/or applying advanced digital technologies (technologies for the 4th Industrial Revolution, or 4IR).³ To achieve this, the population was regarded as comprising all SMEs identified as applicants of an international patent family in the 4IR category in recent years. Finally, N=625 complete interviews were held with the target population between June and October 2021.

‘**Digital innovators**’ are firms that participated in the 4IR survey and mention that they carried out any development work in 4IR technologies over the last three years.

EIBIS

The EIB carries out an annual survey of firms in the EU27, UK and US with the aim of monitoring investment and investment finance activities, while at the same time capturing potential obstacles to investment. The survey covers approximately 12,500 companies across the EU and the UK every year, with just over 800 firms in the US for the last three waves. The first wave of the survey took place in 2016 and the survey completed its sixth wave in 2021, with interviews being held between April and July 2021. The results of the latest wave are used as comparison benchmarks.

In EIBIS, firms are polled about the use of four advanced digital technologies that are specific to their sector. “3D printing” (refers to Manufacturing, Construction, and Infrastructure sectors); “Automation via advanced robotics” (refers to Manufacturing sector); “IoT” (refers to Manufacturing, Service, Construction, and Infrastructure sectors); “Big data/AI” (refers to Manufacturing, Services, and Infrastructure sectors); “Virtual or augmented reality” (refers to Services and Construction sectors); “Platforms”

3 See EPO (2020) for the definition and identification of technologies that are relevant for the 4th Industrial Revolution.

(refers to Services and Infrastructure sectors); “Drones” (refers to Construction sector). They are asked the following question: “Can you tell me for each of the following digital technologies if you have heard about them, not heard about them, implemented them in parts of your business, or whether your entire business is organised around them?”

A firm is identified as a **‘digital adopter’** if one advanced digital technology is implemented in parts of the business and/or if the entire business is organised around one digital technology.

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CHAPTER 12

The COVID-19 pandemic and academic research enterprise

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Kyle R. Myers

Harvard Business School

LOST RESEARCH

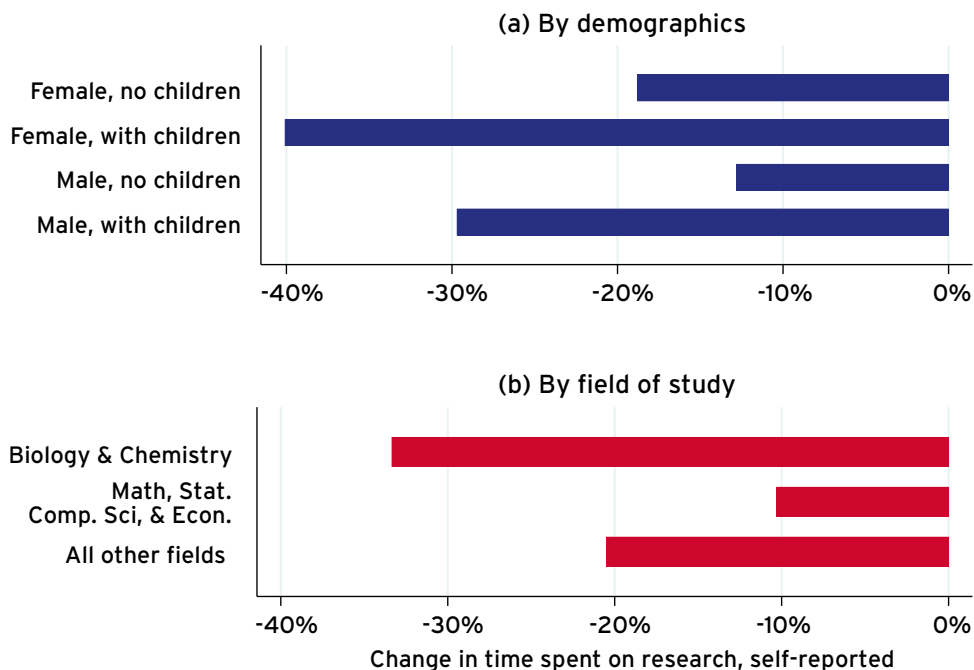
While the COVID-19 pandemic drew immense attention from certain slices of the scientific community, most academic researchers did not apply their skills to the pandemic.¹ Instead, they attempted to continue their research projects amidst a complicated and evolving set of challenges both at work and at home.

Surveys of faculty at institutions across the US and Europe indicated that their total time spent on work declined roughly 10% on average (Myers et al. 2020a). Importantly, the demands for administrative work and teaching did not change much, or often increased (e.g. the need to learn new skills during the transition to online teaching). Thus, the category of work that suffered the most was research, declining by roughly 22% on average. Notably, there were no major differences between US and European researchers despite the large differences in cultural norms and social support structures. This decline in research time amidst a sharp increase in journal submissions (Else 2020) suggests that there was also a shift in the type of research work conducted towards, for example, writing papers. Findings from Gao et al. (2021), discussed later in the chapter, suggest this shift came at the expense of work on new projects and collaborations.

This loss of research time was not felt equally across academics. Figure 1 illustrates the average reported losses in researcher time for different demographic groups (panel a) and different disciplines (panel b). Female researchers and those with young children at home reported the largest declines of any demographic group evaluated. Women reported declines in time spent on research that were roughly 5–10 percentage points larger than men, and those with young children at home reported declines roughly 15–20 percentage points larger than others. These differentials clearly raise concerns for equality and equity, which will be discussed further below in light of institutions' responses.

¹ Estimates from Hill et al. (2021) suggest that roughly 6% of active researchers published a journal article related to COVID-19 during the pandemic. Survey evidence from Gao et al. (2020) suggests a larger fraction (roughly one-third) of researchers directed some attention to COVID-19. Besides sampling differences, the discrepancy between these two estimates would be consistent with a large portion of researchers who pivoted their work towards the pandemic either (a) being unsuccessful in producing a research paper, or (b) focusing on 'research' activities where a peer-reviewed journal article was not the object of interest.

FIGURE 1 LOST RESEARCH TIME IN 2020



Note: Displays group-level averages of the percent change in self-reported time spent on research comparing 2019 to 2020. Based on 4,535 full-time academic faculty surveyed in April 2020; see Myers et al. (2020a) for more on the underlying data and additional analyses.

In addition to concerns about equality, the differential impact on women may have important downstream effects on the supply of scientists given evidence that role models play an important part in female students' career decisions (Bettinger and Long 2005, Porter and Sera 2020) and how gender influences the topics scientists pursue (Koning et al. 2021, Truffa and Wong 2022). The differential impact on parents of young children is important because these are typically younger researchers (on average, ten years younger) and, amongst those in tenure-track positions, they are also more likely to be pre-tenure (roughly 10% more likely). Thus, the large degree of disruptions focused within this set of researchers may have important implications for the transfer of knowledge across generations of researchers.

Panel b of Figure 1 illustrates another important dimension of heterogeneity in lost research time across disciplines. Mathematicians, statisticians, computer scientists, and economists – researchers with relatively low equipment, capital, and travel requirements – all reported much smaller declines than the average. It is commonplace for the work in these fields to not involve more than a personal computer, perhaps even just a pen and paper, which likely permitted a much smoother transition to the work-from-home lifestyle that became pervasive. The 'bench sciences' of biology and chemistry, however, clearly suffered the most, reporting declines on the order of 33%. This likely reflected the fact that 'research' for these individuals typically involves working in on-campus, capital-

intensive laboratories and facilities that were almost entirely closed at the onset of the pandemic in 2020. The large losses experienced by these specific researchers may prove more than transitory given recent evidence that shocks to capital-intensive research can persist for many years (Baruffaldi and Gaessler 2021).

INSTITUTIONAL RESPONSES

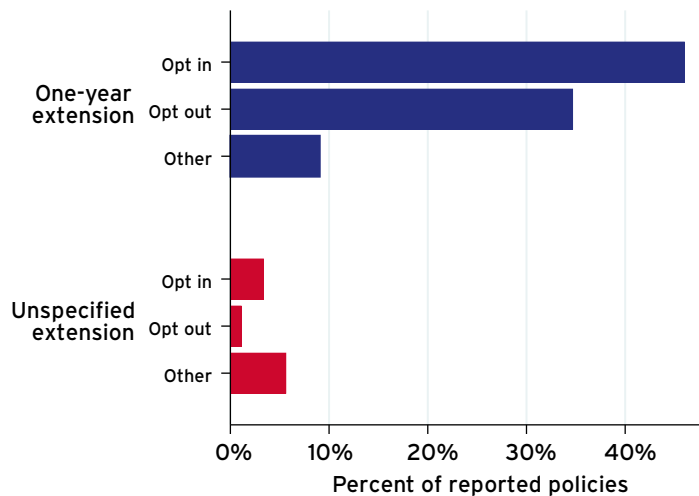
Tenure extensions

Institutions of higher education were relatively quick to respond to the pandemic. By April 2020, nearly all institutions (91%) had closed their doors to most students and staff (Myers et al. 2020a).

Besides these closures, one of the most common policy responses from US-based institutions was to grant pre-tenure tenure-track faculty members an extension on their tenure clock. The specifics of these policies likely varied in many ways, but one of the most important dimensions was whether the extension was granted to all faculty by default (an ‘opt-out’ policy) or whether faculty were required to apply (an ‘opt-in’ policy).

Thanks to a decentralised effort to collect data on such policies across roughly 250 US institutions, Figure 2 illustrates the distribution of these policies along dimensions of whether the extension was for one year or not, or whether it was opt-in or opt-out. Interestingly, roughly 90% of policies provided one-year extensions. This homogeneity stands in stark contrast to the heterogeneity displayed in Figure 1.²

FIGURE 2 TYPES OF TENURE EXTENSION POLICIES ENACTED ACROSS INSTITUTIONS



Note: Displays the distribution of tenure extension policies based on a publicly available, but unofficial, compilation of policies at roughly 250 US-based colleges and universities, which is available here. 92% of reported policies were enacted in either March or April of 2020.

² As reported above, the mean decline in research time in Myers et al. (2020a) was roughly 22%, but the standard deviation in the sample was 50%, suggesting a wide range of different experiences across faculty.

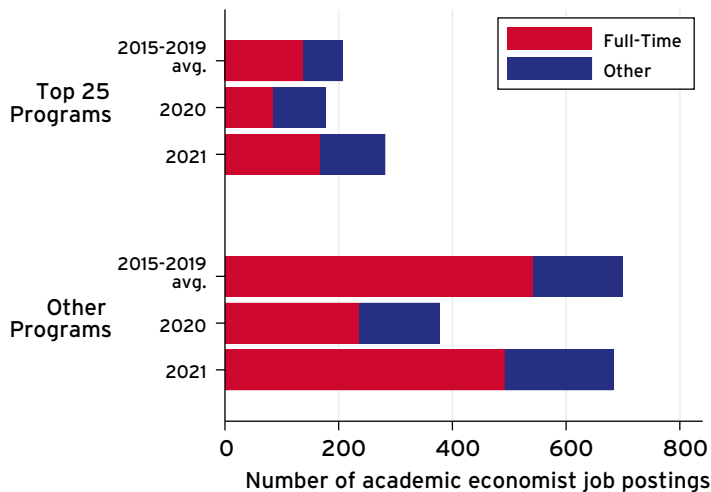
Antecol et al. (2018) provide a clear example of how equality in policy design can lead to inequities by studying the spread of gender-neutral family policies amongst tenure-track faculty. The authors' empirical analyses find that these policies actually increased male tenure rates while decreasing female tenure rates – these equal policies do not account for the unequal productivity losses they are attempting to address.³ These findings suggest that the homogeneity in policy responses indicated by Figure 2, combined with the fact that at least one-third of extensions were awarded by default, should raise some concern that inequities amongst academic researchers may arise in the future.

Reduced recruiting

Another major response of many academic institutions was to reduce recruiting efforts. Anecdotes abound, but data on these reductions has only begun to be compiled so it remains unclear just how large these reductions may be.

The field of economics operates an organised job market, the data for which provide some initial views on how the pandemic altered the supply of, and demand for, new jobs amongst academic researchers. Figure 3 illustrates data on academic jobs from the American Economic Association's online job forum (Job Openings for Economists), separating openings based on the year they were posted, whether they are at schools with one of the top-25 economics programmes or not, and whether the position is full-time tenure-track or not.

FIGURE 3 TRENDS IN ACADEMIC JOB RECRUITING AMONG ECONOMISTS, 2015-2021



Note: Displays the average or actual number of job postings by year(s), based on whether the posting is for a full-time tenure-track position or not (e.g., part-time, adjunct) as well as whether the recruiting institution was ranked among the top 25 economics departments per the 2017 U.S. News & World Report rankings, which are listed here. Data are sourced from the American Economic Association JOE Listings, which is available here.

3 Notably, Antecol et al. (2018) also find no evidence that female-specific family policies have any effect on female tenure rates, suggesting it is difficult for such extensions (as currently designed) to have meaningful effects.

The data tell two different stories. First, among top-ranked schools, there was a modest decline in postings in 2020 compared to prior years (-15%), which was comprised of a relative decrease in full-time positions (-45%) amidst an increase in other positions including part-time, temporary, or adjunct faculty (+25%). By 2021, these schools had rebounded to roughly 30% above 2015–2019 levels, but now with a larger share of non-full-time positions being posted.

Outside of the top 25, there was a much larger relative (and absolute) decline in job postings in 2020 compared to prior years (-60%), with both full-time and other positions seeing large relative declines (-80% and -10%, respectively). By 2021, these schools had rebounded to 2015–2019 levels. And as in the case of top-25 programmes, the share of non-full-time faculty has increased too.

Overall, the total number of job openings has returned to relatively normal levels (2021 totals were 5% above 2015–2019 averages), which may suggest some optimism. However, two other patterns may be worthy of continued attention. First, the rebounds in hiring seen in 2021 were not large enough to offset the declines observed in 2020. This suggests that there are still some ‘missing’ academics at these institutions. The extent to which these missing individuals will lead to more responsibilities (e.g. teaching, administration) for existing academics will depend largely on the degree to which enrolment has changed. Early data suggest that enrolment at US universities and colleges in 2020 and 2021 was somewhere near 5% below pre-pandemic levels.⁴ If the data from economics are indicative of most disciplines, then it appears there are many more missing faculty than there are missing students. Whether faculty can reallocate their time as needed without sacrificing their productivity remains to be seen.⁵

The second pattern of interest is the growth in non-full-time positions. Recent research has shown evidence that monopsony power among higher education institutions⁶ could be a significant force driving a long-run trend towards more non-tenure-track positions (Goosbee and Syverson 2019). The implications of this trend have been discussed at lengths elsewhere (e.g. Ehrenberg 2012, AAUP 2014), and the early data illustrated in Figure 3 suggest the pandemic may have sped up this shift.⁷ The empirical evidence as to the effect of shifts in the composition of faculty types on student outcomes has been mixed (see Ehrenberg 2012 for a review). On an optimistic note, there is some evidence that non-tenure track faculty provide a higher value-add to their students (Figlio et al. 2015).

4 See National Student Clearinghouse (2022) for more.

5 For reference, Deming and Walters (2017) show that shifts in spending at postsecondary institutions has an important effect on degree completion, suggesting that the reduced spending implied by the hiring reductions of 2020 may have important consequences for graduation rates soon.

6 Here, ‘monopsony power’ refers to the fact that there are relatively few faculty positions in higher education institutions relative to the number of potential faculty members, which, combined with other features of this market, can allow institutions to offer compensation packages that are less attractive than they would be in a fully competitive market for faculty.

7 Additionally, the pattern that top-25 schools appeared more able to shift recruiting towards non-full-time positions (see Figure 3) is consistent with Goosbee and Syverson’s (2019) result that monopsony power is highest among top-tier research institutions.

LOOKING FORWARD

It is still too early to evaluate the full spectrum of effects of the pandemic on academic researchers. There are causes for concern, with initial data suggesting there has been a marked decline in new collaborations and new research projects (Gao et al. 2021). Whether the surge in new policies, arrangements and technologies can address these disruptions is still unclear. For example, consider the growth in virtual technologies across academia (e.g. courses, seminars, or conferences conducted via streaming video or other interactive tools). On one hand, there is good evidence that physical interactions play an important role in shaping the direction of research (Catalini 2018), so perhaps some important lines of research have been lost. On the other hand, these technologies introduce a significant amount of flexibility into many previously rigid systems (e.g. by not requiring travel for in-person interactions, or by reducing the marginal costs of expanding access). Such flexibility in work arrangements is a key to promoting equity (Goldin 2014), so perhaps there is still much to be gained.⁸

There is some evidence that variation in institutional policies will prove to be important. Myers et al. (2020b) asked faculty to (1) report their satisfaction with their institution's response to the pandemic and (2) forecast their research output in the coming years.⁹ They find a strong positive correlation between the satisfaction and forecast measures, even after conditioning on a large set of potential confounding variables – faculty with high satisfaction persistently had more optimistic forecasts of their research output. This preliminary evidence suggests that some institutions' policies helped. But how much they helped, and how much they may have decreased or increased inequalities amongst academic researchers, remains to be seen.

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⁸ For an in-depth discussion of such equity issues in the context of the pandemic's effect on female scientists and engineers, see Higginbotham and Dahlberg (2020).

⁹ To account for variation in respondents' beliefs about when the pandemic will end, Myers et al. (2020b) presents a hypothetical question to respondents when forecasting their output, and this hypothetical question includes a randomised value for the supposed duration of the pandemic so that these beliefs can, in theory, be held fixed across respondents.

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CHAPTER 13

The power of attention: Early indications of how the COVID-19 pandemic has affected the direction of scientific research in the life sciences

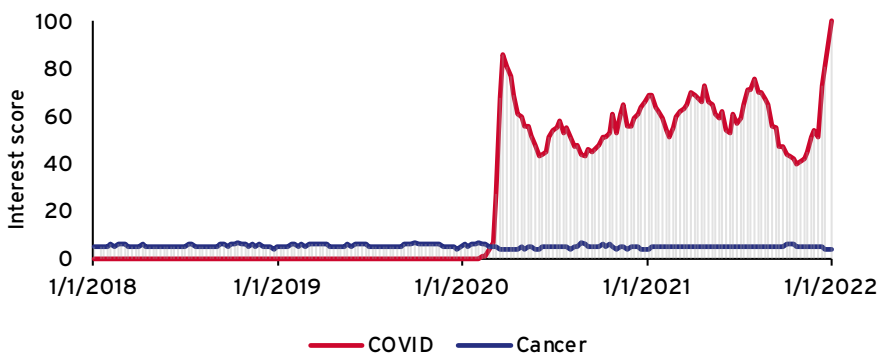
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INTRODUCTION

COVID-19 has garnered a lot of attention since its global outbreak in early 2020. Figure 1 showcases the consuming nature of the pandemic, comparing Google searches on cancer – the previously most searched disease on the internet (Ritchie 2019) – with searches for the term “COVID”.

FIGURE 1 COMPARISON OF WORLDWIDE GOOGLE TRENDS FOR SEARCH TERMS “COVID” AND “CANCER” FROM 01 JANUARY 2018 TO 31 DECEMBER 2021.



Notes: The interest score indicates the search interest relative to the highest point in the chart for the specified period. The value 100 represents the highest popularity of any of the two search terms. The value 50 means that the term is half as popular and the value 0 means that there was not enough data for this term.

Where does this attention for COVID come from? Is it mainly society that is concerned because of the fear of infection, for example, or is it science that is searching for a remedy – or both? Humans only have a limited capacity for cognitive processing of information

(Fiedler and Garcia 1987). Therefore, it is reasonable to ask whether the additional attention has been diverted away from other areas of science that are potentially important for scientific progress and human health. This is particularly relevant when scientists and the public pay less attention to other diseases, which may, for example, lead to an underinvestment in the medium to long term.

Although the true impact of COVID-19 on science will become clear only years from now, one can assess different measures for attention that scientific articles receive as an early indicator (Barakat et al. 2018, Huang et al. 2018). We focus on attention-based measures – derived from, for example, social media mentions or newspaper coverage – since attention is immediately observable. In addition, attention is an important determinant of legitimacy, in turn influencing funding, hiring and promotion decisions (Petkova et al. 2013, Lerchenmueller et al. 2019). Shifts in attention can result from slight changes (Ocasio 1997, Ocasio et al. 2018), and even small shifts can lead to larger consequences in the future. Lorenz (1972) referred to this phenomenon of small changes in one state leading to large differences in a later state as the butterfly effect.

When we refer to ‘shifts of attention’, these could be either reallocations of attention across scientific content or newly generated attention to science. Besides scientists themselves, we also consider shifts in attention of the broader public or policymakers, as they can start a self-reinforcing cycle that has a lasting impact on future research funding, the choice of research priorities and, consequently, on research output, the direction of science and society (Myers 2020, Myers and Pauly 2019).

Making use of attention metrics, our chapter examines the following questions:

1. To what extent has the attention to certain research content shifted during the first months of the COVID-19 pandemic?
2. What group is responsible for an early COVID-induced shift of attention?

METHODS

To address the outlined questions, we construct a novel dataset that compares the attention to roughly 25,000 COVID-related publications to that of almost 420,000 articles unrelated to COVID in the life sciences. To allow for comparisons in attention before and during the pandemic, our sample includes publications from 2018 to 2021. To construct our dataset, we link four main data sources:

- We use publication data from PubMed,¹ a meta-database of more than 33 million article references related to the life sciences, maintained by the United States National Library of Medicine (NCBI).

1 <https://pubmed.ncbi.nlm.nih.gov/> (accessed 4 March 2022).

- We use Clarivate’s Journal Citation Report, which links journals to 89 different life science fields, such as surgery or oncology,² and which ranks journals by their scientific impact based on the frequency with which the published articles are cited by subsequent articles.
- We use the LitCOVID database,³ collecting all COVID-related research recorded in PubMed (Chen et al. 2020).
- We use Altmetric attention score data,⁴ which combines a broad set of attention indicators including mentions of scientific publications in mainstream news, social media (mostly Twitter), blogs, public policy documents, references in Wikipedia and in the patent literature.

To build our dataset, we start with all scientific journal articles in PubMed. In a second step, we assign the journals in which these articles have been published to the 89 life science fields proposed by Clarivate’s Journal Citation Report and select the five most impactful journals for each of the 89 categories to maintain a certain quality threshold for our analysis. Next, we identify all articles published in the selected journals between 1 January 2018 and 31 December 2021 – a total of 442,922 publications. We then use the LitCOVID database to identify COVID-related publications. In all, we classify about 13,000 publications in 2020 (11.0%) and about 12,000 publications in 2021 (10.6%) as COVID-related.

Next, we extract the Altmetric attention score for each publication in our dataset. It is important to note that this score only measures the attention an article has received from a wide audience; it is not a measure of the quality of an article. Social media reactions such as tweets may not be a clear measure of research value since attention can be positive or negative. However, social media attention has the advantage of informing us of the immediate response to the research. Traditional citation information, which is usually a proxy for the quality of the research, takes much longer to acquire (Elmore 2018). Because we are interested in the immediate response to COVID and non-COVID publications – i.e., the starting point of a possible butterfly effect – we prefer the Altmetric attention score to classic measures of quality such as citations.

The final dataset allows us to compare the attention to research output between COVID-related and non-COVID-related publications. The observations from 2018 and 2019 can serve as a baseline measure of how much attention an ‘average publication’ receives in the absence of a pandemic. Differentiating COVID-related from non-COVID-related publications in 2020 and 2021 allows us to assess the extent to which COVID-related research has disproportionately absorbed attention, relative to non-COVID publications

2 If a journal is allocated to multiple fields, we consider the journal only relevant for the field where it is ranked highest in terms of its relative impact.

3 www.ncbi.nlm.nih.gov/research/coronavirus/ (accessed 4 March 2022).

4 www.altmetric.com/about-our-data/the-donut-and-score/ (accessed 4 March 2022).

from the same year but also relative to the baseline in previous years. Due to clear allocation of publications to academic fields, we can further distinguish between within-field and cross-field effects.

In what follows, we use descriptive statistics (comparisons of means) to analyse the attention to science over the past four years. While this approach allows us to uncover patterns in attention to scientific research associated with the exogenous pandemic, there are limits with respect to causal inference that may provide avenues for future research. Additionally, we cannot determine whether a change in attention is due to a redistribution within a particular group of people – i.e., whether particular people who were paying attention to non-COVID research before 2020 are now paying attention to COVID research – or whether attention to COVID research is originating from people who did not pay attention to research before the pandemic. Given that COVID has received unprecedented attention worldwide in the last two years, it stands to reason that many people began to pay attention to science because of COVID.

RESULTS

Overall attention

Overall, there is an increase in attention to research publications in the life sciences during the COVID pandemic. Figure 2A shows that the average amount of attention (i.e., average Altmetric score) plotted against the publication month of articles has increased by approximately 50% starting in January 2020, the onset of the pandemic (Fig. 2A). Figures 2B and 2C together show that the effect is mostly driven by heightened attention to COVID-related research (Figure 2B); attention to non-COVID research has decreased over the considered time window (Figure 2C). Although interpretation of the effect requires caution because more recent articles may have had less time to draw attention than articles published before January 2020, our data indicate that approximately 90% of the Altmetric score accrues within six months of publication. In all, the difference in attention between COVID-related and non-COVID-related research is stark: Figure 2B shows an approximately ten-fold and stable difference in the average Altmetric attention score between COVID and non-COVID research.

FIGURE 2A AVERAGE ALTMETRIC SCORE FOR 442,922 PUBLICATIONS FROM SELECTED JOURNALS AS OF FEBRUARY 2022

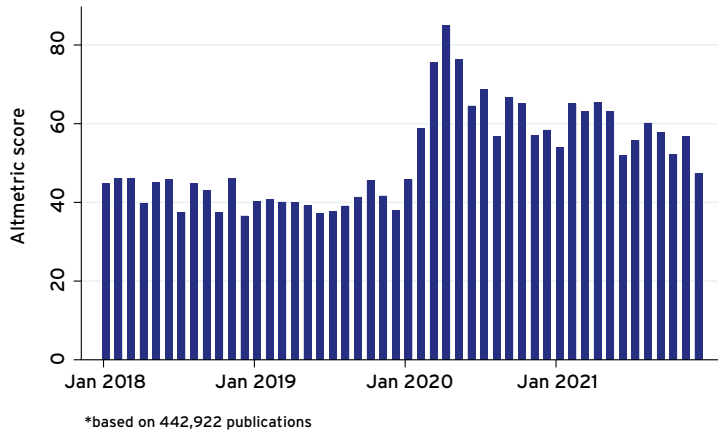


FIGURE 2B AVERAGE ALTMETRIC SCORE FOR 417,595 NON-COVID-RELATED AND 25,327 COVID-RELATED ARTICLES AS OF FEBRUARY 2022

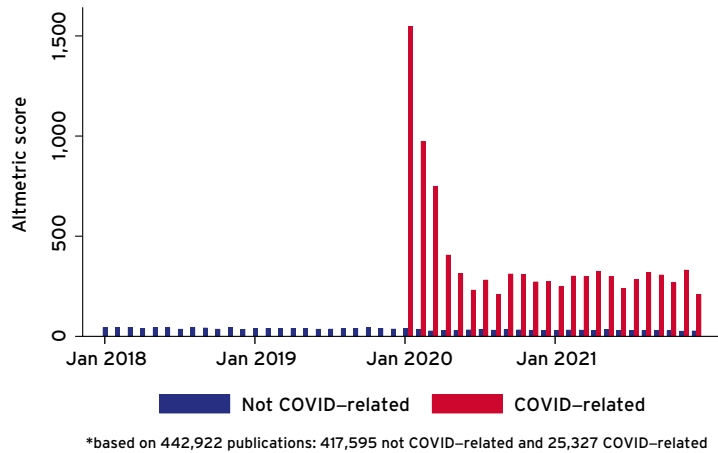
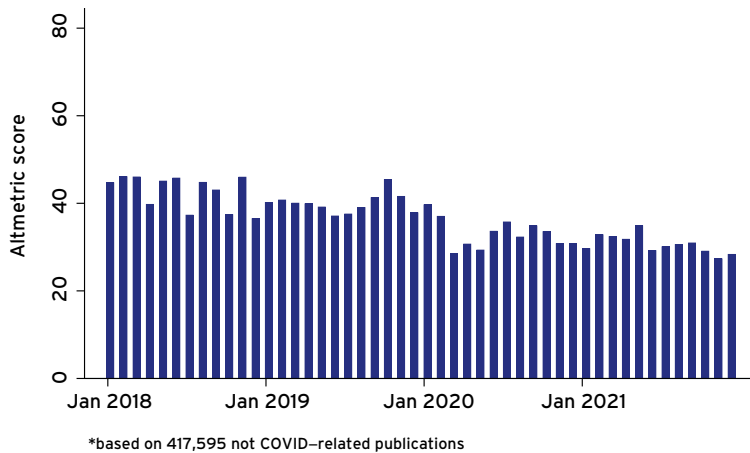


FIGURE 2C AVERAGE ALTMETRIC SCORE FOR 417,595 NON-COVID-RELATED PUBLICATIONS FROM SELECTED JOURNALS AS OF FEBRUARY 2022



Changes in attention by field

The documented increase in attention to COVID-related research is likely not universal across scientific fields. Some disciplines in the life sciences, such as infectious diseases and public health, may have received more attention because the expertise germane to these fields is likely to inform the response to the COVID pandemic. It is also possible that other fields that are less relevant to addressing COVID have suffered from an erosion in attention as the pandemic unfolded.

Table 1 seeks to paint an early picture of possible attention shifts, ranking fields according to the attention gained versus lost. As might be expected, fields such as infectious diseases and public health, and also other fields relevant to COVID such as radiology and the respiratory system, experienced a substantial upward shift in the average attention received. Conversely, critical life science fields like surgery, toxicology or haematology received substantially reduced attention. The fact that the most pronounced erosion of attention coincides with little COVID-relevant research, compared to the sharp increase in attention to fields where the share of COVID-related research is high, suggests that certain fields could have been adversely affected by the immediacy of the pandemic.

TABLE 1 RELATIVE CHANGE IN ALTMETRIC SCORE ACROSS JOURNAL CATEGORIES FOR PUBLICATIONS FROM 2020 VERSUS 2019

| Journal category | Share COVID-related publications (2020) | % Change of Altmetric Score (2020 vs. 2019) | Journal category | Share COVID-related publications (2020) | % Change of Altmetric Score (2020 vs. 2019) |
|----------------------------------------------|-----------------------------------------|---------------------------------------------|------------------------------|-----------------------------------------|---------------------------------------------|
| Infectious diseases | 46% | 282% | Toxicology | 3% | -45% |
| Public environmental & occupational health | 29% | 256% | Psychology experimental | 0% | -44% |
| Otorhinolaryngology | 11% | 196% | Hematology | 6% | -27% |
| Medicine general & internal | 35% | 164% | Physiology | 8% | -27% |
| Immunology | 19% | 148% | Biochemical research methods | 4% | -22% |
| Veterinary sciences | 7% | 135% | Parasitology | 2% | -22% |
| Biochemistry & molecular biology | 17% | 126% | Genetics & heredity | 3% | -18% |
| Respiratory system | 22% | 116% | Nutrition & dietetics | 3% | -17% |
| Radiology nuclear medicine & medical imaging | 10% | 83% | Surgery | 14% | -16% |
| Nursing | 12% | 77% | Environmental sciences | 1% | -15% |

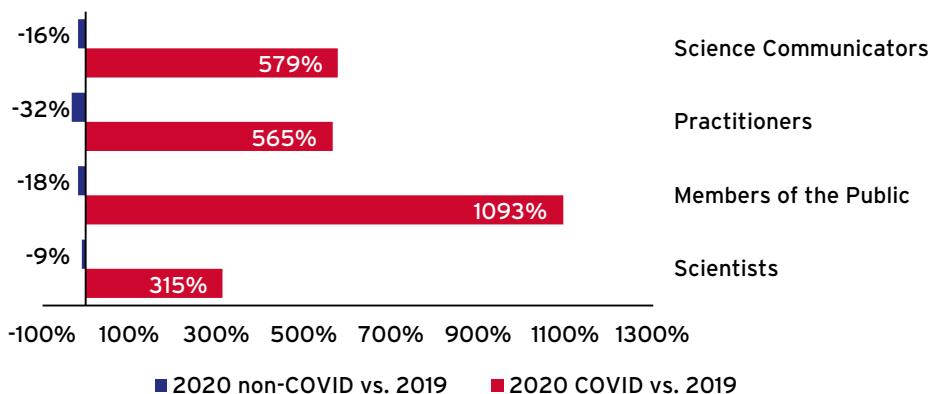
Notes: The left panel shows the ten fields with the largest relative increase and the right panel shows the ten fields with the largest relative decrease in the Altmetric score. There are 89 journal field categories in total. Four multidisciplinary categories and 19 other categories were excluded because of too few observations in the sample period (<200 publications in 2019).

Source of attention

To better understand these shifts in attention, it is important to detect where the changes emerge from. If the heightened attention to COVID research stems mostly from the broader public, then these shifts in attention may represent an increase in the diffusion rate of research findings. In other words, more people become generally aware of new research findings related to COVID. On the other hand, if the additional attention also stems from more specialised audiences, such as policy bodies or fellow scientists, this may lead to a greater rate of knowledge recombination (i.e., this research would not only be noted but also integrated more broadly into research, innovation and policy).

To evaluate the relative merit of these accounts, we decompose the Altmetric score for a granular analysis of the origin of the respective attention. For example, Twitter users referring to a new publication can be assigned to certain demographics, such as scientist or member of the public. Figure 3 shows that the increased attention to COVID-related publications stems markedly from an increase in references from members of the public. However, practitioners, science communicators and scientists also contributed to the heightened attention to COVID research. Interestingly, compared to the increase in attention to COVID-related publications, the relative decrease in the number of tweets referring to non-COVID research was higher for practitioners, science communicators and members of the public than for scientists, among whom attention to non-COVID research nevertheless decreases (Figure 3). One possible explanation is that the crowding-out effect due to the dominance and ubiquity of COVID research led to less discussion about non-COVID research among scientists on social media.

FIGURE 3 RELATIVE CHANGE IN THE NUMBER OF TWEETS REFERRING TO (NOT) COVID-RELATED RESEARCH IN 2020 RELATIVE TO 2019 BY DEMOGRAPHIC GROUP



Notes: The top blue bar, for example, implies a 16% decrease in the number of tweets by Science Communicators referring to not COVID-related publications in 2020 as compared to publications in 2019. The top purple bar indicates a 5.79-fold increase in the number of tweets by Science Communicators referring to COVID-related research in 2020 as compared to publications in 2019.

DISCUSSION, OUTLOOK AND CONCLUSION

In seeking responses to the COVID pandemic, society leaned heavily on contributions of the scientific community. Vaccines were conceived, approved and brought to market at warp speed. Beyond this eminent achievement, science informed policy responses at a new scale (Yin et al. 2021), and played a major role in public education that fostered societal support for, in part, drastic interventions (Bavel et al. 2020).

Yet, as science influenced the course of the pandemic, so did the pandemic impact scientific research. Entire scientific communities devoted most of their resources to furthering our understanding of the causes and consequences of the pandemic, possibly de-prioritising existing or future projects (Gao et al. 2021). New collaborations were formed internationally that produced evidence on COVID at speed and scale (Zastrow 2020).

Against this backdrop, our chapter explores a different angle to the impact COVID might have on scientific research – a shift in attention to and away from certain content – with potential longer-term consequences. Comparing the attention to pre- and post-COVID publications from different interest groups, we provide evidence for the immediate impact of COVID on the direction of scientific research. Overall, we document an increase in attention to scientific publications with the onset of COVID, based on comparing the average Altmetric score of articles published prior to versus during the pandemic. If this heightened level of attention were to persist and all articles – COVID-related or otherwise – were to benefit, then the scientific research enterprise would stand to benefit collectively. Our early evidence, however, suggests otherwise. Altmetric data indicate that COVID-related research received a stable ten-fold difference in average attention relative to research unrelated to COVID. In fact, attention to non-COVID research appears to have declined in the first two years after the outbreak of the pandemic.

Of course, it is too early to firmly evaluate if this diversion in attention will endure. There may be fields that will experience a lasting reduction in attention. Sustained attention erosion can take at least two forms, with different long-term implications. If scientific fields lose attention, primarily from the broader public, then those fields may suffer from fewer resources, including less public funding. If the scientific community shifts attention away (as well), scientists in some fields may find it difficult to build cumulative knowledge for innovation. Publications go unnoticed if they are not immediately spotted because new articles follow constantly. This can delay innovation or even prevent it in the long run. Studying long-term effects is an important task for future research.

Overall, our results suggest that changes are occurring. However, this is not to say that the developments will disadvantage non-COVID fields. A concentration of attention and resources on certain areas is not necessarily harmful; such a concentration may well

have positive effects across fields of science. The advancement of the mRNA vaccine technology, for example, can pave the way for broader applicability, from vaccines against other infectious diseases to immuno-oncology.

In conclusion, the science community marshalled resources in an unprecedented way to respond to the COVID pandemic. The resulting focus may have longer-term consequences for what research receives attention and, ultimately, how scientific research may translate into innovation and societal progress more broadly.

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CHAPTER 14

COVID-19 and clinical trials

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COVID-19 AND CLINICAL TRIALS | KYLE

INTRODUCTION

The COVID-19 pandemic spurred a race for treatments and vaccines in both the public and private sectors. The appropriate use of these treatments depends critically on medical evidence supporting their safety and efficacy. In the absence of this evidence, patients may be harmed either directly (because they receive a treatment that is dangerous or ineffective) or indirectly (because they do not receive a more appropriate or effective treatment). In addition, the use of ineffective treatments consumes resources that could be more productively deployed elsewhere.

In general, the clinical trials that generate this information are expensive to conduct, and running these trials is a large component of research and development (R&D) spending on drug development. The design of these trials is an important determinant of the quality of the information they yield. The case of ivermectin, an antiparasitic drug discovered more than 40 years ago, provides a useful illustration. After laboratory experiments suggested that it might be effective against COVID-19, its use was promoted in social media outlets and by some doctors. Many small clinical trials also yielded results that were interpreted as ivermectin significantly lowering the risk of death, and sales of ivermectin soared.¹ Unfortunately, closer scrutiny of those trials (Hill et al. 2021) and results from a much larger trial (Reis et al. 2022) indicate that there is no evidence that ivermectin is a useful treatment for COVID.

This chapter summarises the clinical trial landscape for COVID-19 interventions. I begin by comparing COVID-related trials to those related to other diseases. Because of the extraordinary efforts by governments to find solutions to the pandemic, I next examine differences between the public and private sector in the level and design of clinical trials. The types of interventions tested for COVID – treatments versus vaccines, and new molecules versus those in use for other diseases – are then discussed. Finally, I describe the characteristics of industry sponsors involved in COVID trials.

¹ "Ivermectin Doesn't Help Covid, But Generic Drug Makers Are Cashing In," *Bloomberg Business Week*, 13 October 2021.

DESCRIPTION OF CLINICAL TRIALS

Clinical research to assess medical outcomes in human subjects encompasses observational studies, in which individuals are observed over time but not prospectively assigned to an intervention or treatment group, and clinical trials, which aim to evaluate the effects of a pharmaceutical, surgical, medical device or behavioural intervention. Clinical trials for pharmaceuticals and vaccines are conducted in three phases. Phase I tests an intervention (drug, vaccine, etc.) in a small group of healthy people, primarily to evaluate safety and side effects. Phase II trials are larger, with the aim of estimating the effectiveness of an intervention. Phase III trials involve even more patients, often from different populations and tested with different dosages or combinations ('arms' of the trial). Positive results from Phase III trials are a key element of obtaining regulatory approval to market a new treatment. As such, industry has more interest in sponsoring interventional trials than observational trials. Following approval, Phase IV trials may be conducted to monitor safety and efficacy over a longer time horizon or in more diverse populations than initially considered in earlier phases. In general, the cost of trials increases with its size and length.

Clinical trials are sponsored by a variety of organisations, including government agencies, non-profit institutions, academic medical centres and industry (drug developers or manufacturers). The sponsor designs the study, obtains funding and monitors the collection of data and procedures used during the clinical trial. Studies that are randomised and blinded are generally considered high quality, as these designs are well-suited for evaluating causal relationships and minimise the risk of bias. Studies with high enrolment and with multiple arms are more likely to generate statistically valid results and to allow exploration of nuanced treatment effects. However, randomised, blinded and multi-arm trials are more complex and expensive to conduct. Throughout this chapter, I refer to any trial without an industry sponsor as 'public' research.

DATA

I use the publicly available information from the US government's registry of clinical trials, clinicaltrials.gov, maintained by the National Library of Medicine (NLM).² Since 2000, US regulations have required that all Phase II and higher trials be registered on this site, in order to help patients find trials in which they might participate. Registration of trials increased markedly in 2005 following the joint decision of the editors of major medical journals to publish results of clinical trials only if they had been registered. While other registries exist, including in Europe, there is substantial overlap in the trials included in them. A key advantage of clinicaltrials.gov relative to other registries is the ease in downloading and classifying trials. The underlying data are provided

² <http://clinicaltrials.gov>

by the trial sponsor, and many fields are not standardised or verified independently. Despite imperfect compliance with registration requirements, this registry provides a good overview of clinical activity over time, and has been used in a number of academic studies (among others, Budish et al. 2015, Agarwal and Gaule 2022).

The tables below draw on the entire clinicaltrials.gov registry as of 10 March 2022. In general, I rely on the coding of variables native to the registry. For example, each trial includes a field for whether it is industry-sponsored, its phase, its location, and so on. While trial sponsors also provide information on the disease targets and the names of the interventions used, these are not standardised. An intervention may be listed under its generic name, a brand name or a lab code. Similarly, diseases or conditions may be known under many terms, and vary in their specificity. I therefore use the search tools provided by the clinicaltrials.gov API to identify trials concerning COVID-19 and other diseases as well as interventions.³ These tools exploit the NLM's Medical Subject Headers (MeSH).

ANALYSIS

1) COVID trials differ markedly from non-COVID trials.

I begin with a simple comparison of trials associated with COVID-19 to all others, presented in Table 1. The unit of analysis is a trial, and the counts and means of variables capturing trial characteristics are in the rows.

COVID-related trials number 7,667, less than 2% of the total 407,244 registered but about 10% of all trials started after the beginning of 2020. The public sector is responsible for most registered clinical trials, and even more present in COVID trials: while about one-quarter of non-COVID trials are industry-sponsored, only about 17% of COVID trials have industry participation. COVID trials are also less likely to be interventional, or designed to test a drug, vaccine or procedure. Non-interventional or observational trials comprise only about a quarter of non-COVID registered trials, but almost half of COVID trials. Because observational trials are more likely to be conducted by public sponsors, these patterns are consistent with efforts by academic medical centres and other hospitals to collect and analyse observational data, with the hope of understanding the disease better even if not testing a specific intervention. It is also possible that COVID observational studies were more likely to be registered than non-COVID studies, if researchers were motivated to share and diffuse information more broadly due to the urgency of the pandemic.

3 [Clinicaltrials.gov](https://clinicaltrials.gov) defines a trial as COVID-related based on synonyms for COVID (SARS-CoV-2, coronavirus disease, etc.) in the condition field.

TABLE 1 COMPARISON OF TRIALS

| | | Non-COVID trials | COVID trials |
|-------------------------------|------|------------------|--------------|
| Industry-sponsored | No. | 399,577 | 7,667 |
| | Mean | 0.24 | 0.17 |
| Interventional | No. | 399,577 | 7,667 |
| | Mean | 0.78 | 0.56 |
| Blinded, if interventional | No. | 311,206 | 4,318 |
| | Mean | 0.45 | 0.49 |
| Randomized, if interventional | No. | 311,206 | 4,318 |
| | Mean | 0.65 | 0.73 |
| Phase I, if interventional | No. | 311,206 | 4,318 |
| | Mean | 0.17 | 0.15 |
| Phase II, if interventional | No. | 311,206 | 4,318 |
| | Mean | 0.22 | 0.32 |
| Phase III, if interventional | No. | 311,206 | 4,318 |
| | Mean | 0.13 | 0.20 |
| Phase IV, if interventional | No. | 311,206 | 4,318 |
| | Mean | 0.09 | 0.06 |
| Number of arms | No. | 342,876 | 6,368 |
| | Mean | 2.09 | 2.33 |
| Number of trial sites | No. | 354,829 | 6,991 |
| | Mean | 7.38 | 4.46 |
| Number of trial countries | No. | 354,815 | 6,991 |
| | Mean | 1.50 | 1.23 |
| Number of collaborators | No. | 132,353 | 2,725 |
| | Mean | 1.80 | 2.53 |
| Trial enrollment | No. | 392,850 | 7,631 |
| | Mean | 4791.22 | 36024.81 |

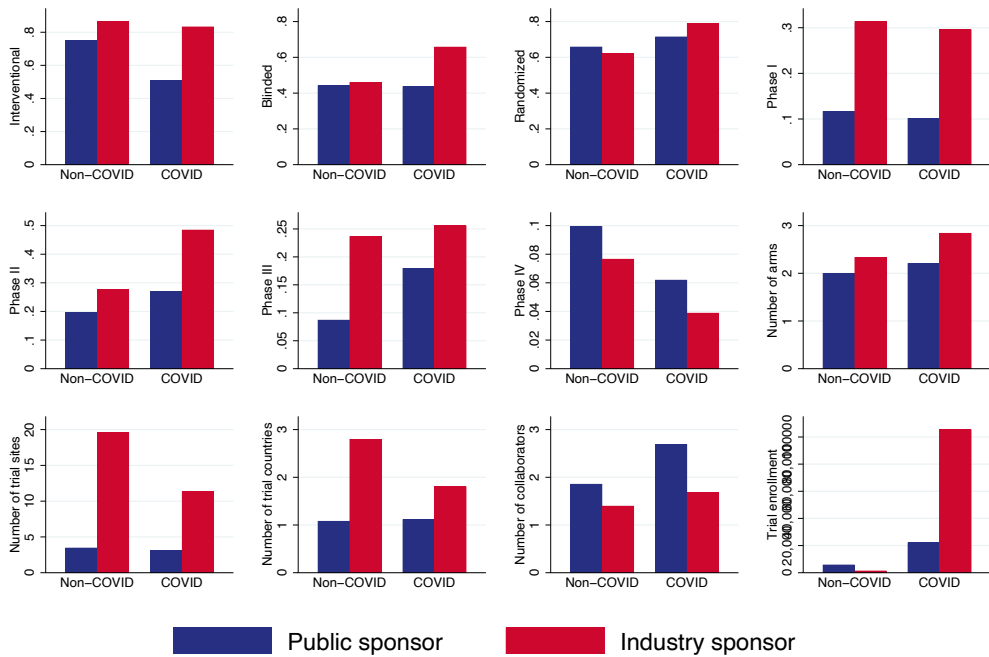
Restricting the sample to interventional trials, COVID research displays other notable differences. COVID interventional trials are more likely to be blinded and randomised, and have a higher number of arms. These are indicators of the complexity of study design and the cost of a trial. While COVID trials involve fewer trial sites and countries, they are substantially larger in terms of patient enrolment, and also involve more collaborators. Registered interventional COVID trials are more likely to be in Phase II and III of clinical development than are non-COVID trials.

2) Differences between COVID and non-COVID trials are larger for industry than for the public sector.

Public sector research is important in many diseases. The ‘war on cancer’ beginning in the 1970s and the response to HIV in the 1980s are two examples. However, the mobilisation of public money in response to COVID was especially pronounced. Because of its speed, in particular, one concern is that the quality of the publicly funded research may have suffered as funding agencies had little time to vet applications. In addition, regulators may (or industry may have expected regulators to) have opted for speed over quality in evaluating treatments for a pandemic, which could have changed the choices of trial design by industry in its pursuit of COVID treatments and vaccines.

I next turn to a comparison of industry and non-industry trials in COVID clinical research with research on other diseases. For each trial characteristic, in Figure 1 I present the mean for public sponsors (in blue) and industry sponsors (in red), for non-COVID and COVID-related trials.

FIGURE 1 COMPARISON OF COVID TRIALS BY TYPE OF SPONSOR



A number of differences between public sponsors and industry sponsors are evident when looking at non-COVID trials. Not surprisingly, industry is more likely to be involved in interventional trials; while observational studies may generate valuable information, that information is a public good and unlikely to yield profits for a firm. In particular, regulators generally do not accept data from observational studies as sufficient evidence for granting marketing authorisations. Industry-sponsored trials are more likely to be

blinded, have more arms and involve more trial sites and countries. These are all factors that are linked to higher costs. However, public trials involve more collaborators, have higher patient enrolment (which may reflect greater sponsorship of observational trials, which are often larger) and are more likely to be Phase IV (conducted after a marketing authorisation has been granted). In other words, the differences in trial characteristics between the public sector and industry reflect their different missions and audiences. While industry trials are designed for regulatory approval, public trials often provide evidence that is harder to appropriate.

Differences between COVID and non-COVID trials conducted by the public sector are less pronounced. However, public COVID trials are less likely to be interventional, more likely to be randomised, have more trial arms, involve more collaborators and have higher enrolment than public non-COVID trials. These patterns are consistent with interventional COVID trials in the public sector being more expensive to conduct than those for non-COVID conditions, despite the time pressures to organise and implement COVID trials as quickly as possible. Significant government funding for these trials may also have contributed, not just in the number of trials but also in the quality.

Relative to non-COVID trials sponsored by industry, industry COVID trials are more likely to be interventional, as well as be randomised and blinded, with more arms. While they have relatively higher enrolment, they involve fewer sites, countries and collaborators. These differences are not present for public trials: indeed, public trials for COVID involve more collaborators than for non-COVID. Perhaps the ease in finding trial participants during a pandemic allows firms to run more geographically concentrated trials, or the urgency to obtain results as quickly as possible leads firms to design trials with a lower organisational burden of coordinating across many sites, countries or collaborators.

3) COVID trials, like those initiated just prior to the pandemic, used treatments previously employed in many other trials and over many years.

I turn now to the characteristics of the interventions used in clinical trials. Because the information on interventions is provided by trial sponsors, it does not use a consistent vocabulary or naming convention for the interventions tested. For example, the Pfizer/BioNTech COVID vaccine can appear as “Pfizer/BioNTech COVID vaccine”, variations of “BNT162”, or “COMIRNATY” in the intervention field. However, the NLM does attempt to assign MeSH terms to trials, including MeSH terms for interventions, and I use these NLM-assigned MeSH headers to identify treatments. Unfortunately, COVID vaccine candidates and some very new drugs do not have associated MeSH headers at the time of this writing.

For comparison, I consider the interventions tested in non-COVID trials initiated during 2018–19, the two-year period prior to COVID, to the interventions tested in trials identified as COVID-related from 2020–2021. By focusing on the immediate period prior to COVID, I hope to avoid confounding effects of policy changes or significant shifts in

science. I select all trials involving a drug or biologic that are COVID related (“COVID trials”) or that began in 2018–19 (“pre-COVID trials”). I then take the list of MeSH terms assigned to the interventions in both groups and look for other trials with the same MeSH term to determine the recency of the intervention in clinical trials, its use by industry and non-industry sponsors, and the number of conditions for which it has been tested in trials.

To provide a sense of what types of interventions were being explored or used in clinical trials before the pandemic, I show in the first column of Table 2 a summary of the interventions tested in 2018–19. For each characteristic, I show both the mean and median because the distributions are often highly skewed. The pre-COVID interventions were, on average, used in about 170 industry-sponsored trials and 420 non-industry trials in the entire registry, and in trials involving an average of about 138 different conditions. Almost 40% of these interventions were at least 20 years old, having first appeared in a registered trial prior to 2000. This suggests that a significant share of these interventions are off-patent and easily accessible for use in clinical trials. Very new interventions, appearing in a registered trial for the first time in 2016 or later, account for only about 10% of the pre-COVID interventions tested in 2018–19 trials. Some of these interventions were subsequently tested for use with COVID in a mean of roughly two industry-sponsored COVID trials and about eight non-industry COVID trials.

TABLE 2 COMPARISON OF INTERVENTIONS BASED ON MESH

| | | Non-COVID interventions | COVID interventions |
|-------------------------------------------|--------|------------------------------------|--------------------------------|
| Number of industry-sponsored other trials | Mean | 199.09 | 340.07 |
| | Median | 28 | 62 |
| Number of non-industry other trials | Mean | 495.68 | 806.68 |
| | Median | 65 | 152 |
| Number of industry-sponsored Covid trials | Mean | 2.33 | 6.76 |
| | Median | 0 | 0 |
| Number of non-industry Covid trials | Mean | 9.70 | 26.33 |
| | Median | 0 | 3 |
| Number of conditions for which tested | Mean | 157.98 | 246.79 |
| | Median | 56 | 108 |
| Intervention more than 20 years old | Mean | 0.43 | 0.70 |
| | Median | 0 | 1 |
| Intervention less than 5 years old | Mean | 0.08 | 0.02 |
| | Median | 0 | 0 |

The second column of Table 2 presents the corresponding statistics for the interventions used in a COVID-related trial. These were tested in more COVID trials than the pre-COVID interventions, with a mean of nine industry-sponsored trials and a mean of 36 non-industry COVID trials. These same interventions were also used in a large number of non-COVID trials, and to an extent greater than the non-COVID interventions of 2018–19: about 450 industry-sponsored non-COVID trials and 1,028 non-industry sponsored trials. The COVID interventions are also more likely to be more than 20 years old, and only 2% of the COVID interventions with MeSH terms were first tested in 2016 or later. These patterns suggest that researchers turning to COVID employed many interventions for which substantial evidence already existed, at least concerning safety.

Both the pre-COVID and COVID interventions show that very new treatments comprise a small share of those tested. The prevalence of ‘old’ drugs in trials can reflect either the search for a new use of an existing therapy (‘repurposing’; see Chong and Sullivan 2007), or their use as ‘standard of care’ in a non-experimental arm of the trial. Some high-profile examples of the former include hydrochloroquine and ivermectin, but many more were screened beginning soon after COVID’s spread.⁴ These older therapies may be less costly to test if they are widely available as generic drugs, as well as appealing to governments because if effective, less costly to procure. Unfortunately, it is difficult to identify easily whether the intervention associated with the MeSH term was used in the experimental arm(s) of a trial or the control arm.

As noted above, the use of MeSH headers has some limitations. An alternative is to examine the list of 77 treatments identified by metaCovid.⁵ Vaccines names are recorded in clinicaltrials.gov very inconsistently, and it is not possible to identify specific vaccine candidates reliably. I therefore restrict this analysis to non-vaccine interventions. While I do not have a similar list of non-COVID treatments to compare to, I can nevertheless provide some information on the characteristics of these drugs.

These results are presented in Table 3. Industry-sponsored trials are less prevalent in this sample than in the overall registry, reflecting the greater share of vaccines among industry-sponsored trials. Older treatments are used in a higher number of both industry and non-industry trials, and COVID and non-COVID trials. However, there appears to be some effort by industry to repurpose relatively new drugs for COVID; a number of antiretrovirals and monoclonal antibodies are in this category. For example, the monoclonal antibody avdoralimab, developed by Innate Pharma, was tested for advanced solid tumours in a trial beginning in 2018; it was subsequently tested for severe COVID in 2020. Remdesivir, developed for Hepatitis C by Gilead Sciences, received emergency authorisation for use on COVID patients in October of 2020.

4 “Old Drugs May Find a New Purpose: Fighting the Coronavirus,” *New York Times*, 30 April 2020.

5 <https://covid-nma.com/metacovid>

TABLE 3 COMPARISON OF INTERVENTIONS IDENTIFIED BY metaCOVID

| | | First trial before 2000 | First trial 2001-2015 | First trial after 2016 |
|-------------------------------------------|--------|----------------------------|--------------------------|---------------------------|
| Number of industry-sponsored other trials | Mean | 262.86 | 59.79 | 0.81 |
| | Median | 140 | 18 | 0 |
| Number of non-industry other trials | Mean | 688.73 | 61.79 | 0.31 |
| | Median | 329 | 14 | 0 |
| Number of industry-sponsored Covid trials | Mean | 5.08 | 2.21 | 4.88 |
| | Median | 2 | 1 | 2 |
| Number of non-industry Covid trials | Mean | 44.68 | 16.88 | 14.12 |
| | Median | 15 | 6 | 4 |
| Number of conditions for which tested | Mean | 305.76 | 46.79 | 1.19 |
| | Median | 203 | 26 | 0 |

4) Half of the industry sponsors of COVID-related trials were new to clinical research, but experienced firms conducted more COVID trials.

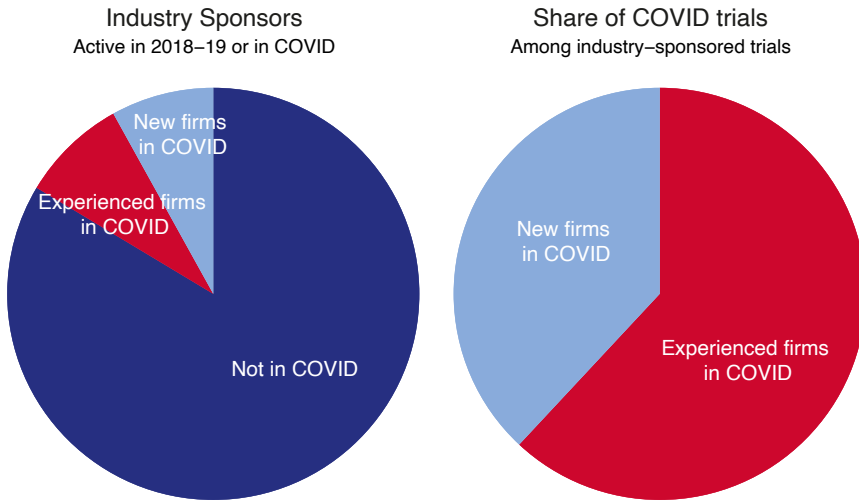
Prior work has shown that firm scale and scope can be an advantage in drug development, at least in later stages, though smaller and younger firms have contributed to many of the pharmaceutical innovations commercialised in recent decades. The COVID crisis created a need for both new ideas and rapid development. In this section, I provide some descriptive statistics on the types of firms that engaged in COVID research.

I create three samples: industry sponsors that started at least one clinical trial in 2018–19, but not in COVID; industry sponsors that started at least one clinical trial in 2018–19 and in COVID; and industry sponsors newly active in COVID. Figure 2 presents the number of firms in each sample, and the number of COVID trials each sample conducted. In all three, I consider only the lead sponsor listed for a trial. I make no attempt to correct for spelling differences or subsidiaries. For each industry sponsor as recorded in the registry, I determine their experience with clinical trials and the types of clinical research they engage in. These characteristics, with their means and medians for each sample, are shown in Table 4.

TABLE 4 COMPARISON OF INDUSTRY SPONSORS

| | | Active 2018-19, not in COVID | Active 2018-19 and in COVID | Newly active in COVID |
|-------------------------------------------------------|--------|------------------------------|-----------------------------|-----------------------|
| Years since first trial | Mean | 7.69 | 10.44 | 3.71 |
| | Median | 5 | 8 | 2 |
| Years since first trial | Mean | 0 | 2.27 | 1.41 |
| | Median | 0 | 1 | 1 |
| Number of non-COVID trials | Mean | 10.86 | 90.79 | 1.87 |
| | Median | 4 | 8 | 0 |
| Number of conditions | Mean | 7.41 | 28.63 | 2.57 |
| | Median | 4 | 9 | 0 |
| Number of trials for basic science | Mean | 0.34 | 5.13 | 0.01 |
| | Median | 0 | 0 | 0 |
| Number of trials for diagnostics | Mean | 0.23 | 0.73 | 0.03 |
| | Median | 0 | 0 | 0 |
| Number of trials for preventative interventions | Mean | 0.31 | 6.36 | 0.34 |
| | Median | 0 | 0 | 0 |
| Number of trials for treatments | Mean | 7.33 | 60.82 | 1.19 |
| | Median | 2 | 5 | 0 |
| Number of trials using drugs | Mean | 8.71 | 83.81 | 1.04 |
| | Median | 1 | 4 | 0 |
| Number of trials using biologics | Mean | 0.93 | 13.79 | 0.57 |
| | Median | 0 | 0 | 0 |
| Number of COVID trials for basic science | Mean | 0 | 0.04 | 0.01 |
| | Median | 0 | 0 | 0 |
| Number of COVID trials for diagnostics | Mean | 0 | 0.03 | 0.09 |
| | Median | 0 | 0 | 0 |
| Number of COVID trials for preventative interventions | Mean | 0 | 0.66 | 0.31 |
| | Median | 0 | 0 | 0 |
| Number of COVID trials for treatments | Mean | 0.01 | 1.22 | 0.70 |
| | Median | 0 | 1 | 1 |
| Number of COVID trials using drugs | Mean | 0.01 | 1.21 | 0.58 |
| | Median | 0 | 1 | 0 |
| Number of COVID trials using biologics | Mean | 0.01 | 0.84 | 0.42 |
| | Median | 0 | 0 | 0 |

FIGURE 2 COMPOSITION OF INDUSTRY SPONSORS



More than 3,800 firms started at least one trial in the immediate pre-COVID period of 2018–19. Of these, 340 launched COVID-related trials. Compared to other firms that were active in clinical research in the immediate pre-COVID period, those that initiated COVID trials are relatively more experienced: they had an average of almost three years’ additional experience in clinical research and had sponsored many more trials – with twice the median number of trials as those firms that did not move into COVID. These patterns suggest that prior experience, such as existing relationships with clinicians and familiarity with the challenges of designing trials and recruiting patients, may have been an advantage in responding to demand for COVID treatments.

However, there are about the same number of new entrants – firms that did not start a clinical trial in 2018–19, but did start COVID trials – as ‘experienced’ COVID firms. While some also sponsor trials for non-COVID conditions, their focus appears to have been treatments for the pandemic. The median number of COVID trials sponsored by new entrants is one, the same as for the experienced entrants, though the latter have a larger mean. The entrants have a higher presence in diagnostics (though the number of COVID trials for diagnostics is very small for both types of firms).

CONCLUSION

The COVID crisis and the extraordinary commitment of public funds to addressing it triggered an explosion of clinical research. Some of this research was directly supported with public funding, which also contributed to fundamental research that ultimately resulted in novel vaccines (Mugabushaka 2021, Kiszewski et al. 2021). Purchase commitments through programs such as Operation Warp Speed in the US also motivated industry to invest significant resources in developing treatments.

This chapter provides some detail about this response. Other work has examined how science responded to the COVID pandemic using data on scientific publications (Jones et al. 2022), and the magnitude of the response to COVID relative to its estimated market size (Agarwal and Gaule 2022). I show that COVID clinical research differs from that for other diseases in a number of ways. It has a larger presence of non-industry sponsors, as well as a larger share of observational studies. For interventional trials, the study design is of slightly higher quality – that is, more likely to be randomised and blinded – whether sponsored by industry or not. The use of older, established treatments is particularly widespread. About half of the firms that started COVID-related clinical trials are relatively new to drug development, although experienced drug developers sponsored more clinical trials for COVID.

While there have been some obvious successes, most notably in vaccines, it is still too early to assess the average performance of COVID clinical trials as measured by progression through trial phases. Further study is also warranted to understand how the results of COVID trials influence clinical practice. For example, is the use of treatments equally influenced by suggestive but weak evidence from a trial without randomised assignment as by well-designed trials? Finally, an empirical examination of the role of government funding of COVID trials, and how this varies across countries, may be informative for the development of science and innovation policy going forward.

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CHAPTER 15

The new mRNA breakthrough technology for vaccines: A lucky shot?

Reinhilde Veugelers

KULeuven and CEPR

mRNA TECHNOLOGY: A GAME CHANGER

The development, approval and availability of mRNA vaccines has been one of the great achievements in society's battle with COVID-19. This achievement is especially remarkable because mRNA is a novel technology for the production of human vaccines and human drugs more generally. Rather than putting weakened or inactivated viruses, or components of them, into our bodies, *synthetic* mRNA-based vaccines teach our cells how to make a protein – or even just a piece of a protein – that triggers an immune response.¹ The ability of mRNA vaccine developers to design antigens *in silico* allows for much faster testing of vaccine candidates, compared to the conventional technologies. The production of synthetic mRNA vaccines can also be more easily standardised and scaled. mRNA technology is seen as game changer not only for the current pandemic, but also for future development and production of vaccines against other infectious diseases. Furthermore, mRNA has the potential to transform many other areas of medicine, including cancer and rare diseases.

In this chapter, we ask whether the stellar performance of mRNA technology in the COVID-19 pandemic was to be expected/in the making, or if we were lucky this time. Can we trust the bio-medical innovation ecosystem to deliver breakthroughs like mRNA? Can we trust our public policy innovation system to support a novel technology like mRNA?²

mRNA FOR DRUG DEVELOPMENT: A LONG AND BUMPY ROAD

mRNA technology did not come out of the blue. The fast and successful development of the mRNA COVID-19 vaccine should be considered as the outcome of a long and bumpy process of accumulation of innovation capacity over time, which had reached sufficient maturity at a key moment when researchers could mobilise the technology they had been

1 From the genetic sequence of a pathogen, a potential antigen-encoding segment is identified. Its corresponding RNA is synthesised. The synthesised sequence is packaged into an RNA carrier (typically lipid nanoparticles, or LNP) to be deliverable into the body. Once in the body, cells receive instructions to make copies of the protein. The human body recognises that the protein should not be there and builds T-lymphocytes and B-lymphocytes that remember how to fight the target virus when infected in the future. For more on mRNA for vaccines, see for example Dolgin (2021).

2 A more elaborate assessment of the mRNA technology for vaccines can be found in Veugelers (2021).

developing for many years to fight the novel coronavirus. A decade or more of research by many scientists helped inform the development of SARS-CoV-2 vaccines using the technology (e.g. Dolgin 2021).

The discovery of mRNA was reported in *Nature* in 1961; the path to synthesise mRNA in a test tube in 1984. By 1990, it was demonstrated that the injection of synthetic mRNA into animals led to the expression of the encoded protein, which opened the path for this system to be used to turn human bodies into medicine-making factories. Yet, there remained critical problems. In vitro-transcribed mRNA could be destroyed by the body fielding an immune response, or it could cause serious side effects. No one knew how to make mRNA safe and effective in animals, let alone humans. In the 1990s and much of the 2000s, conventional wisdom among scientists and interested companies was that mRNA was too tricky and risky.

In 2005, a breakthrough occurred in applying mRNA technology for human drugs, when Katalin Karikó and Drew Weissman, discovered that when they replaced one of mRNA's chemical building blocks – uridine – with a slightly modified nucleoside called pseudouridine, it could enter into cells without alerting the RNA sensors. Their research was published in *Immunity*, after being rejected by several leading journals. Though their breakthrough article is now extensively cited, and both researchers are highly recognised and the recipients of numerous prestigious prizes, Kariko had tried unsuccessfully for years to obtain research funding. Her research was considered too risky, as she could not show preliminary findings (e.g. Franzoni et al. 2022). Weissman was able to fund their early research with other research funding he had available.

The University of Pennsylvania filed and obtained patents on Karikó and Weissman's invention, then granted exclusive patent rights to Cellscript, a small company in Madison, US, that produced lab reagents. Karikó and Weissman started their own company, RNARx. However, RNARx did not manage to secure a licensing agreement with Cellscript and ceased operations in 2013. A few other scientists-entrepreneurs picked up on their findings. A team led by Derrick Rossi used the pseudouridine mRNA approach to successfully transform skin cells. In 2010, Rossi co-founded Moderna. Ingmar Hoerr, with a PhD on mRNA vaccines from the University of Tübingen, had already founded Curevac together with his supervisors in 2000. Ugur Sahin and his wife Ozlem Tureci, at the University of Mainz in Germany, also began studying mRNA technologies in the late 1990s for application in cancer drugs. They started BioNTech in 2007. In 2013, Karikó became senior vice president at BioNTech. Cellscript licensed non-exclusively to BioNTech and Moderna. CureVac did not use the stabilisation through pseudouridine approach, and therefore did not need a license of the University of Pennsylvania patent.

Pre-COVID-19, these and a handful of other young biotech firms were actively developing mRNA-based drugs. They were working on infectious diseases, but also covering a wider set of applications.³ No mRNA-based human drug projects had reached the market yet.

THE FIRMS BEHIND THE mRNA COVID-19 VACCINES: YOUNG BIOTECH WITHIN THE WIDER BIOPHARMA ECOSYSTEM

Pre-COVID-19

Pre-pandemic, the global vaccines market was highly concentrated, with four big vaccine producers – GSK, Merck, Sanofi and Pfizer – jointly accounting for about 90% of global vaccine revenues in 2019 (Statista 2021). Johnson & Johnson entered the vaccines market only recently. Novartis was previously one of the leading vaccine companies, but left the vaccines market in 2018 when it sold most of its vaccine business to GSK. This high concentration in four big players reflects the importance of scale for vaccine technology, production, and distribution capacity. Clinical trial expertise, brand name, and deep financial pockets are other major advantages for big pharma.

In the early 2000s, the four leading incumbent vaccine producers had the mRNA technology on their radar, but were not actively developing mRNA vaccine projects. Their own development projects used the incumbent viral vector or protein-based technologies. With mRNA being a new, risky, disruptive technology for vaccine development (and drugs in general), it is unsurprising that new players, rather than the incumbent vaccine producers, were the first movers to develop this disruptive technology for infectious diseases. Nevertheless, some of the leading incumbents engaged in cooperative agreements with young mRNA biotech firms.⁴

COVID-19

As soon as the genetic code of the novel coronavirus became public in January 2020, the young biotech firms were very quickly willing and able to use the mRNA platforms they had been developing to work on a COVID-19 vaccine.

BioNTech identified several candidates for a COVID-19 vaccine, ready to start clinical trials. In March 2020, it entered into a partnership with Pfizer to co-develop and co-commercialise one of its vaccine candidates (BNT162). BioNTech received an upfront payment from Pfizer, and future milestone payments were also agreed. The deal gave Pfizer the right to use BioNTech COVID-19 vaccine patents. They agreed to split any

³ Beyond Curevac, Moderna and BioNTech, there were also other mRNA start-ups, such as Translate Bio, a Massachusetts-based company founded in 2011, and Arcturion Therapeutics, a Californian company founded in 2013.

⁴ A team at the Novartis research hub in Cambridge, MA was working on RNA technology for vaccines in 2013. Novartis was at that time a leading vaccine producer. The project however never got traction. GlaxoSmithKline, which had acquired most of Novartis's vaccine assets, began evaluating an RNA-based rabies vaccine in 2019. Pfizer entered into a partnership in 2018 with BioNTech to develop flu vaccines based on BioNTech's mRNA platform. Also, Sanofi Pasteur, the global vaccines business unit of Sanofi, entered into a cooperation agreement in 2018 with Translate Bio to use the mRNA platform that the company had been developing.

possible revenues from a vaccine 50/50. Their partnership built further on their 2018 collaboration, combining BioNTech's mRNA vaccine technology and expertise with Pfizer's deep financial pockets, its clinical development and regulatory expertise, and its vaccine production capacity. The initial production of the BNT162 vaccine at small scale for the initial clinical trials was done in BioNTech and Pfizer facilities. For the larger-scale production of BNT162, however, Pfizer's production infrastructure in the US and Belgium was critical.

Moderna began developing a coronavirus vaccine on its mRNA platform in January 2020. Unlike BioNTech, Moderna did not cooperate with another (big) pharma partner. However, Moderna did engage in several strategic research and licensing agreements, including with Merck and AstraZeneca. For the large-scale manufacturing of its COVID-19 vaccine, it entered into agreements with contract manufacturing firms.

Curevac was also in a position to use its mRNA platform to quickly start developing a COVID-19 vaccine. Unlike BioNTech and Moderna, it chose to use an unmodified, self-replicating mRNA approach. Building on initial clinical trial successes, CureVac also started to prepare for production at large scale, setting up a series of partnerships with big pharma companies including Bayer, GSK and Novartis, and with contract manufacturing firms. In June 2021, however, CureVac reported disappointing CT₃ results. In October 2021, CureVac abandoned its mRNA vaccine project. It started working on a new COVID-19 vaccine, this time using unmodified mRNA in collaboration with GSK.

With the exception of Pfizer, who partnered with BioNTech, the major incumbent vaccine developers were, with their viral vector or protein platforms, late or unsuccessful movers in developing a vaccine for COVID-19.⁵ Johnson & Johnson, which had only entered the vaccine market recently, developed a COVID-19 vaccine with the viral vector technology. AstraZeneca, another big pharma company but one not specialised in vaccines, entered into an agreement with Oxford University to co-develop and commercialise Oxford's COVID-19 vaccine, which uses viral vector technology. The rollout of both vaccines has been turbulent (e.g. Veugelers 2021).

5 Merck had two COVID-19 vaccine projects, both of which it abandoned in January 2021. GSK joined forces with Sanofi to develop a COVID-19 vaccine based on Sanofi's protein-manufacturing platform, used for its seasonal flu vaccines, together with GSK's adjuvant platform. After poor CT_{1/2} results, they had to reconfigure their vaccine. With an improved antigen formulation, they are at the time of writing in CT₃. Alongside its joint project with GSK, Sanofi joined forces in June 2020 with TranslateBio to use the latter's mRNA platform to develop a COVID-19 vaccine. In September 2021, Sanofi fully acquired TranslateBio. At the end of September 2021, Sanofi announced it would drop its mRNA-based COVID-19 vaccine, because CT_{1/2} results, although positive, were not considered strong enough to compete with the mRNA vaccines already on the market.

Overall, it is fair to say that the pivotal actors behind the breakthrough performance of the mRNA technology for COVID-19 vaccines were young US and EU biotech firms.⁶ But this happened within a wider biomedical ecosystem with partners from academia, incumbent big pharma and biopharma services/production providers.

Post-Covid-19

The race for the next generation of mRNA vaccines and drugs is already underway (Rosa et al. 2021). With its characteristics as a platform plug-and-play technology, companies are trying to apply mRNA technology to other infectious diseases, rare diseases and, in particular, cancer. Now that mRNA has proved a viable commercial platform, other young biotech companies, but also big pharma, are jumping on the mRNA train. Several of the giants have aligned with young, small mRNA players for an array of mRNA collaborations. Big pharma is also carving out positions in the mRNA market by scouting for acquisitions of young, small mRNA companies. Early young pioneers now possess more leverage when forging deals with big pharma and other collaborators. In particular, their experience and technological know-how, protected through their patent portfolios, and their deeper own and more diversified external financial resources are important bargaining chips when entering into agreements with other players in the ecosystem.

THE FUNDERS BEHIND THE mRNA COVID-19 VACCINES

Public funding plays a substantial and critical role in vaccine development and production. Besides co-funding R&D projects, governments are the main purchasers of vaccines and can support vaccine R&D projects if they commit to buying before approval, through advance purchase agreements, at guaranteed prices, improving the risk/reward trade-off for vaccine R&D projects (e.g. Kremer et al. 2020). Yet, the funding stories of the young mRNA vaccine firms, BioNTech, Moderna and CureVac, demonstrate the importance of private funding, especially in the pre-pandemic, risky, early stages of development of the mRNA technology. Private venture capital, including corporate venture capital support from big pharma, philanthropy and public equity financing proved critical for these companies.

BioNTech

BioNTech's initial financing came from various private venture capital sources. The German Strüngmann brothers were early investors in BioNTech, and are currently the majority shareholder. BioNTech's 2018 partnership with Pfizer provided financing for the development of its mRNA platform (cf supra). And right before the outbreak of the

⁶ Beyond BioNTech, Moderna and Curevac, there are more than 20 projects in CT1 and/or CT2 using mRNA technologies to develop coronavirus vaccines, and more than 30 preclinical projects (i.e. about 20% of all coronavirus vaccine projects). A few projects in the early phases of development originate from outside the EU and US. China's Academy of Military Medical Sciences, jointly with Suzhou Abogen BioSciences, has an mRNA-based vaccine in late development (Veugeliers 2021).

pandemic, BioNTech raised \$150 million via its Nasdaq initial public offering (IPO). The Gates Foundation provided equity investment for BioNTech's mRNA-based HIV and tuberculosis vaccines.

Public funding for BioNTech prior to COVID-19 was limited. The ERC grant its founder, Sahin, received in 2018 was for his mRNA cancer research. The European Investment Bank (EIB) provided a €50 million loan in December 2019 for its work on cancer treatments. Public funding became more substantial after the pandemic outbreak, most notably from the German government and EIB loans. Advance purchase agreements also brought in substantial funding, split with Pfizer.

Moderna

Moderna received substantial public money in its early stage. A 2013 US Defence Advanced Research Projects Agency (DARPA) grant of up to \$25 million for developing mRNA-based therapeutics was small but critical, because of its early stage. In its early stage, Moderna also secured substantial venture capital funding from various sources. Unlike BioNTech, Moderna did not enter into co-development agreements with big pharma. Nevertheless, it benefitted from the deep pockets of big pharma through several corporate venture capital deals. Like BioNTech, it also went public with its December 2018 IPO on Nasdaq, raising \$600 million. Since the outbreak of the pandemic, it has received substantial public funding from DARPA and the Biomedical Advanced Research and Development Authority (BARDA). It ran its clinical trials in collaboration with the National Institute of Allergy and Infectious Diseases (NIAID). The returns made on its advance purchase agreements with the US and, later and to a smaller extent, with the EU also filled its financial pockets.

Curevac

In its early years, Curevac had to rely on private venture capital, initially mostly small amounts from friends and family. The most important early venture capital funding came from German billionaire Dietmar Hopp, who co-founded SAP. The Gates Foundation and Baillie Gifford (which also invested in Moderna) also jumped in as early equity investors. CureVac went for an IPO somewhat later than BioNTech and Moderna. 2020 turned out to be a good year for CureVac to attract public funding, following an apparent attempt by then US President Donald Trump to secure CureVac vaccine supplies. Equity investment from the German public development bank KfW, grant funding from the Federal Ministry of Education and Research (BMFB), debt financing from the EIB and the advance purchase agreement with the European Commission filled its coffers. It remains to be seen how its financing will evolve given that it had to abandon its mRNA vaccine. Its next coronavirus vaccine is being done jointly with GSK, which has also taken an equity stake in the company.

PUBLIC FUNDING

DARPA is frequently heralded for its success in funding high-risk breakthrough projects. Key to its success is attracting programme staff, who more resemble risk-taking, idea-driven entrepreneurs than administrators. Combined with high accountability and clear targets, programme directors have high individual discretion to design and select projects (Azoulay et al. 2019). DARPA recognised early on the high gain potential of mRNA technology and was willing to take on the risk of supporting the development of mRNA for vaccines. In 2012, it began funding groups at Novartis, Pfizer, AstraZeneca, Sanofi Pasteur and elsewhere to work on RNA-encoded vaccines and therapeutics. However, none of the big-name firms stuck with the technology. Only CureVac and Moderna continued, and DARPA provided \$33 million for CureVac in 2011 and \$25 million for Moderna in 2013. Although the DARPA amounts were small compared with the total funding portfolio of these companies, they were nevertheless important as they covered early-stage and highly risky projects in the firms' portfolios in their early lives.

At the outbreak of the COVID-19 pandemic, the US government set up an interagency partnership between BARDA and the Department of Defense, known as Operation Warp Speed (OWS). BARDA/OWS funded later-stage development, increases in manufacturing capacity and advance purchase contracts. With a total budget for vaccines committed up to August 2021 of about \$28 billion, most of this budget (about 70%) went to such advance agreement. About 70% of the BARDA/OWS vaccine budget went to Pfizer and Moderna.

A major new public-private funder dedicated to vaccine R&D at the global level is the Coalition for Epidemic Preparedness Innovations (CEPI), set up in 2017. CEPI supports a range of vaccine technology approaches for a range of infectious diseases. CEPI funds not only the research but also preclinical and early-stage clinical projects. In addition to funding, it also operates as a facilitator, establishing partnerships for standardising clinical trials, as well as aiding manufacturing and distribution of vaccines. Its funding is a mix of public and private funding. Its advisory committee has executives from big pharma. Although CEPI had several coronavirus-vaccine projects in its portfolio, most of its funding went to the incumbent viral vector and protein technologies. Oxford was the major CEPI fund receiver for its VV coronavirus vaccine project. Only a small share of CEPI's budget went to Moderna's and Curevac's mRNA-based coronavirus vaccines (Veugelers 2021). Its limited budget constrained CEPI in supporting more risky, novel approaches.

The EU Framework Programme for research typically does not fund late-stage development. It has more recently started, albeit on a small scale, to engage in public-private partnerships to co-fund development stages for specific (rare) diseases, through the Innovative Medicines Initiative (IMI). IMI, the EU's public-private partnership for funding early-stage development of drugs, had no mRNA vaccine projects in its portfolio prior to the pandemic.

Before the COVID-19 pandemic, the EU did not engage in advance purchase agreements, which is an EU member state competence. In response to the pandemic, the European Commission was able to use €2.15 billion from the Emergency Support Instrument, a special mechanism put in place by the EU, to coordinate negotiations for the advanced purchase of vaccines. The Commission signed seven advance purchase agreements with vaccine developers, including for the Pfizer/BioNTech and Moderna mRNA vaccines, and also the CureVac mRNA vaccine. However, its lower budget and later purchase of major shares of mRNA vaccines limited the impact of these EU supply agreements in incentivising private R&D investments in mRNA technology (Veugelers 2021).

THE ROADMAP FOR A PUBLIC R&D POLICY

With COVID-19, mRNA technology has shown its breakthrough value for delivering fast and highly effective vaccines at large scale. While it is now considered a breakthrough and a promise of future medicine, the mRNA vaccines story does show that the research and development of such vaccines was difficult. The story could easily have turned out differently.

The mRNA story suggests improvements can be made to the current biomedical ecosystem. It is a strong testimony to the importance of stubborn scientists, new entrepreneurs and out-of-the-box risk-capital providers. For new disruptive breakthrough technologies, like mRNA, the competencies and incentives to deploy them often do not reside in incumbent players. The private vaccine ecosystem therefore needs to be sufficiently contestable, incentivising new players with their risky breakthrough ideas. For small young, small biotech companies developing new risky breakthroughs, clear IP rights are especially important to be able to appropriate the value of their unique technological knowhow. They also need well-developed and competitive risk-capital markets and a well-developed market for biomedical services, where they can contract large-scale clinical trial expertise and production and distribution capacity at competitive prices.

Public policy, with its competition and regulatory policy instruments, should ensure the framework conditions for a deep, well-developed and well-connected biomedical corporate ecosystem which is competitive and contestable. The public sector also plays a key role as financier of R&D projects through grants, subsidies or tax credits and as an advanced procurer of vaccines. The mRNA story demonstrates the case for necessary improvements to public funding, to avoid missing potential breakthroughs. Public funding should cover the early risky research stages, but also the later, more expensive phases of development and production and supply. For early-stage research and development public funding, the mRNA story illustrates the importance of a DARPA-type approach to avoid the risk bias that hinders the funding of more risky breakthroughs at early stage. To diversify risks, a portfolio of supported projects is needed across multiple vaccine technologies. Such a risk-taking portfolio approach requires substantial budgets.

Another weakness in the public funding system highlighted by the mRNA story is its reluctance to support the later, more expensive development stages, especially in the EU (Aghion et al. 2020).

As major co-funders of vaccine R&D projects, but especially as pre-procurers through advanced purchase contracts, governments can and should be not only ensuring vaccine availability for their own citizens, but also availability at volumes and prices that are globally socially optimal. Although governments have the right to impose compulsory licensing or patent waivers in case of pandemics, activating this option ex post risks disincentivising future private investment. To avoid this, conditions on the use of vaccine patents should only be imposed as part of a comprehensive policy package designed ex ante, combined with a public funding deal that secures proper private incentives. Imposing access conditions by limiting IP rights should take into account that private incentives for investing in vaccines R&D need to be safeguarded. This may imply higher levels of public support when tying this support to IP rights conditions. Tying public funding to conditions on IPR rights may be particularly challenging for new young developers with risky projects. For these young biotech companies, access to external (public) funding is critical but at the same time, clear and strong IP rights are especially important for them, so they can engage on a fair footing in agreements with other complementary asset holders. When designing conditions for public support and advanced purchase contracts, the incentives for these new young developers should be properly taken into account, given that they are a major source of new risky breakthrough technologies.

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CHAPTER 16

COVID and the US creative economy: Supply, demand, and the hastening of the future

Joel Waldfogel

University of Minnesota

The COVID-19 pandemic has affected patterns of production and consumption in many industries. Demand for goods has risen while demand for services has fallen, giving rise to disruptions in many industrial sectors (Chetty et al. 2020). How about the creative sector?

The creative sector has a few features that make it interesting. For some creative products – movies and music – some important forms of consumption (watching movies at theatres and attending concerts) involve interacting with other people in public. This is, of course, not the case for television viewing and book consumption. Second, even prior to the pandemic, digitisation had facilitated consumption in private. Streaming of movies and music, and online purchase of physical and electronic books, made it possible to consume creative products without leaving the house.

The pandemic made public consumption activity unappealing to many consumers. Even before governments issued ‘stay in place’ orders, demand for theatrical viewing and live concerts dried up (Goolsbee and Syverson 2021). Given the pre-pandemic developments, one might expect the pandemic to hasten a shift already underway, towards consumption of premium content (such as first-run movies) at home.

How about the supply side? The production of some creative products – movies and television, for example – require working together with people. During a pandemic, this exposes actors and crew to infection, so we might expect some disruption in the supply of new creative goods in some sectors. Other products – such as books and perhaps music – can be produced with less exposure to disease, so we might expect less disruption to new supply.

This chapter considers three questions. First, what happened to new supply of creative products during the pandemic? Second, what happened to demand for creative products during the pandemic? And third, what emerging trends, if any, might survive the pandemic? Said another way, to what extent has the pandemic hastened the arrival of a future already on its way in the creative industries?

SUPPLY

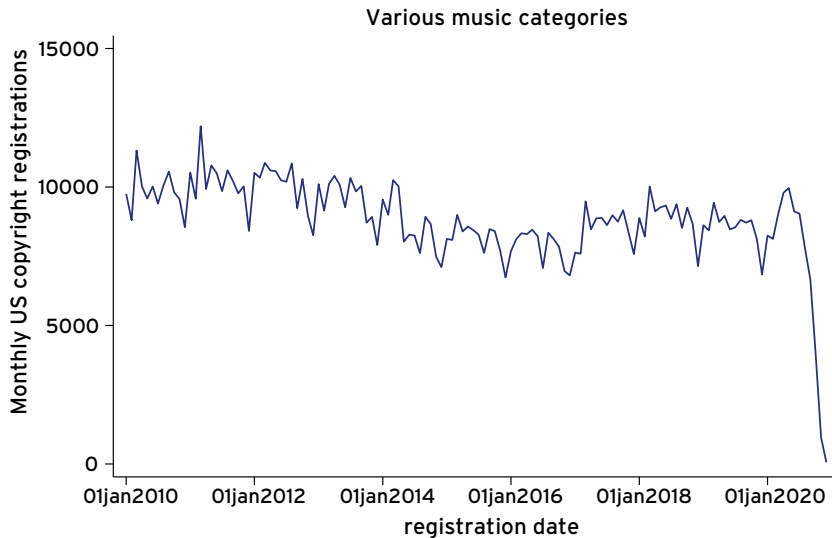
Measuring the number of new creative products is in principle easy but in practice a bit more complicated, for two reasons. First, it is not entirely clear what to include as products, even putting data concerns aside. Which written texts are books? Which segments of video are movies? Is a product a product for having been created? Or if offered for sale? While this tension exists for all products, it has been heightened for creative products during the digital era with the large increase in content produced and distributed without the permission of traditional gatekeepers (Waldfogel 2018).

And then there is the practical concern of finding systematic sources of information documenting the numbers of new products created. For example, copyright registrations might seem an appealing source of information. But copyright registration is not a legal necessity, and as I will show below, registrations significantly lag the counts of new products from other information sources. With this as prologue, what has happened to counts of new products in the major creative sectors?

Music

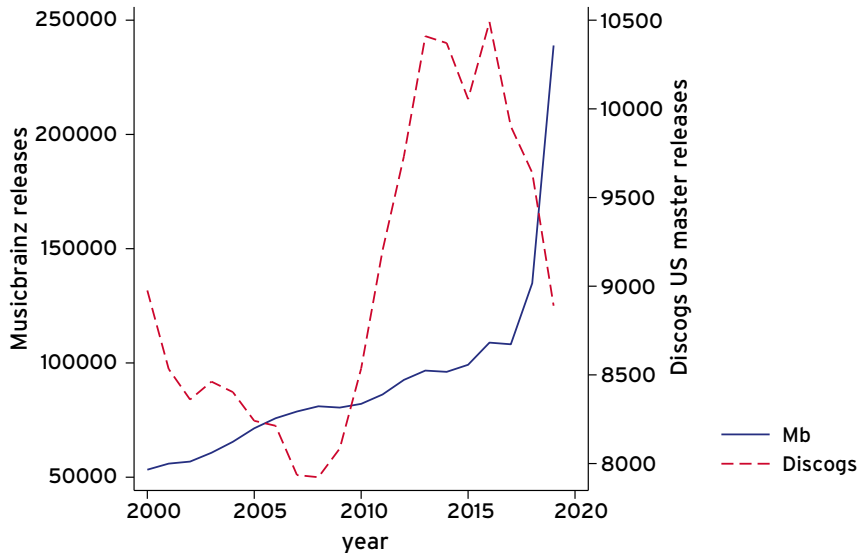
As Figure 1 shows, US copyright registrations (for musical compositions and sound recordings) slowly declined between 2010 and 2020. The monthly time series also falls off precipitously during 2020, but it is likely that this decline reflects processing of copyright registrations rather than underlying creative activity.

FIGURE 1 US COPYRIGHT REGISTRATIONS FOR MUSIC



The time pattern of music-related copyright registrations stands in rather sharp contrast with other sources of information about the production of music over time. Figure 2 shows two measures of new US recorded music products. One is the annual number of new US records, from the Discogs database.¹ The other is the number of country-specific recordings in Musicbrainz, by year. Both rise, overall, and rather substantially over the time period. It is difficult to say much about new music creation during the pandemic from the figure, but it is rather doubtful that one can rely on the US copyright registrations as a measure of creative activity.

FIGURE 2 NEW MUSIC PRODUCTS IN DISCOGS AND MUSICBRAINZ



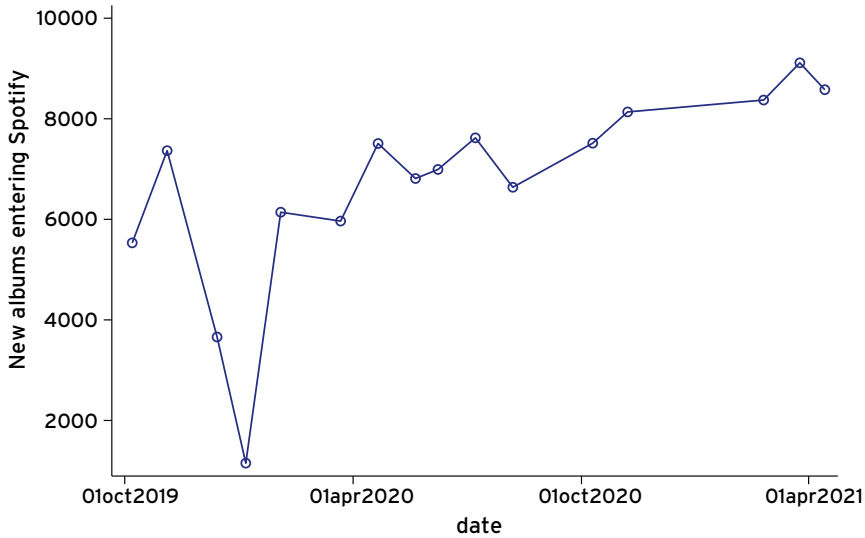
Spotify has emerged as the world's largest interactive music streaming platform. A Spotify data scientist named Glenn McDonald maintains a website called everynoise.com, which contains weekly counts of the numbers of new records entering Spotify.² I am able to get weekly counts for selected weeks from late 2019, just before the pandemic, until early 2021; and these are reported in Figure 3. Apart from a dip in a January week just prior to the pandemic, the number of albums averages over 6,000 and rises beyond 8,000 per week by early 2021.³ It seems clear that the pandemic did not interrupt the creation of recorded music.

1 In particular, these data are responses to the following Discogs query: www.discogs.com/search/?type=master&year=2022&country_exact=US.

2 See, for example, https://everynoise.com/new_releases_by_genre.cgi (as well as archived copies of the page at the Internet Archive's Wayback Machine).

3 It is important to note that this is a count of albums, not songs. The track count is higher, but I am able to create a comparable time series using this measure for the pandemic.

FIGURE 3 MUSIC ENTERING SPOTIFY, AS REPORTED BY EVERYNOISE.COM



Movies

Movies are somewhat more complicated to document, particularly if we make the distinction between movies produced versus movies released, and particularly if ‘released’ carries its traditional connotation of being released into theatres.

As Figure 4 shows, using data from boxofficemojo.com, both box office revenue and the number of movies released into theatres in the US fell substantially after 2019. The number of new movies produced, as opposed to theatrically released, tells a different story. Figure 5 shows the number of US-origin feature films and documentaries produced by year from 2010 -2021. The number produced is roughly ten times the number of movies released in theatres. While there is a substantial decline between 2017 and 2019, these are pre-pandemic years. There is only a modest decline as the pandemic arrived. The number of new movies fell only slightly, from 7,925 in 2019 to 7,805 in 2020, then rose to 8,429 in 2021. Based on production measures, the pandemic had little or no effect on the number of movies created.⁴

⁴ It is possible that the number of movies released, despite not falling, is depressed due to production slowdowns. For example, as of April 2022, IMDb reports 1,246 US-origin movies planned for release in 2023, another 181 for release in 2024, and 53 for 2025. Absent the pandemic, some of these movies might have been released earlier.

FIGURE 4 US THEATRICAL RELEASES AND BOX OFFICE REVENUE

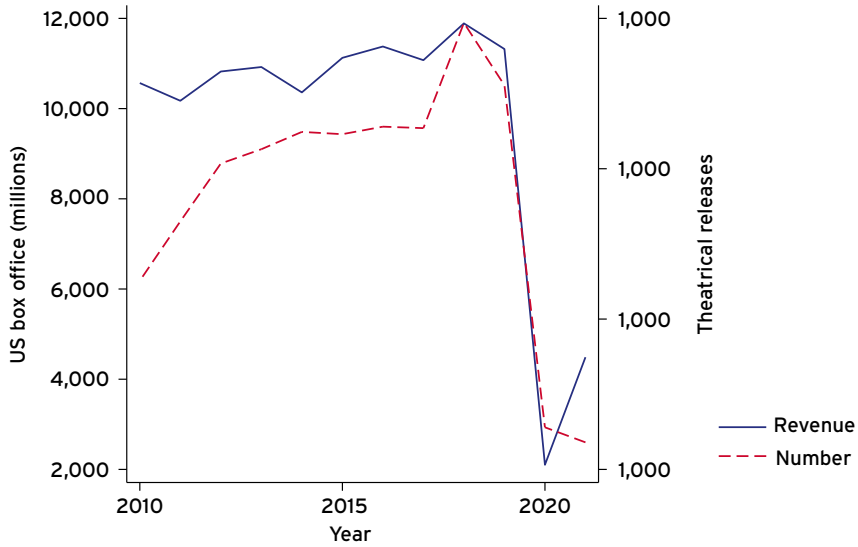
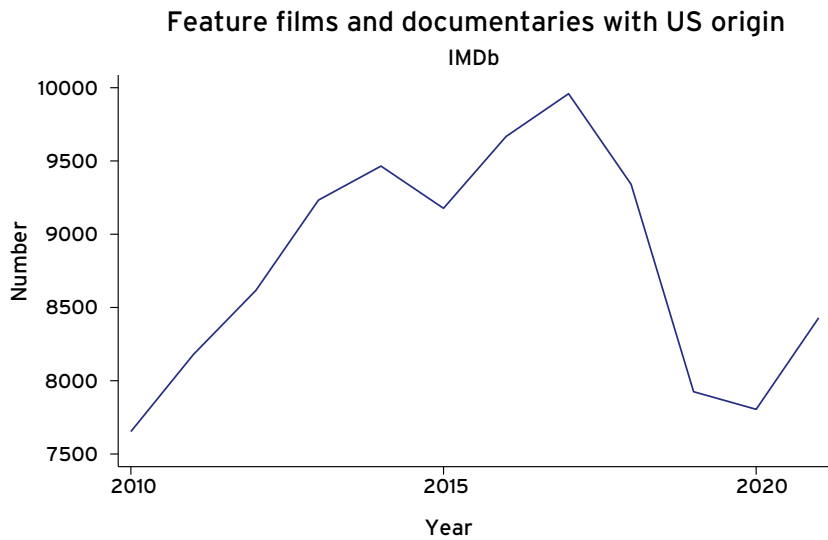


FIGURE 5 US MOVIES PRODUCED



Source: IMDb.

It is worth noting, as a peripheral point, that the number of movies in US copyright registrations (see Figure 6) is essentially flat for 2010–2020, a period when the number of movies produced as reported in IMDb rises from 7,653 to nearly 10,000 in 2017. As with music copyrights, there is a sharp decline during 2020, but this reflects processing delays rather than reduced creation.

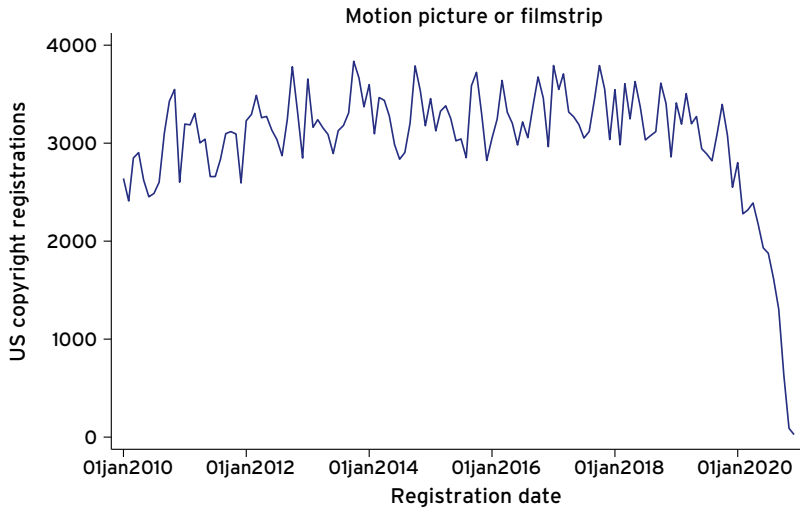
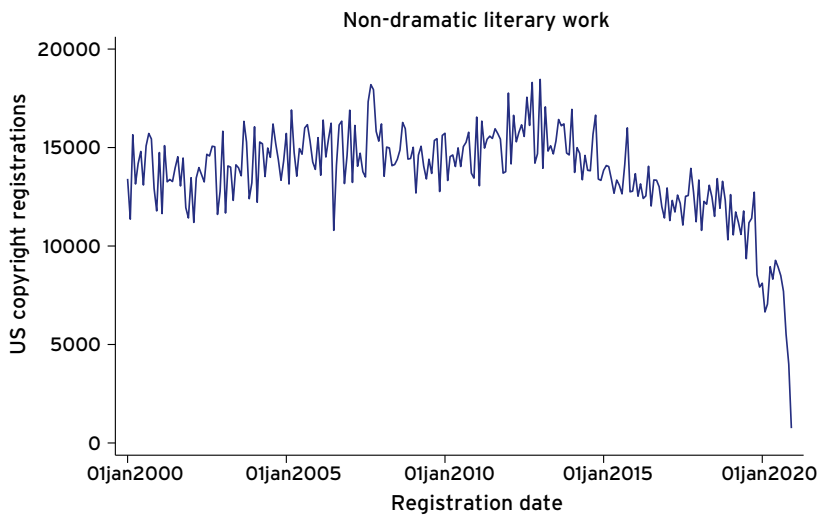
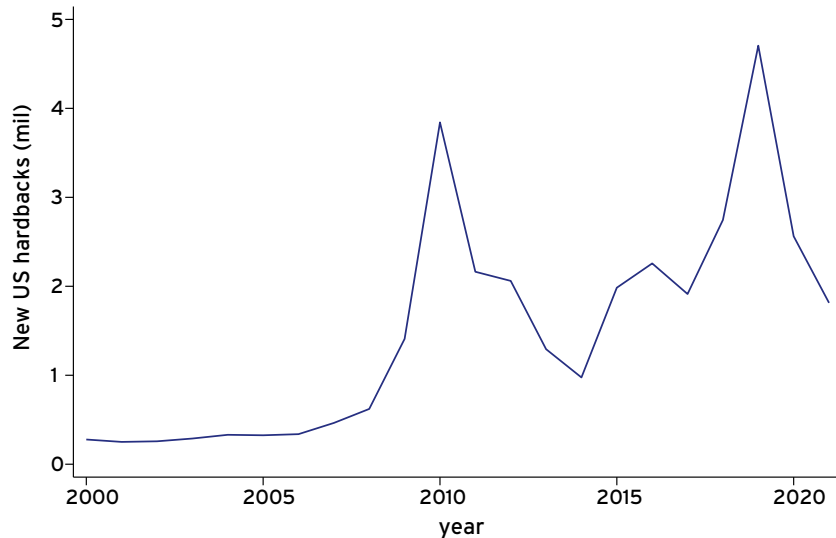
FIGURE 6 US COPYRIGHT REGISTRATIONS FOR MOVIES**Books**

Figure 7 shows US copyright registrations for books for 2010–2020. The number declines, from about 15,000 per month in 2010 to about 10,000 per month by 2019. It is worth noting that copyright registration does not require publication; many of the texts for which authors seek copyright registrations are unpublished, so Figure 7 overstates the number of new publications which authors have registered while at the same time understating the number of new works created (including those not registered).

FIGURE 7 US COPYRIGHT REGISTRATIONS FOR BOOKS

How does the apparent number of new books created suggested by copyright registrations comport with other sources of information about the number of books published? Figure 8 shows the number of new US hardback books reported in Bowker's Books in Print.⁵ This time series has the curious feature of enormous peaks in 2010 and 2018. The 2010 peak is known to be dominated by print-on-demand versions of pre-existing titles.⁶ Putting aside this peak, there is nevertheless growth in the number of new titles, from a few hundred thousand in 2000 to totals in excess of one million after 2014.

FIGURE 8 NEW US HARDBACK BOOKS IN BOWKER'S BOOKS IN PRINT



Much of the growth reflects growth in self-published titles, which accounted for under 0.5 million works in 2013 and over 1.5 million by 2018. The number of new US hardback titles in Bowker does fall substantially between 2019 and 2020, which could reflect the pandemic.

Two messages emerge from a review of information on cultural production during the pandemic. First, while copyright registrations might in principle provide a guide to the volume of underlying activity in copyright-protected industries, the US copyright registrations for music, books, and movies appear to deviate substantially from other sources of information about new products in these categories. Second, the pandemic appears to have had little effect on the volume of new US product creation, at least in music and movies.

⁵ I restrict attention to one prominent format, "hardback books," in order to avoid counting both various formats for the same book (ebooks, paperbacks, etc.) as additional books.

⁶ "These books, marketed almost exclusively on the web, are largely on-demand titles produced by reprint houses specializing in public domain works and by presses catering to self-publishers and 'micro-niche' publications" (see <http://www.noshelfrequired.com/bowker-study-shows-print-is-not-dead/>).

DEMAND

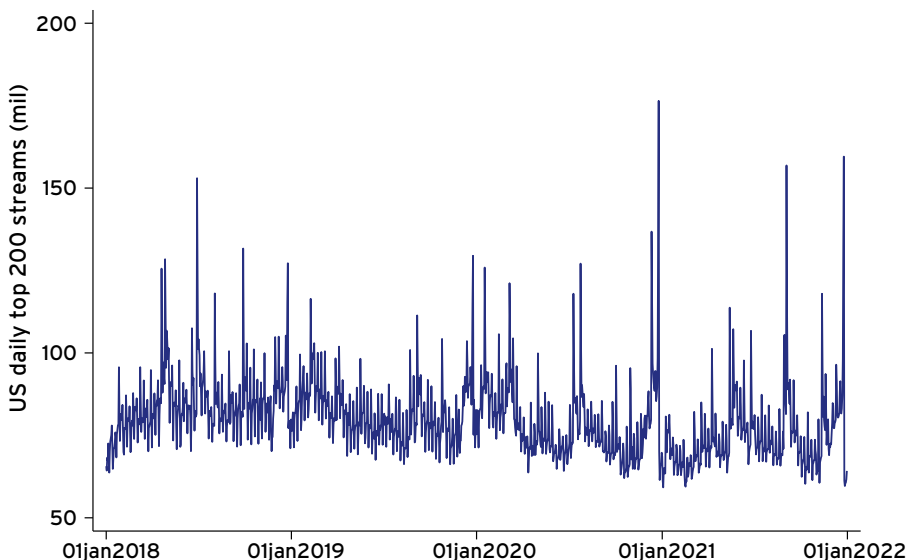
During the pandemic, people have spent more time at home, raising the possibility that they would consume creative products remotely. Fans stopped attending concerts: between 2019 and 2020, worldwide concert revenue fell from \$5.5 billion to \$1.2, according to Pollstar.⁷

Music

Prior to streaming, recorded music generated revenue when people purchased physical or digital music products (albums, CDs, or even iTunes downloads). Listening itself did not generate revenue for rights holders. With streaming, each instance of listening generates revenue. This is potentially important during a pandemic, as listeners can generate revenue for the industry without leaving home.

Spotify, one of the largest interactive music platforms, has long made its top-200 songs' daily streams available.⁸ While these data cover only the top 200 songs by country and day, they nevertheless provide information that can be compared over time. Figure 9 shows these top-200 streams for the US for 2018–2021. There are fluctuations and potentially a drop shortly after the arrival of the pandemic. If there is any drop, it is not large (see also Sim et al. 2022).

FIGURE 9 SPOTIFY US TOP 200 STREAMS, 2018-2021



⁷ www.statista.com/statistics/380120/global-music-tour-gross-revenues/ .

⁸ <https://spotifycharts.com/regional>.

Data on recorded music revenue provide another glimpse at music demand in the US during the pandemic. According to the Recording Industry Association of American, retail revenue rose from \$9.7 billion in 2018 to \$15.0 in 2021, with substantial increases during the pandemic years of 2020 and 2021 (see Table 1). Much of this was driven by growth in streaming subscribers, whose US ranks stood at 35.3 million in 2017 and at 60.4 million during the last pre-pandemic year. Subscribers grew 25% in 2020 and another 11% in 2021. Demand for music, as manifested in both listening behaviour and revenue, appears to have been robust during the pandemic.

TABLE 1 RIAA US RECORDED MUSIC REVENUE, 2017-2021

| Year | Retail revenue (US\$ billions) | US streaming subscribers (millions) |
|------|--------------------------------|-------------------------------------|
| 2017 | | 35.3 |
| 2018 | 9.7 | 46.5 |
| 2019 | 11.1 | 60.4 |
| 2020 | 12.1 | 75.5 |
| 2021 | 15.0 | 84.0 |

Source: www.riaa.com/wp-content/uploads/2022/03/2021-Year-End-Music-Industry-Revenue-Report.pdf

Movies

As Figure 4 above showed, box office revenue fell substantially during the pandemic. But the existence – and growth – of various platforms distributing video content to the home made it possible for consumers to purchase access to new movies and television. As Table 2 shows, time spent “watching television” rose by 11% between 2019 and 2020, based on the American Time Use Survey.

In contrast to box office revenue, which is widely publicised, other movie industry revenue is largely concealed. It is difficult to know how many people watched movies via streaming platforms or how much revenues the rights holders earned from the viewings.

That said, it is possible to see entry of additional platform operators around the time of the pandemic. Moreover, information on the number of subscribers to these platforms is disclosed, and it shows substantial subscriber growth during the pandemic.

Netflix, Amazon Prime, and Hulu (as well as various cable companies) had been distributing movies and premium television content into homes for a number of years. Although the launches were presumably planned independent of the pandemic, additional platforms’ availability were well timed for pandemic consumption. Disney+ was launched in the US on 12 November 2019,⁹ HBO Max was launched on 27 May 2020.¹⁰

⁹ <https://en.wikipedia.org/wiki/Disney%2B>.

¹⁰ https://en.wikipedia.org/wiki/HBO_Max

Disney+ attracted nearly 130 million worldwide subscribers by the first quarter of 2022, all of whom were added during the pandemic. North American Netflix subscriptions rose by over 15 million at the start of the pandemic.¹¹ US Hulu subscriptions grew about 50% during the pandemic as well, reaching 45 million by 2022.

TABLE 2 TIME USE IN 2019 AND 2020 FROM THE AMERICAN TIME USE SURVEY

| | Year | Total hours per day, 15 years and over |
|---------------------------------------------------|------|----------------------------------------|
| Total, all leisure and sports activities | 2019 | 4.99 |
| | 2020 | 5.53 |
| Participating in sports, exercise, and recreation | 2019 | 0.32 |
| | 2020 | 0.37 |
| Socialising and communicating | 2019 | 0.66 |
| | 2020 | 0.54 |
| Watching TV | 2019 | 2.74 |
| | 2020 | 3.05 |
| Reading | 2019 | 0.28 |
| | 2020 | 0.34 |
| Relaxing/ thinking | 2019 | 0.33 |
| | 2020 | 0.44 |
| Playing games and computer use for leisure | 2019 | 0.45 |
| | 2020 | 0.62 |
| Other leisure and sports activities | 2019 | 0.21 |
| | 2020 | 0.16 |

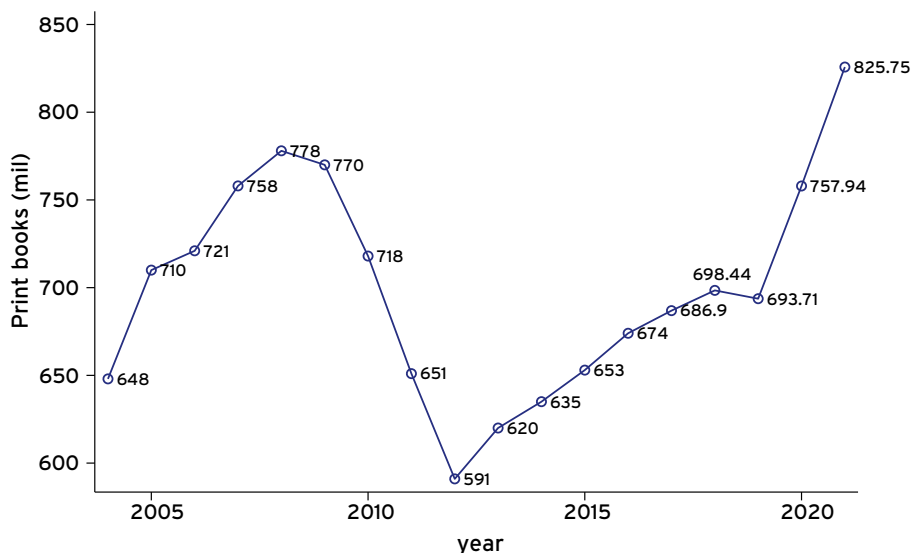
Source: www.bls.gov/news.release/atus.t09.htm and <https://www.bls.gov/news.release/atus.nr0.htm>

Books

Between 2019 and 2020, according to the American Time Use Survey, time spent reading rose by 21%. Over the same time period, US print book sales jumped by 9.2%, as Figure 10 shows. The increase in sales continued in the second year of the pandemic, as print sales reached 825 million units, according to Nielsen. It is important to note that this figure excludes ebook sales. Demand for books appears to have risen substantially during the pandemic.

¹¹ www.forbes.com/sites/joewalsh/2020/10/20/netflix-subscriber-growth-slows-after-surg-ing-during-pandemic/?sh=243d7fb6244e.

FIGURE 10 NIELSEN US PRINT BOOK SALES



THE FUTURE

The safest predictions about the future are the trends already underway, and one such prediction is that home consumption of movies will continue.

Just a few years ago, circumventing theatrical runs and distributing movies straight to home bore a strong stigma. Streaming movies that might have brought audiences into theatres was of course threatening to theatre chains such as Regal or AMC; it was also distasteful to film makers. As recently as 2019, director Steve Spielberg argued that movies released straight to streaming platforms such as Netflix should be disqualified from Academy Award consideration.¹²

Spielberg was not alone in his disdain for streamed movies. The president of the International Confederation of Arthouse Cinemas considered “giving three awards to Roma a devaluation of the Oscars”, which threaten to become another version of the Emmys, honouring “television productions”.¹³

By necessity, many of the 2022 Best Picture nominees have been available on streaming services rather quickly after theatrical release, and without controversy. For example, *Don't Look Up* was released in theatres on 5 December 2021 and available on Netflix on 24 December. *The Power of Dog* had a similarly short window, as did *King Richard* and *Coda*.

¹² <https://variety.com/2019/film/awards/steven-spielberg-oscars-netflix-1203155528/>.

¹³ www.hollywoodreporter.com/news/general-news/giving-awards-roma-is-a-devaluation-oscars-say-european-exhibitors-1190434/

To the extent that stock prices reflect expectations about future profits, investors appear to share the view that theatrical consumption will remain diminished. As of early 2022, the market capitalisation of Cineworld, the second largest worldwide cinema chain (and owner of the Regal chain in the US), is 85% below its pre-pandemic value.

Because theatrical consumption occurs in public, demand for theatre tickets is affected by COVID risk. Some jurisdictions have instituted COVID pass requirements for theatre attendance. For example, Italy and France instituted such requirements during the summer of 2021. These passes have two offsetting effects. First, they bar consumption by unvaccinated people, which directly reduces the potential audience and therefore revenue. But by keeping infected people out of theatres, they may attract COVID-concerned consumers into theatres, giving rise to a second – and positive effect – on revenue. There is some evidence of these offsetting effects. In Waldfoegel (2021), I find that the COVID pass in France reduced box office revenue for movies appealing to all ages of viewers, while the passes in Italy appear to have reduced demand for movies targeted at the young but raised revenue for movies targeted to older audiences. If COVID lingers, it is possible that exhibitors will see it in their interest to institute passes, if local laws allow this.

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related issues, including the impact of piracy on the revenue in recorded music, motion pictures, and television. Since 2010 he has done research, and has published papers, on the broader impacts of digitization on the supply of new products in creative industries.

CHAPTER 17

Online consumption behaviour and how infringement levels changed during lockdown

UK Intellectual Property Office

BACKGROUND

The UK's creative industries are a global success. In 2019, the UK Department for Culture, Media, and Sport (DCMS) estimated that the creative industries contributed £115.9 billion to the UK, accounting for 5.9% of the UK economy. The production and consumption of digital content forms a large part of that and has a significant role in promoting UK creativity on a global stage. However, the sudden outbreak of COVID-19 significantly impacted the UK creative industries and changed the way people experience digital content. Conducting research in this space is complex, as the ways in which consumers access and share copyright material online change regularly, and infringement levels are notoriously difficult to measure. However, the research discussed aims to measure the impact that lockdown had on the creative industries and how users and consumers interact with digital content – legally and illegally.

The UK Intellectual Property Office (UKIPO) publishes annual research on consumer behaviour in relation to online copyright infringement (OCI),¹ which monitors how people interact with digital content and aims to gain an understanding of current levels of consumption within the UK. Although the OCI is a long-established tracker, waves 10 and 11 of the research asks about periods when the majority of the UK faced restrictions (2020 and 2021) due to the COVID-19 pandemic (UKIPO 2021a, 2021b). This therefore presented an opportunity to assess what impact COVID-19 may have had on people's online behaviour and what trends we can see as a result. This chapter will outline key findings from both the OCI research and a further nine-week study that aimed to understand the impact restrictions had on the creative industries (PEC 2020).

¹ The OCI is a series of research that aims to gain an understanding of current levels of consumption of pirated content within the UK, draw comparisons with previous waves to track changes, and find motivating factors for consumption. Since 2019, UKIPO has commissioned AudienceNet to conduct the research and to enable comparability with previous waves key elements of the survey have remained consistent.

The research focuses on nine content categories: music, film, TV programmes/series, live sports, video games, software, e-books, digital magazines, and audiobooks. Whilst the OCI focuses on three-month consumption, the additional survey focuses on a weekly survey to capture fluctuations in consumption due to COVID-19 (e.g. government interventions and changes to local lockdowns). During the nine-week study, six weeks of data were collected in consecutive weeks spanning April and May 2020, when the UK was in a full national lockdown. There were three subsequent waves of the study carried out in July, August, and September, during which some parts of the UK were in local lockdowns at various points. The data and responses from the surveys will show how COVID-19 restrictions (such as having to spend more time at home), mental wellbeing consequences and economic effects impacted consumption habits.

DIGITAL CONSUMPTION AND ONLINE INFRINGEMENT DURING COVID-19: INSIGHTS FROM THE OCI TRACKER

During wave 10 of the OCI tracker (2020), respondents were asked to reflect on and provide insight into their day-to-day lives since COVID-19 had struck and the restrictions were imposed. Most commented that without entertainment, their experience would have been far less tolerable, and their mental wellbeing would have deteriorated without this form of distraction. In addition, many said they had relied heavily on certain categories to fill their time and transport them away from the realities of restrictions. Therefore, for respondents, it is clear that entertainment played a pivotal role during restrictions.

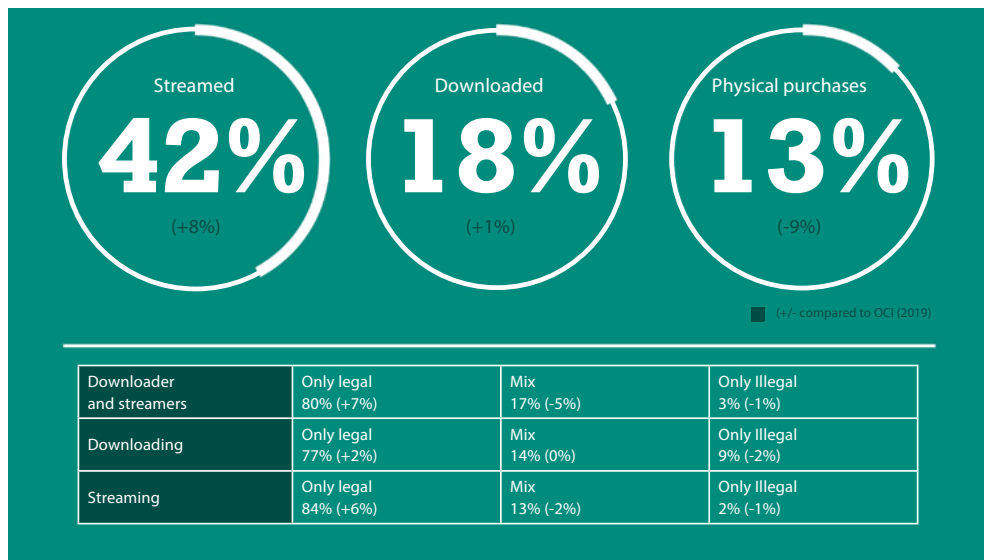
During the qualitative phase of the research, it was found that those on furlough reported a definite increase in consumption of their favourite forms of digital entertainment, while those who were still working noted their consumption remained relatively consistent. The reason for an increase in entertainment consumption among those with lots of free time during restrictions was the comfort and distraction found in activities such as reading, listening to music, watching films, and playing video games, and so on. Surprisingly, although some voiced concerns about finances during restrictions, none mentioned cancelling any of their online entertainment subscriptions. Therefore, cost remained a key factor in accessing illegal sources of entertainment but did not appear to play a significantly more important role than before the impact of COVID-19 for most.

Consumption (i.e. downloading or streaming content online) was consistent across a number of categories compared to the previous year (2019). However, some key differences included a decline in the proportion of our sample who had downloaded music and TV and a decline in the proportion who had streamed live sport, whilst there was an increase in those streaming films. The overall level of infringement for all content categories, excluding digital visual images, was at 23%, which is 2 percentage points lower than where it had been for the previous four years.

Engagement with film (wave 10 - 2020)

Streaming was the most common method of accessing films, with 42% having done so in the past three months. Comparing the results to the previous year (2019), the proportion who had streamed films over the previous three months was up by 8 percentage points to 42%, the highest it has been over the past six years, and matches the proportion of those who had streamed TV. Physical purchasing saw a decline of 9 percentage points. The overall level of infringement (i.e. anyone who had used an illegal source for films in the past three months) experienced a large decline, going from 27% in 2019 to 20% in 2020. The main notable shift in the type of infringement was the increase in those using only legal sources.

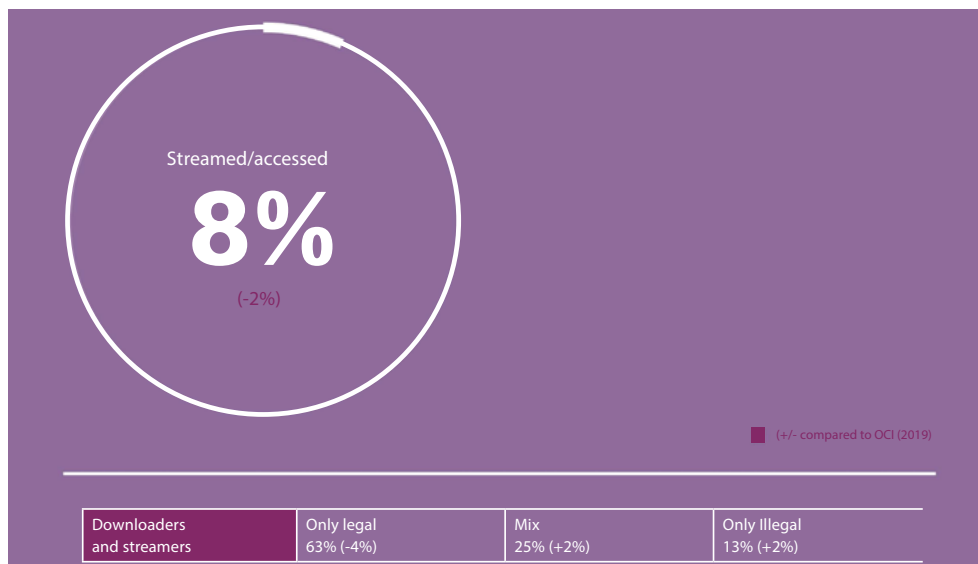
FIGURE 1 METHODS OF ACCESSING FILMS IN OCI WAVE 10



Engagement with live sport (wave 10 - 2020)

Among the total sample, 8% had streamed live sport in the past three months. This represented a 6 percentage point decrease compared to last year. The proportion who had streamed live sport had almost halved compared to 2019, which is not surprising given that the COVID-19 pandemic resulted in fewer sporting events taking place for much of the period. The overall level of infringement (i.e. anyone who had used an illegal source for live sport in the past three months) experienced a small increase (34% in 2019 to 37% in 2020), whilst there was a decline in those using only legal sources.

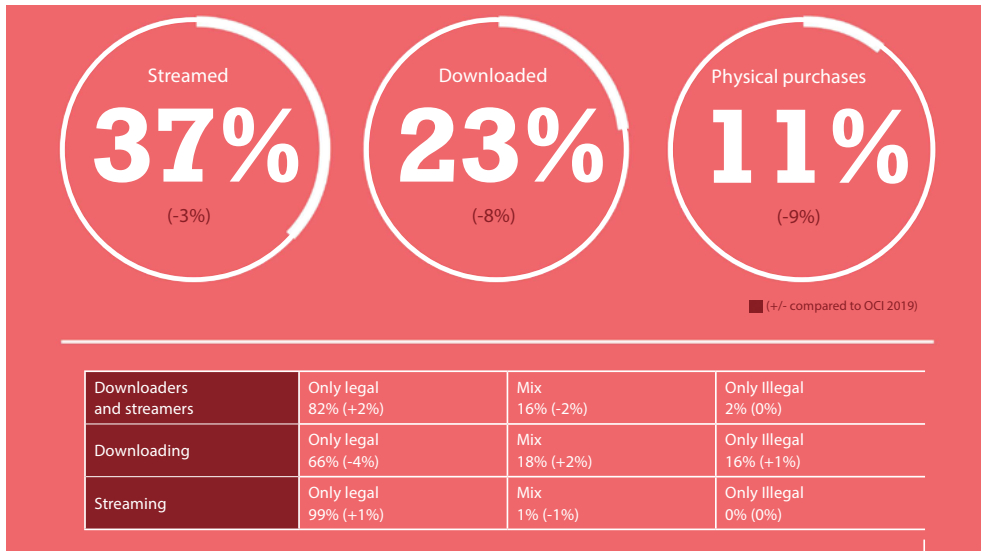
FIGURE 2 METHODS OF ACCESSING LIVE SPORT IN OCI WAVE 10



Engagement with music (wave 10 - 2020)

In the previous three months, 47% had engaged with music (i.e. either by downloading, streaming, sharing, or purchasing physical products). Streaming was the most common method of accessing music, with 37% having done so in the past three months. Downloading followed at 23%, with notably fewer having purchased physical music (11%). Streaming music remained relatively stable compared to 2019 (a decline of 3 percentage points), while downloading and physical purchases experienced steeper declines of 8 and 9 percentage points, respectively. The 37% who had streamed music online were asked questions about frequency and volume. Although the number of people streaming music remained relatively stable, the results showed that the amount of music streamed since the COVID-19 pandemic had increased for over half (56%) of respondents. Approximately a third of respondents (38%) said the amount of music they had streamed hadn't changed, with very few (6%) saying it had decreased. Before COVID-19, respondents had streamed, on average, 76 hours of music every three months.

FIGURE 3 METHODS OF ACCESSING MUSIC IN OCI WAVE 10



Evolution over subsequent restrictions (wave 11 - 2021)

Similar to wave 10, wave 11 also asked about a period (2021) when the UK was in a state of restrictions due to the pandemic. The qualitative collection of this wave took place during the third official national restrictions in the UK in May 2021. However, there are also some shifts which potentially point to differences in terms of how these restrictions were experienced.

During the qualitative part of the research, it was found that those who had increased their consumption of music via illegal sources during the past year did so due to the circumstances surrounding the COVID-19 pandemic and the related social restrictions. Some of the impacts of these circumstances included reduced income for some, meaning a greater need for free content and more free time to listen to more music. In addition, participants gave further detail about how and when they accessed entertainment categories online. Many participants noted a general increase in their consumption of entertainment content compared to their level before the pandemic, either due to a greater reliance on such content or to fill free time. Some participants said that their general increase in consumption had also led to an increase in access from unofficial sources, as a way of finding more content in a cost-effective manner.

The results show that consumption (i.e. downloading or streaming/accessing content online) increased across a number of categories. This was most evident in streaming/accessing, where all categories were at the highest point seen in the study so far. The proportion streaming live sport returned to the levels seen before COVID-19, increasing by 7 percentage points to 15%. However, streaming in other content categories increased compared to the previous wave. This was particularly evident in music (+5 percentage points) film (+3 percentage points) and TV (+3 percentage points), which all grew to the

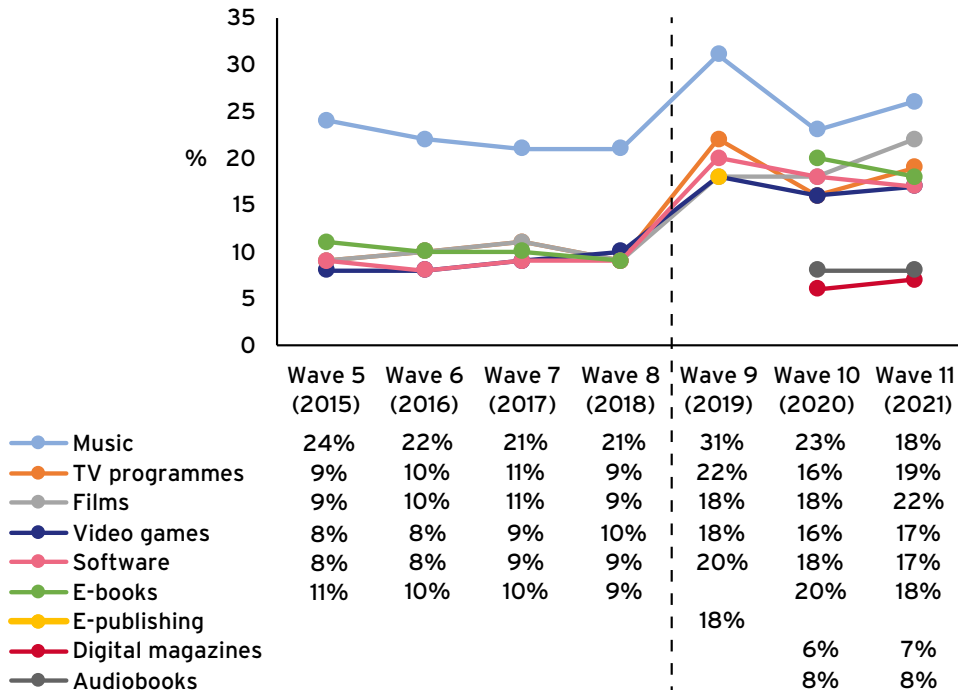
highest points seen in the study. Downloading in most categories bounced back from the low levels seen in the previous wave. There were increases for film (+3 percentage points), music (+3 percentage points) and TV (+3 percentage points). While film was at the highest level seen so far in this study, music and TV were both below their previous peaks.

In wave 11 of the OCI survey, the number of respondents who had downloaded content in each category in the previous three months either increased or remained steady in most categories compared to the previous wave. The proportion downloading remained lower than the peaks seen previously (pre-COVID-19), apart from in one category (film).

- The largest increases between Waves 10 and 11 were for music, film and TV, which all increased by 3 percentage points.
- Digital magazines increased by 2 percentage points, with either 1 percentage point increases or no change in video games and audiobooks.
- There was a 1 percentage point decrease in software and a 2% decrease in e-books

FIGURE 4 DOWNLOAD ACTIVITY BY CATEGORY, 2015-2021

Have you downloaded any of the following through the internet in the past 3 months?
By downloaded we mean transferring/saving a copy of a file onto your device
(e.g. computer, laptop, smartphone, etc.)



Note: Base for Wave 11: n=5,000 (total sample). Break in the series between Wave 8 and Wave 9 represents change in methodology.

The drivers for infringement, as in previous waves of qualitative research, remained cost and greater access to content that was not available on paid subscriptions or other legal methods. The overall level of infringement for all content categories (excluding digital visual images) was 25%, which is 2 percentage points higher than the previous year but the same as in four of the previous five years. The largest decrease in the proportion who had infringed between waves 10 and 11 was in live sport, where it fell by 8 percentage points to 29%; this is also 5 percentage points lower than the pre-COVID-19 levels. Below is a further breakdown of the infringement levels in comparison to the previous year (2019). The level of infringement refers to anyone who has used an illegal source to access content in the previous three months.

CONSUMPTION DURING RESTRICTIONS: INSIGHTS FROM THE AUDIENCENET SURVEY

AudienceNet was commissioned to design a further study and conduct a weekly nationally representative survey to understand digital consumption during COVID-19 restrictions. This study found that restrictions appeared to have grown the audiences for digital cultural content. It also provided more insights into patterns of respondent behaviours and profiles, as presented in this section.

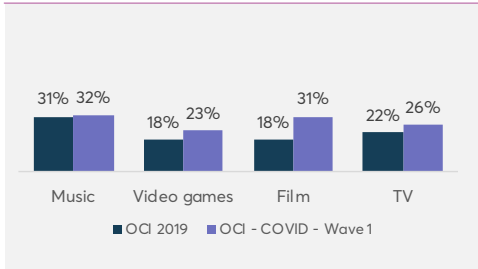
Data were collected across six consecutive weeks (9 April to 24 May 2020), with further data collection in July, August and September 2020. The first part of the survey, referred to as waves 1 to 6, was carried out over six weeks from April to May, when the UK was in a full national lockdown. The national lockdown ended on 4 July, although local lockdown restrictions remained in some places. There were then three further waves of the study, referred to as waves 7 to 9, carried out in July, August and September, during which some parts of the UK were in local lockdowns at various points.

Comparison with the OCI study

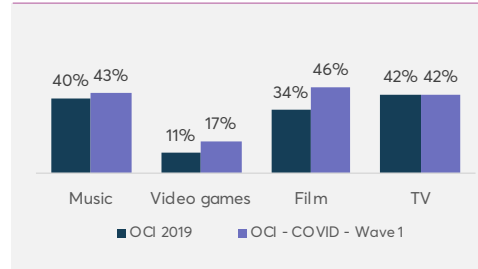
The annual OCI study focuses the-month consumption as opposed to weekly consumption. As such, in wave 1 of the weekly survey, data also captured a three-month period to help contextualise the wave-on-wave results. Comparisons can be made between the three-month data points captured in the 2019 OCI and in wave 1 to some extent; however, the weekly data cannot be compared in a like-for-like way due to the timeframe being very different. During week 1, covering the period 2–12 April, all core categories saw increases in the proportions accessing them compared to 2019 levels. Overall, the category with the highest proportional increases (across both streaming and downloading) was film.

FIGURE 5 DOWNLOAD ACTIVITY BY CATEGORY FROM OCI, 2019 AND WAVE 1, 2020

Proportion of total sample who had downloaded content in these categories in the past 3-months



Proportion of total sample who had streamed content in these categories in the past 3-months



Geographical location

During week 6 of the weekly survey, covering the period 14–20 September, the data showed useful information on how variations in restrictions across areas in England impacted the consumption of culture and people's wellbeing and happiness. This period saw new local restrictions come into place in some regions in England, such as in the North East, while other areas remained relatively open. One clear, though not particularly surprising, finding is that people in areas under local restrictions watched more television and films than those in less restricted areas.

Content creation and sharing

This survey also looked in detail at the proportion of respondents who created and shared their own content across the six weeks of data. The results shown that younger respondents were more likely to be weekly content creators.

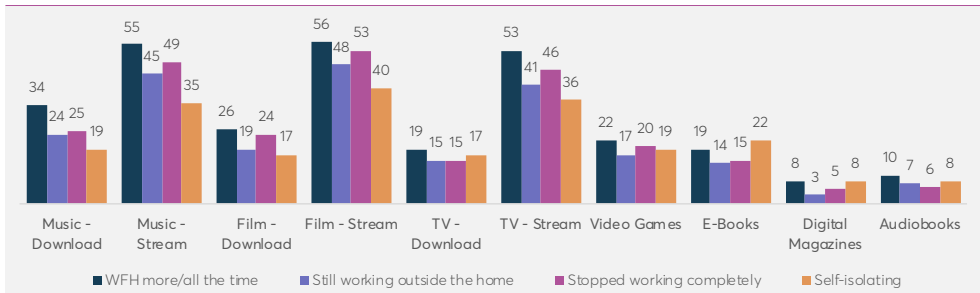
- Those aged 25–34 were, in most weeks, the age group most likely to create content at least once in a week. The proportion doing so increased from 36% in week one to between 41% and 45% for the proceeding weeks.
- Those aged 16–24 saw the proportion creating on a weekly basis fluctuate week to week, going from a high of 45% in week 2 to a low of 34% in week 5. The content creation behaviour of the older age groups (35–55+) remained more consistent across the weeks, with fairly minimal increases or decreases in uptake.

COVID-19 working status

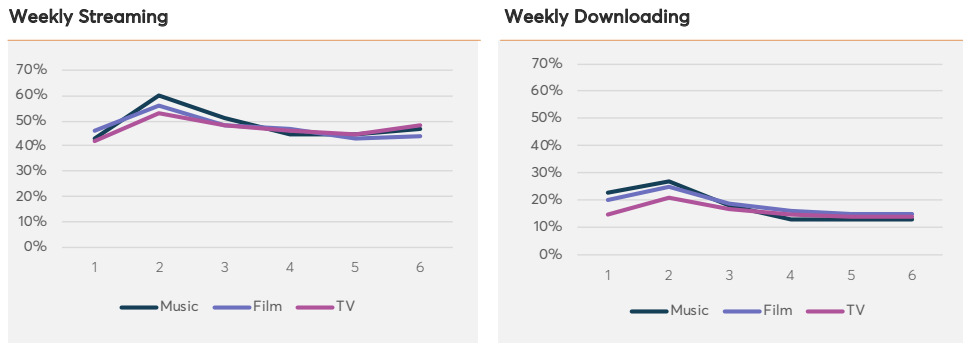
During the weekly survey, respondents were asked about changes in their personal circumstances (e.g. Were they working from home? Had they been furloughed? Were they self-isolating?). Those who were working from home (either all the time or more than usual) were consistently more likely to engage with content online at least once in a week when compared to those who had stopped working completely (i.e. were furloughed) or were still working outside of their home. Those who were self-isolating were generally least likely to engage with any content, with the main exception being e-books.

Age is likely to be an important consideration in this – of those self-isolating, over half (56%) were 55+, a group who, compared with their younger peers, were generally less likely to engage with cultural content in many of the categories in question. In addition, the proportion of people who used video conferencing software, such as Zoom, for work was highest in wave 9 (covering the period 14–20 September), at 31%, possibly the result of furlough schemes coming to an end and people returning to work.

FIGURE 6 PERCENT OF TOTAL SAMPLE WHO HAD ACCESSED CONTENT IN THESE CATEGORIES IN WAVE 1 DURING THE PREVIOUS WEEK (BY WORKING SITUATION DURING RESTRICTIONS)



In terms of weekly consumption during the study (i.e. as opposed to the three-month period), the proportion of respondents who had used at least one illegal source to access online content varied considerably by category. The lowest levels of infringement occurred in streaming music and were negligible (i.e. between 0% and 2% each week). Music downloading generally had the highest proportion of consumers accessing illegal content out of all categories each week. The overall number downloading music illegally decreased over the six weeks of the study. However, it is interesting to note that those using only illegal methods to do so increased from 9% in week 1 to 22% in week 4, after which it remained stable. Many categories exhibited a similar pattern whereby the levels of infringement were highest in week 1 and then declined over the course of the study.

FIGURE 7 WEEKLY STREAMING AND DOWNLOADING CONSUMPTION

SUMMARY

The insights provided by this research highlight how important culture and the creative industries are for people, especially those who are physically isolated by strict restrictions. It is clear that the sudden outbreak of COVID-19 changed the way people experience online content, with most participants saying that access to entertainment during the past year helped their mental health by distracting them from the daily reality of the pandemic and negative news stories. In some instances, the creative industries facilitated forms of social interaction online or within households, at a time when interaction was otherwise restricted. The pandemic boosted everyday content creation and appears to have boosted the long-run trend for streaming to outgrow downloading.

Passion for content categories continued to be significant among respondents, with many indicating that the categories asked about were central to their lives. The latest findings (2020) show the overall level of infringement for all content categories (excluding digital visual images) was 25%, which is 2 percentage points higher than in the previous year but the same as in four of the previous five years. Despite the previous two years of research being carried out during the COVID-19 pandemic, the key drivers of infringement remained the same. These include the choice/variety of content on offer, the ability to access it immediately, and also the cost. However, respondents who did record an increase in accessing illegal content tried to limit spending money on different providers with separate subscriptions and reported a greater need for free content due to reduced income during restrictions. In addition, access to free sources meant they could search for fresh content; a driver for this may be the lack of new TV content being produced during COVID-19 restrictions. Over the six-week survey, many categories exhibited a similar pattern whereby infringement levels were highest in the first week and then declined, but some (video games and e-publishing) were more variable over time. The volume of content consumed generally declined over the six weeks, but this was the case for content from legal as well as illegal sources, making it difficult to assess the extent of cannibalisation of legal sales by illegal activity. This insight provides an understanding to creative businesses to help minimise increased infringement.

During COVID-19 restrictions, many participants valued the entertainment they consumed to a greater extent, even if their general consumption stayed the same. The evidence shows the importance of considering what factors affect people's likelihood to consume digital content. For example, who consumes TV, film and music online varies significantly with age. This is evident in the weekly survey, where increases in downloading and streaming were generally more common among younger age groups. However, it is interesting to note that the pandemic appears to have influenced a lot of people's behaviours – for example, the over-55s recorded the highest proportion of new content creators, with a quarter (26%) saying they did not do this before the pandemic. It will be interesting to learn more from future surveys as self-isolation and restrictions come to an end.

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The **Intellectual Property Office** (IPO) is the official UK government body responsible for intellectual property (IP) rights including patents, designs, trade marks and copyright. IPO is an executive agency, sponsored by the Department for Business, Energy & Industrial Strategy.

CHAPTER 18

The COVID-19 impact on artistic income: Evidence from Germany¹

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INTRODUCTION

In early 2020, audience access to theatres, museums and concert venues in Germany was temporarily restricted by government authorities and, as in many other countries, people were asked to stay and work from home due to the spread of the COVID-19 virus. Obviously, the pandemic crisis hit supply and demand in the cultural and creative sectors hard and impacted these sectors in various ways, but it was particularly challenging for those working under non-standard contracts in the industry. This chapter assesses the overall impact on self-employed income from artistic practices among artists in Germany, based on novel and rich data released from official sources in early 2021.²

We find that the first year of the pandemic (2020) impacted artists in the various creative and cultural sectors differently, with net income losses over 2019 ranging between 3% and 13%, depending on the specific sector. This compares to a general decline in total employment income in Germany of around 4% in 2020.³ More precisely, our results indicate that musicians and performing artists were among the most vulnerable groups in terms of their 2020 income losses. Notably, some of the losses also depend on the specific non-pharmaceutical public interventions implemented in German states (for example, the number of lockdown days). Furthermore, we show that gender income differences and income differences at different career stages predate the 2020 outbreak, and these pre-pandemic differences largely prevail over the first pandemic waves. Finally, the evidence suggests that artists in rural regions were no less affected by the crisis than urban artists.

We contribute to a growing number of economic studies assessing the impact of the pandemic and of specific containment measures (Baldwin and di Mauro 2020, Cusmano and Raes 2020, von Bismarck-Osten et al. 2020), and, more specifically, the impact on the

1 The authors gratefully acknowledge data donation by the Kuenstlersozialkasse. They also would like to thank Andreas Kissling and seminar participants at the Onassis Foundation, Athens, for valuable advice and comments on earlier versions of the paper.

2 The chapter builds on a more extensive technical background report, first published in *COVID Economics: Vetted and Real-Time Papers* (Cuntz and Sahli 2021).

3 See, for example, data and analysis from Eurostat at https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Impact_of_COVID-19_on_employment_income_-_advanced_estimates#cite_ref-2.

arts and culture sectors (Buchholz et al. 2020, Jacobs et al. 2020). For example, topical research by UK's Creative Industries Policy & Evidence Centre (PEC) documents a temporary contraction of the UK labour market and fewer hours worked in these sectors. Using data from the national Labour Force Survey (LFS), the study estimates a loss of 55,000 jobs, which equates to a 30% decline in music, performing and visual arts labour markets, between the first and the third quarter of 2020 (Owen et al. 2020). A number of recent studies by the European Parliament show similar contractions of these sectors across the EU, based on Eurostat data (De Vet et al. 2021). Moreover, other EU studies track national public support measures for creators and identify the many non-standard workers, such as self-employed and part-time workers, as the most vulnerable group in these sectors during the first wave of the 2020 pandemic (IDEA Consult et al. 2021).

Our research is backed by the latest available data from an official public insurance scheme dedicated to artists working and residing in Germany. It covers all self-employed income generated throughout the first pandemic year (2020) vis-à-vis income generated in pre-crisis years. Different to other COVID-19 impact studies, our study does not forecast losses based on historic data and events which, arguably, might not always compare to the current situation, and it may be less prone to non-response and other biases present when conducting a survey and having to rely on a smaller sample of artists.

Our findings are intended to help policymakers to better target public support and limited resources in post-pandemic years. We hope our estimates can help inform the tailoring of financial and other support for the most vulnerable groups and regions. In the following section, we briefly introduce the data and outline the empirical approach.

A NOVEL SOURCE OF INCOME DATA

Income data for close to 200,000 artists comes from social insurance records of the *Kuenstlersozialversicherungskasse* (KSK) and have been used in previous research on the financial health of creators (Cuntz 2018, Kretschmer 2005). The sample of insured artists can be seen as representative of the overall population of self-employed artists and creative workers located in Germany, corresponding to 34% of the total employees in cultural occupations based on census data.⁴ The dedicated low-cost insurance scheme of the KSK targets artists resident in Germany. It requires them to report self-employed income on an annual basis, which they later also report to tax authorities. Applicants to the scheme self-identify as (self-employed) artists, and so, from a methodological perspective, there is no need for us to survey artists or to define sample criteria ex ante. In addition, once artists have opted in, they self-select into one out of four artistic categories:

⁴ Based on German census data from 2018, 436,000 people were self-employed in cultural and creative occupations without other employees. This group of self-employed accounts for 34% of the total employees in cultural occupations (as compared to the relatively lower 10% share of self-employed in the total working population), and it accounts for 88% of the total self-employed in Germany (National Statistical Office 2020). Other census data suggest that past trends in the rising number of insured under the KSK scheme and the overall expansion of the labour market for self-employed cultural and creative occupations moved in parallel between 1998 and 2008 (Kelleter 2009).

fine arts, performing arts, music or writing/literature. Public funding measures as a policy response to the crisis are highly unlikely to bias reported income under the KSK scheme, as funds were not yet distributed in the federal system at the end of 2020.

KSK records provide information on the average (mean) income from artistic self-employment and the number of insured artists per artistic group by gender, age and location (NUTS-1 *Laender*, or states). The aggregate data are available for four consecutive years of reported income (2017 to 2020) and thus only account for the impact on income from the first and second waves of the pandemic in 2020. Furthermore, the data distinguish artists at their early career stages from the total insured population (KSK defines ‘early stage’ careers as the first three years of reporting artistic self-employment to them).

Tentative analysis of the number of insured artists suggests that the total stock of insured persons did not change in 2020 over previous years (results not reported in this chapter). However, insurance participation might not provide a meaningful indication of a possible contraction of the labour market for self-employed artists. While most artists stay insured under the scheme in the pandemic, they might be forced to work fewer hours and should report lower income levels accordingly. Note further that the income data do not provide any information on alternative sources of income for insured artists beyond their self-employment (which the KSK scheme permits up to a certain income threshold) or on artists working in multiple jobs and other sectors to subsidise their artistic income. Alternative income sources might arguably have been similarly impacted by the 2020 pandemic year and the overall allocation of working hours by artists working in multiple jobs may have changed in due course. Moreover, there is little chance that the income data are biased by public funding and recovery packages, as funds to artists took time to implement and distribute locally. However, some of the income streams derived from intellectual property (IP) – for example, copyright royalties from pre-pandemic times – were only distributed in 2020. Both aspects could flatten and lower the observed impact of the crisis on reported income, so that the true impact on income might be slightly underestimated. In Cuntz and Sahli (2021), we provide further details on the potential limitations and benefits of our data and the overall analysis.

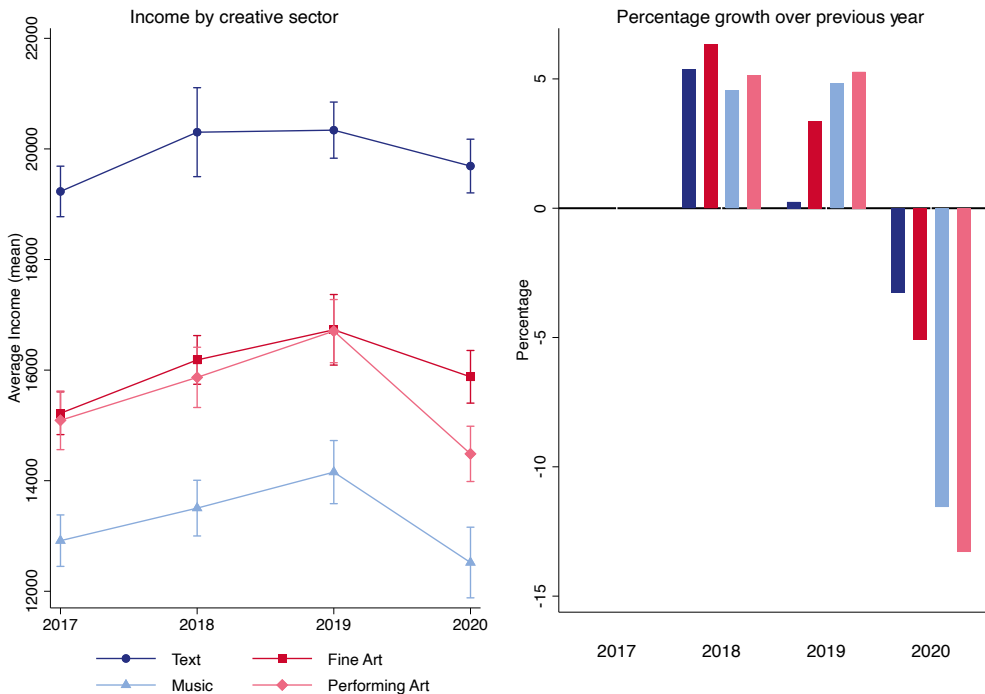
In the analysis that follows, we report straightforward income estimations for each artistic sector, and then test the statistical significance of income difference observed between 2019 and 2020. In the estimations, we take into account artists’ age (cohort), gender, career stages and the state they reside in. In the background report (Cuntz and Sahli 2021), we go beyond this initial set of results by accounting for heterogeneous policy responses and regional differences in the adoption of COVID-19 rules (not reported in this chapter). For example, artists and their income streams were exposed to fewer or longer periods of lockdown, depending on their residence (state). Even though we do not find statistically significant differences in artistic income from that analysis, we still want to highlight the need for future research in this area. The next sections summarise key takeaways from the analysis.

IMPACT ON ARTISTIC INCOME

Have all artistic professions suffered equally?

Main results suggest an economically significant, negative income drop in 2020 over previous years and across all creative sectors. We observe the strongest decline for the group of performing artists, with an average estimated income loss of about 13% (€2,220) in 2020, 12% (€1,640) for musicians, 5% (€850) for fine artists, and 3% (€640) for writers. This loss of income from artistic self-employment is substantial when compared to the reported (mean) income in 2019 of performing artists (€16,700), musicians (€14,200), fine artists (€16,700) and writers (€20,300).

FIGURE 1 INCOME BY CREATIVE SECTORS



Note: The panel on the left shows absolute income levels by creative sectors, with writing (dark blue), fine arts (dark red), music (light blue) and performing arts (light red). The panel on the right presents relative income changes from one period to the next.

We present the main results in Figure 1. Notably, fine artists and writers such as self-employed and freelance journalists, authors or other publicists follow a slightly different pattern to other artistic categories with regards to their average income losses; they experienced relatively lower losses in self-employed income in the 2020 pandemic year. Arguably, point estimates indicate that writers and fine artists, more than other artists, were able, and might have been better positioned, to continue their work and commercial activities online and offline when theatres and concert venues were closed.

Figure 1 also reveals sectoral differences pre-dating the crisis, with average self-employed income highest for writers over the entire period of observation, followed by fine artists, musicians and performing artists.

Is there a gender income gap and how did the pandemic impact it?

In general, gender differences in creative sectors pre-date the 2020 crisis and largely prevail over the course of the 2020 pandemic year. On average, self-employed women artists earn roughly 10% to 35% less than self-employed men working in the same sector. The largest income gaps are observed for the performing and visual arts sectors. On average, income gaps are substantially higher in creative sectors than elsewhere in the overall work force population (currently standing at 18% according to 2021 data from the National Statistical Office).⁵ This finding, however, must be interpreted cautiously as comparability of income generated by women and men is limited in our data (for example, it does not allow us to account for gender differences in hours worked).⁶

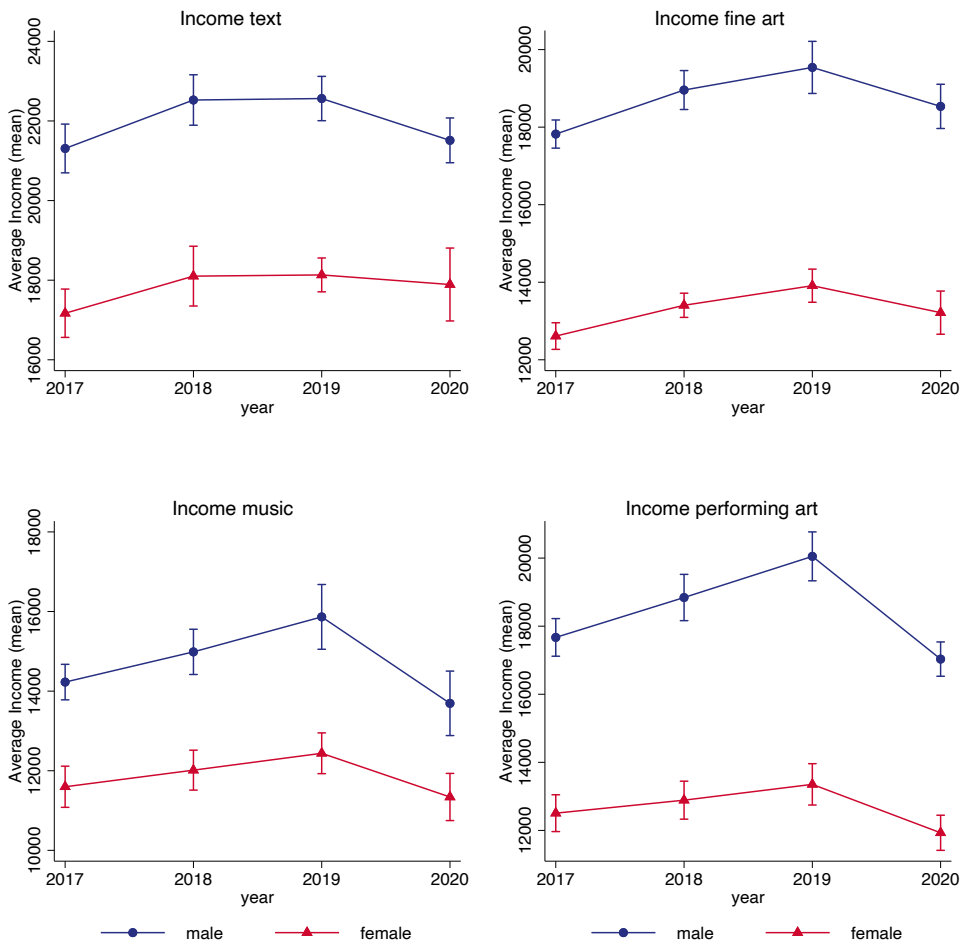
Still, as Figure 2 illustrates and as shown in the previous literature, the impact of the pandemic has not affected women and men artists uniformly.⁷ Here, it is interesting to note that female writers seem to have outperformed their male counterparts in 2020, based on our estimates. Put differently, while men clearly lost some of their income compared to 2019 levels, women writers, on average, lost relatively less and generated a comparable income over the same period. This is a notable result as it is at odds with the notion developed in many other studies on the impact of COVID-19 (e.g. Xue and McMunn 2021). Findings there suggest that women, more often than men, took over additional household hours during the pandemic (for example, when home schooling children). Arguably, this should also be reflected in hours worked in professional lives as well as the relative changes in income observed for each group. At the same time, it could be that female writers had more flexible work arrangements in the first place (for example, working from home/remotely more regularly in pre-pandemic times), shielding them from some of the losses male writers experienced.

5 https://www.destatis.de/EN/Press/2022/03/PE22_088_621.html;jsessionid=72D92ABFBA9B604793EAD0D29F814EB7.live742

6 Several studies have looked systematically at gender pay differences and survival of men and women in art occupations; see, for example, quantitative research by Marchenko and Sonnabend (2022) as well as Bille and Jensen (2018).

7 Petzold et al. (2020) study the psychological distress, anxiety and depression caused by the COVID19 pandemic in Germany and find that woman showed overall higher scores than men, in line with other research (e.g. Qiu et al. 2020, Wang et al. 2020).

FIGURE 2 INCOME BY GENDER



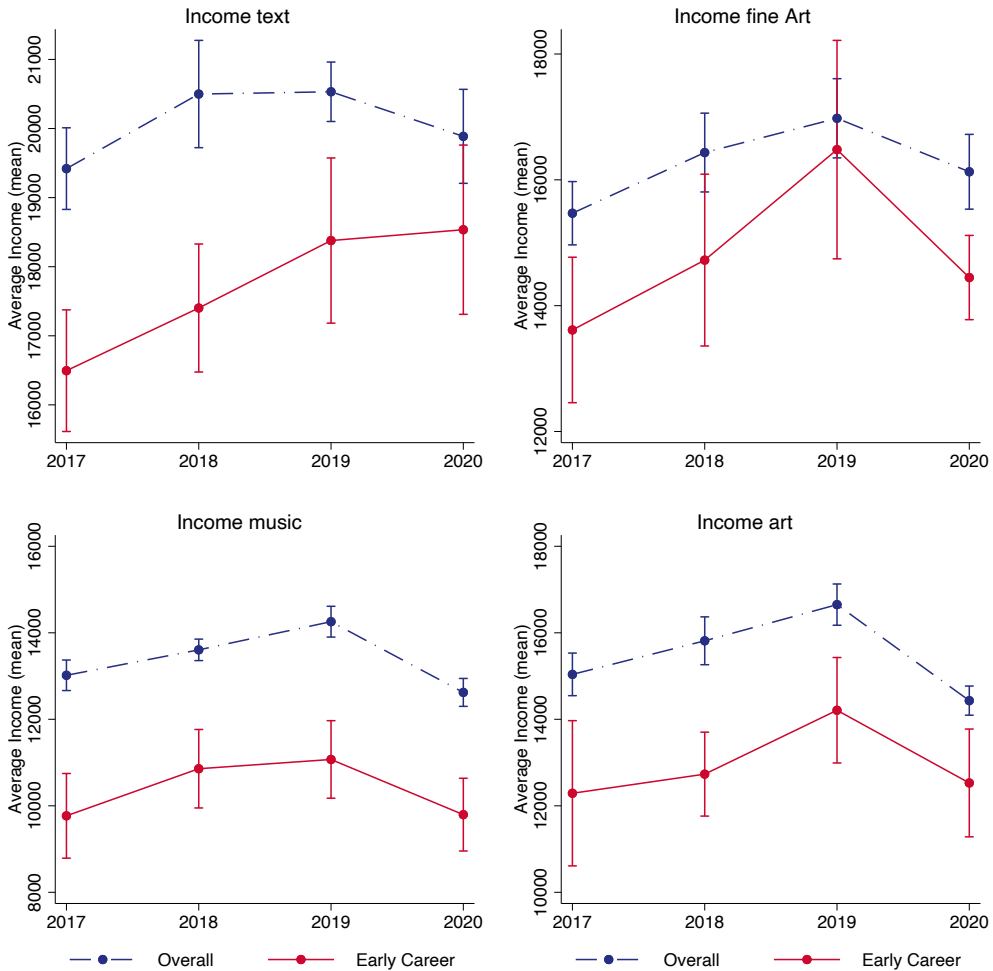
Note: Panels show predictive margins for each sector and over the observation period. Margins are calculated for women (red) and men (blue).

In other sectors, such as the performing arts, pandemic losses in 2020 should be assessed against the observation that, unfortunately, women did not fully participate in the income growth during pre-pandemic years, which mostly benefited male performers working in the same sector. So, the impact of the pandemic on income has had little overall effect on the existing, pre-crisis pay gap in the creative industries; in most sectors, women lost self-employed income from artistic practices equally. The next section looks more closely at the impact of the pandemic on artists at different career stages and artists working in different places.

Were younger and urban artists more exposed to the pandemic?

We now turn to the income situation of artists at different career stages and the impact on artists residing in different regions of Germany. We first test whether younger artists were more exposed to the pandemic than other, well-established artists working in the same sector, and provide some theoretical arguments for why this may be the case.

FIGURE 3 INCOME BY CAREER STAGE



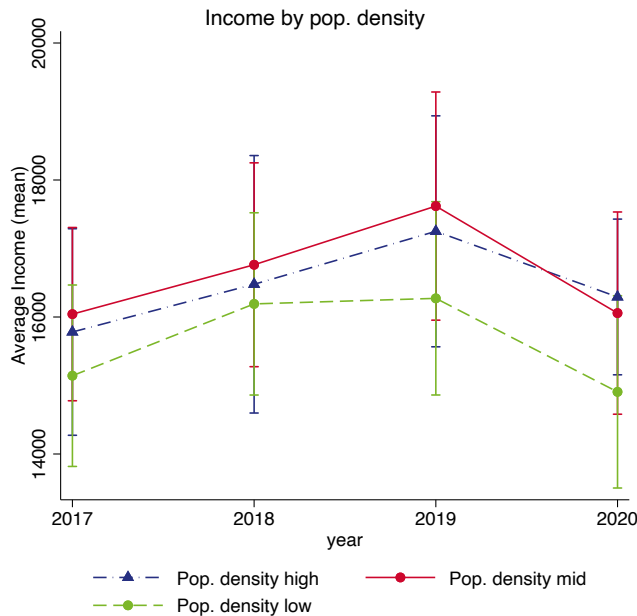
Note: Panels show predictive margins for each sector and over the observation period. Margins are calculated for early-stage artists (red) and the total population (blue). Observations that do not contain information on early-stage career artists are excluded from the estimation sample.

Average income reported in Figure 3 suggest that early-stage artists typically have lower income levels than the average artist in the total population. Again, our estimates indicate that the pandemic impact varies from one sector to the next. Often, it is the younger writers at less advanced career stages that outperformed average trends among writers in the sector. From an economic viewpoint, it is possible that as likely early adopters of

technologies, their work is more reliant on digital sources ex ante and thus their income may have been more resilient to the impact of the current pandemic. Ultimately, however, we cannot validate this line of argument as this would require additional research and better data. The impact on incomes also differs for fine artists. Here, early-stage visual artists experienced a more pronounced drop in their incomes than artists that are well advanced in their careers.

The next question we address is whether artists in different locations saw similar changes throughout the pandemic. Did artists residing in larger urban areas such as Berlin, Munich or Hamburg, for example, see similar losses to artists working in the same sector but residing in the countryside or a less populated region? As the pandemic began to spread and access to cultural and creative infrastructure and income from traditional sources deteriorated, some places may have been better equipped than others to accommodate and provide artists with alternative or new opportunities to generate self-employed income from artistic practices. Moreover, some urban agglomerations experienced higher infection rates and saw more restrictive and longer-term counter-measures set up in due course.

FIGURE 4 INCOME BY TYPE OF REGION



Note: Regions with high/medium/low population density are defined as Pop Density/ km² (high) > 1000 > (mid) > 200 > (low). More specifically, the first group includes Berlin, Hamburg, Bremen, the second group includes North Rhine-Westphalia, Saarland, Baden-Wuerttemberg, Hesse, Saxony, Rhineland-Palatinate and the third group the remainder Laender.

Source: German Statistical Office 2017.

Figure 4 depicts sectoral trends for urban and rural areas in Germany depending on their population density. Predictive margins indicate that, on average, artists in more populated areas typically earn higher self-employed income. Income trends over time do

not show significant variation in regional differences during the 2020 pandemic waves. If anything, artists resident in regions with medium-level population densities, such as North Rhine-Westphalia or Baden-Wuerttemberg, saw lower losses than comparable artists located in either more urban or more rural areas (states).

POLICY DISCUSSION

From a policy perspective, it is impossible to judge whether damage to the financial health of artists will be permanent or not based on the evidence available to us. At this point in time, it is also unclear how much public policy and recovery packages will make up for income losses among artists,⁸ or can help rebuild some of the cultural institutions and places (theatres, night clubs, etc.) that may not survive the overall pandemic. This is, of course, also a question of political priority. At the same time, we trust that our income estimates do not suffer from funding bias, as much of the financial support granted and distributed from public and private sources to artists in Germany will only become visible in the 2021 income data.

Moreover, there are already a number of policies in place, including cultural policies, copyright policies, social safety net policies and various others, that together can all help address financial vulnerability of certain groups of artists in the course of the pandemic. As concerns copyright, some national policies explicitly target the improvement of bargaining positions for individual creators in markets vis-à-vis more dominant stakeholders in the industry,⁹ so this is one possible road to follow to improve financial health in the longer term – if that is what policies aim to achieve.

Finally, beyond the income losses we document in this chapter, some of the economic impact of the pandemic may in fact be positive. In some creative sectors, the pandemic seems to have served as a catalyst for digitisation and a means to greater artistic collaboration and production, as evidence from recent industry reports indicates (Arndt et al. 2021). So, it may be that in some creative sectors previously lagging behind and perhaps more reluctant to adopt new technologies, we might see efficiency and productivity gains in the near future. However, that goes beyond what our data can tell us. Ultimately, a more holistic assessment of the impact of the pandemic will be needed that also accounts for this aspect of potential technological upgrading of sectors.

⁸ For example, federal-level recovery programmes such as the *Neustarthilfe* targeting self-employed, which provides one-time funding of up to €7,500 for individuals to recover income/revenue losses. See <https://www.ueberbrueckungshilfe-unternehmen.de/UBH/Navigation/DE/Dokumente/FAQ/Neustarthilfe/neustarthilfe.html> for more information.

⁹ An example of such contract-related policies is the 'best-seller clause' which German copyright laws and most recent EU Directives (Article 20 DSM, 2019) provision. Put simply, the clause gives sellers of a license (e.g. creators) legally enforceable rights to renegotiate contracts and claim higher revenue shares in case the work (unexpectedly) turns out to be a blockbuster *ex post*.

CONCLUDING REMARKS

We provide quantitative evidence that, over the course of the first year of the pandemic, the creative and cultural sectors in Germany were heavily impacted but on different scales, with musicians and performing artists experiencing the biggest relative losses in self-employed income. Net income losses range between 3% and 13%, depending on the specific sector. This compares to a general decline in total employment income in Germany of around 4% in 2020.¹⁰ The crisis has not substantially changed the existing gender income gap across creative and cultural sectors and nor have income differences at different career stages disappeared, all which predated the outbreak of the pandemic. We also find that artists residing in urban or rural areas suffered equally from income losses, independent of their location. Admittedly, our findings must be considered preliminary as, based on the data available to us at the end of May 2021, the impact of COVID-19 is restricted to the 2020 waves and public interventions, so we cannot account for the 2021 pandemic effects yet.

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CENTRE FOR ECONOMIC POLICY RESEARCH

The Covid-19 pandemic has profoundly affected the ecosystems that spur innovation and creativity around the world. Innovators faced demand shocks, heightened uncertainty, far-reaching supply disruptions and a radical shift in the demand for new technologies. How did they respond?

A new ebook published by CEPR untangles how the Covid-19 shock shaped the innovation landscape of the world's major economies, and how scientists, entrepreneurs and creative professionals responded to the crisis. The ebook's 18 chapters – authored by institutional and academic economists – paint a picture of resilience and ingenuity. They not only document that innovation was at the centre of addressing the public health emergency, but also how the Covid-19 shock has unleashed a new entrepreneurship wave driven by digital technologies that has reshaped economic activity

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