



Early R&I insights into COVID-19



R&I PAPER SERIES

LITERATURE REVIEW



Research and Innovation

Early R&I insights into COVID-19

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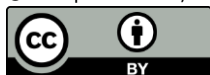
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Literature review

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INTRODUCTION

This review is developed by the 'Economics of R&I' team of the Chief Economist unit of DG Research and Innovation. It provides a brief summary of a selection of recent publications on R&I economics and policy. Contributors: Lukas Borunsky, Ana Correia, Roberto Martino, Oliver Podmanicky, Ruzica Rakic (coordinator for the review), Julien Ravet (team leader).

This edition of the review presents recent papers that analyse the role of R&I in the context of the COVID-19 crisis. As highlighted in this review, R&I is at the core of the response to the coronavirus pandemic, as part of a fast and innovative healthcare response, but also for monitoring and containing the spread of the infection, with for instance Industry 4.0 providing solutions for the production of personal protection equipment.

The current crisis is expected to have significant economic and social consequences. The growth and innovation potential of companies, in particular start-ups, are at risk, with experience from previous crises showing that availability of venture capital is likely to decrease with

economic contraction. This calls for counter-measures to support a recovery that should build on bold industrial and investment policies. The emergency of the situation also changes the nature of our R&I activities: innovators and firms find themselves engaged in new relationships and we can observe remarkable shifts of funds to cope with the new virus.

There is an opportunity today to ensure a recovery that is consistent with an aspiration towards a fair, green and digital Europe. This aspiration is the guiding thread of the 2020 edition of the Science, Research and Innovation Performance of the EU 2020, which is also presented in this review.



A FAIR, GREEN AND DIGITAL RECOVERY

European Commission (2020). Science, Research and Innovation Performance of the EU 2020. A Fair, Green and Digital Europe.

Messages

1. Research and innovation play a key role in providing solutions to overcome immediate challenges such as the coronavirus pandemic and in making our society more resilient in the long term. 2. EU R&I policy should shift to a transformative policy.

The Science, Research and Innovation Performance of the EU 2020 analyses Europe's performance in science, research and innovation and the driving factors behind that performance in a global context.

The Covid-19 crisis is unprecedented and the world has been struggling to contain the pandemic. More than ever, an anticipatory, rapid and effective R&I response is crucial. While R&I is at the core of the response to the pandemic itself in the areas of virology, vaccines development, treatments and diagnostics, it will be also crucial in the economic recovery from the crisis, not only to spur economic activity, but also to accelerate the transitions that our planet and society need. In global

emergencies, such as the Covid-19 pandemic, it is also essential to remove all obstacles to the free flow of data,

researchers and ideas.

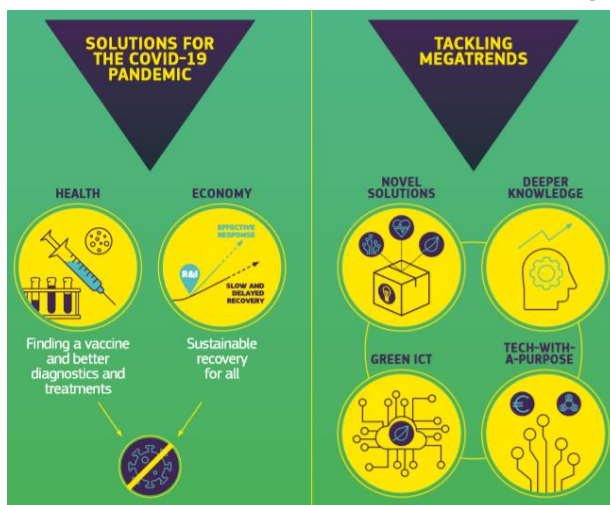
At the same time, Europe and the world are facing major long-term environmental and social challenges. These range from climate change, biodiversity loss, and depletion of natural resources, to an ageing population and growing inequalities.

The interconnection between social, economic and environmental issues calls for systemic change in which R&I plays a

key role. Hence, to deliver on the Green Deal, EU R&I policy should shift to a transformative policy.

The report provides 11 policy recommendations to support our people, planet and prosperity. The five principles that should guide

R&I policy in Europe are co-creation, diffusion, uptake, transformation and directionality.



INDUSTRY 4.0 FOR FIGHTING COVID-19 PANDEMIC

Javaid, M., Haleem, A., Vaishya, R., Bahl, S., Suman, R. Vaish, A. (2020). Industry 4.0 technologies and their applications in fighting COVID-19 pandemic. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*.

Messages	1. Industry 4.0 technologies can have an important role in combatting the global public health crisis related to the COVID-19 pandemic. 2. The benefits include monitoring and containing the spread of the infection, enabling virtual working arrangements, improved testing and diagnosis. 3. In the manufacturing sector, Industry 4.0 solutions has helped with customised and automated solutions for the production of masks and other personal protection equipment.
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The authors explain that digital technologies such as AI and IoT allow e.g. for real-time processed information for more flexible production lines. Moreover, the production of medical equipment can also benefit from 3D printing and other digital manufacturing technologies to produce certain parts of products. This paper performs a literature review on the technologies of Industry 4.0 and their applications in the COVID-19 pandemic, using text mining techniques applied to databases such as PubMed, SCOPUS, Google Scholar and Research Gate. This led to the identification by the authors of the following Industry 4.0 technologies that can play a key role in tackling COVID-19: Artificial intelligence, Internet of things, Big data, Virtual reality, Holography, Cloud computing, Autonomous robots, 3D Scanning, 3D printing, and Biosensor.

AI can help in predicting the outbreaks, monitor the spread of the virus, optimise clinical trials for drugs and vaccines, be embedded in robots programmed for e.g. sanitisation jobs, or produce CT scans. In addition, IoT and other connectivity

solutions can enable tracing the origins of outbreaks, or in telemedicine to avoid overcrowding of hospitals in pandemic times. Big data can enable predictions and forecasts of the reach and impact of the virus, leading to more anticipatory decision-making. Virtual reality is also regarded as an efficient alternative to video calls and travelling that also enables new strategies for working in teams. Holography is also gaining some momentum, as its “ultra-realism” can provide a new option to live events. Moreover, cloud computing and its infrastructure enables innovation, reduces costs and efficiently manages servers, storage, or databases. Autonomous robots can also be used to ensure people respect the lockdowns, and minimize the disruptions in hospitals. 3D Scanning is another relevant Industry 4.0 technology that can provide thoracic chest scanning for COVID-19. 3D printing has become one of the most popular technologies when the stocks of personal protection equipment were limited. Finally, biosensors can allow for the early detection and then the monitoring of the symptoms of COVID-19.

Artificial
intelligence

Internet-
of-Things

Big data

Virtual
reality

Holography

Cloud
computing

Autonomo
us robots

3D
Scanning

3D printing

Biosensor

FAST AND FRUGAL INNOVATIONS IN RESPONSE TO THE COVID-19 PANDEMIC

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

Messages	1. Repurposing, reuse & rapid deployment are the three approaches towards a fast and innovative COVID-19 healthcare response. 2. The pandemic may serve as the greatest equaliser of our time and teach us to recognise the fragility in all our healthcare systems.
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The lack of time and resources available to respond to the crisis, as well as the need for rapid scaling in every context, has led to an explosion of innovative responses. India and Pakistan are refitting their rolling stock of trains to become hospital wards for patients with COVID-19. China constructed a 1,000-bed hospital in 10 days. Distilleries have pivoted to produce millions of bottles of hand sanitizer and the UK has commissioned all of its private-sector hospitals for use by the National Health Service.

healthcare in the best way possible under given circumstances. The authors identify three approaches in responding to the COVID-19 threat: repurposing, reuse and rapid deployment (see table).

The accelerated pace of clinical-trial approval around the world, has shown how traditionally conservative institutions can act rapidly in times of urgency. The physical barrier to co-creation posed by social distancing has been mitigated partly through the greater use of digital tools.

These responses bear the hallmarks of ‘frugal innovation’—that is, doing more, with less. Frugal innovation in healthcare does not mean low quality but instead means the ability to provide safe

Necessity is the mother of invention, and human beings can be resourceful, particularly in crisis. Thus, the pandemic may teach us to recognise the fragility in all our healthcare systems.

	Feature	Frugal Innovation Approach	Opportunities for scaling	Challenges
Hydroxychloroquine	Anecdotal evidence suggested some benefit as prophylaxis.	Repurposing from malaria prophylaxis and treatment.	Cheap and readily available	The evidence base is currently weak.
Ventilator multipliers	3D-printed device available to connect multiple ventilator hoses to a single ventilator chine.	Rapid production and reuse of existing ventilator machines.	3D printing enables rapid prototyping and production.	Testing showed potential but it has not yet been tested on human subjects
Face masks	A4 acetate sheet used for overhead projector presentations repurposed as a face shield.	Reuse of existing material and assets available widely in the office place.	To partially obviate the need for full face protection.	Full protection is unlikely.
DIY face masks	Countries that made wearing a face mask mandatory incentivised people to make their own masks using household material.	Reuse of existing material, skills and assets for rapid production.	Idle workforce in homes and other places can be utilized to produce protective equipment.	Little evidence that household fabric and materials can provide effective protection.
Frugal ventilator machines	Mercedes-Benz and Tesla are applying their manufacturing capability to produce ventilator parts. Oxford, UCL and King's College reverse engineered a continuous positive airway pressure breathing aid.	Repurposing and reuse of existing material for rapid production.	The device was granted approval by the UK Medicine and Healthcare Product Regulatory Agency in record time.	Order fulfilment and delivery has stalled in early stages.

STARTUPS IN TIMES OF CRISIS

Kuckertz, A., Brändle, L., Gaudig, A., Hinderer, S., Reyes, C. A. M., Prochotta, A., Steinbrink, K. M. and Berger, E. (2020). [Startups in times of crisis – A rapid response to the COVID-19 pandemic](#). *Journal of Business Venturing Insights* 13.

Messages	1. While start-ups are successfully leveraging their available resources as a first response to the crisis, their growth and innovation potential are at risk. 2. Policy measures should not only provide first aid to start-ups by alleviating the pressure caused by constrained cashflow, but also involve long-term measures embedded in and supported by the wider entrepreneurial ecosystem to ensure rapid recovery and growth.
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The lockdown measures threaten the existence of many innovative start-ups with a growing impact on the global economy. Start-up founders report trying to gather capital through internal measures and applying for government support. However, services offered by government policy often exclude start-ups because they are not bankable, or the support programmes are beset by bureaucratic hurdles.

From a policymaker's perspective, it would be unwise to rely solely on entrepreneurial initiative to fix the economic damage triggered by lockdown measures; instead, it should be a key priority of policymakers to guarantee that innovative start-ups can call on sufficient resources.

The authors' quantitative analysis of the international media discourse

differentiates measures called for by stakeholders such as entrepreneurs, scholars, or lobbyists (40.98%) and policy measures announced by government or central banks (59.02%) suggesting that most governments reacted promptly to the COVID-19 crisis. Most measures represent short-term aid; with the most popular policy measure announced being to reduce loan interest rates or to improve loan availability.

The rapidity of the outbreak and spread of COVID-19 meant that most countries (87.80%) looked at providing immediate relief. Nevertheless, the first calls for long-term measures are emerging (in 17.07% of countries) e.g. the Chinese call to secure the accessibility of financial capital for innovative start-ups. However, countries announcing policy measures explicitly addressing start-ups are the exception (26.83%).

Challenges	Start-up options	Policy options
Avoid immediate start-up failure	<ul style="list-style-type: none"> • Use resources at hand to create solutions to new problems • Activate network resources 	<ul style="list-style-type: none"> • Offer payment delays, wage subsidies, direct payments • Communicate community feeling to stimulate mutual assistance
Adapt due to disruptions in core start-up infrastructure	<ul style="list-style-type: none"> • Focus of channelling resources only on recently viable and value generating activities • Downsize other activities 	<ul style="list-style-type: none"> • Offer employee development programs • Support temporal downsizing through wage subsidies
Continue start-up growth against all odds	<ul style="list-style-type: none"> • Discover opportunities creating value in solving consequences of the crisis (e.g., developing hygiene or digital work solutions) 	<ul style="list-style-type: none"> • Secure future innovativeness through mid-, or long-term policy measures • Lay foundations for post-crisis recovery by incentivising investors
Respond to mismatch of initial policy measures	<ul style="list-style-type: none"> • Gather information and best-practice through entrepreneurial networks • Support lobbying initiatives of (trade) associations to be included in policy decisions and programs 	<ul style="list-style-type: none"> • Provide information and support services addressing the specific challenges of start-ups • Decrease specific barriers for start-ups in the application of start-up specific support

FINANCIAL DISTANCING AND INNOVATION

Howell, S., Lerner, J., Nanda, R. and Townsend, R. (2020). Financial Distancing: How Venture Capital Follows the Economy Down and Curtails Innovation. Harvard Business School Working Paper.

Messages

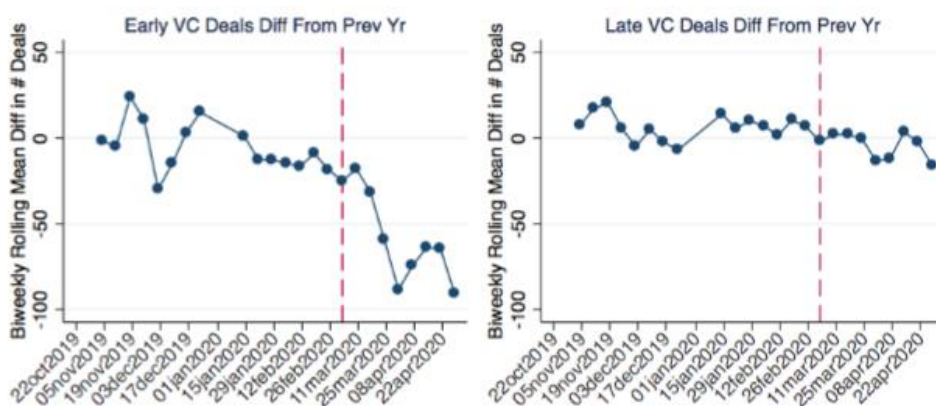
1. The paper finds that early-stage venture capital (VC) behaves procyclically, declining during crises. Such behaviour is common to “standard” economic and financial crises and it characterised the most recent COVID-19 crisis as well, with a 38% fall in the United States. 2. This bears a negative impact on innovation by VC-backed companies, both in terms of volumes and quality as measured by patent citation.

It is often claimed that VC tends to be insulated from economic downturns, justifying institutional asset allocation to and increasing policy interest for the sector. Given the importance of VC for innovative start-ups, such immunity would ensure innovation also during recessions. The paper investigates whether this has been the case in the most recent COVID-19 crisis and in other economic downturns as of 1976, exploiting data for the United States on VC financing and patents.

Results seem to support the procyclicality of innovation (and its diffusion) as reported by some of the recent literature. While later-stage VC has been relatively unchanged both in

the last and in previous recessions, early-stage tends to decline with economic output. In the case of the COVID-19 crisis, early stage VC declined by nearly 38% between March and May 2020.

This has important implications for VC-backed start-ups in terms of innovation output. While VC-backed companies are relatively more innovative than competitors, their patents declined both in volume and in quality, as measured by the share of highly-cited patents. The authors find that these trends are likely to be explained by reduced supply of VC, which becomes scarcer, more costly and more risk adverse during recessions.



Note: the figure plots the number of US VC deals by investment stage using data from Pitchbook.

INNOVATION AND SURVIVAL OVER THE BUSINESS CYCLE

Cefis, E. and Marsili, O. (2019). Good times, bad times: innovation and survival over the business cycle. Industrial and Corporate Change, Oxford Academic.

Messages

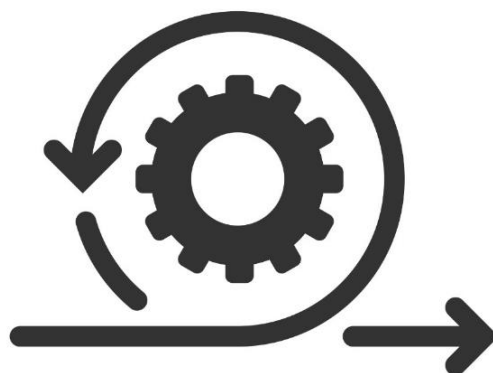
1. New firms innovating within the first two years from their founding enjoyed a long-term adaptive survival premium during and after the crisis. 2. Product innovation is a primary source of survival during and after the crisis, while process innovation has a short-lived positive effect during the crisis. Organizational innovation and marketing innovation are ancillary or even detrimental.

The paper investigates how the founding innovative capabilities of new firms created in the Netherlands in 2001–2006 affected their survival likelihood before, during and after the 2008 financial crisis, by exploiting the data from the Community Innovation Survey.

New firms that innovate at the time of the founding build distinctive and long-lasting adaptive capabilities, which increase their chances of survival to shocks. This outcome is unconditional on their investment decisions during and after the crisis. The authors also argue that adaptive capabilities vary by type of innovation, comparing technological innovations, in products and processes, to managerial innovations, in organizational and marketing practices. Early capabilities in product innovation are critical for building long-term resilience, extending over the period of (tentative) recovery

from the crisis. Conversely, relying on efficiency and cost-saving improvements (process innovation) or on changes in managerial practices (organizational innovation) can help young firms to survive the onset of a financial crisis, but does not sustain their survival in the longer term.

From a management perspective, new firms need to find rapid ways to adapt because of internal resource constraints, otherwise available to established firms as a buffer to external scarcity. From a policy perspective, new firms may need to be protected, before they develop the complementary assets necessary to commercialize their innovative ideas. The most worrying threat of a financial crisis is to halt process of entrepreneurial experimentation, which is essential to promote economic growth and to boost the system out of a recession.



CONFINEMENT MEASURES AND EU LABOUR MARKETS

Fana, M., Tolan, S., Torrejón, S., Urzi Brancati, C., Fernández-Macías, E. (2020). COVID confinement measures and EU labour markets. JRC technical report, JRC120578.

Messages	<p>1. The impact is likely to concentrate on people with lower wages and worse employment conditions.</p> <p>2. The forced transition to a large-scale telework regime is likely to have been much more difficult in some countries than others.</p> <p>3. Counter-measures should include bold industrial and investment policies that provide large scale opportunities, such as an ambitious European Green Deal.</p>
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The paper assessed impact of the confinement measures introduced to halt the spread of coronavirus on the labour markets in Germany, Italy and Spain. All three countries have regulated lockdowns by identifying essential and not essential activities in health, food, security, education and administrative services. The evidence from three countries uncovers differences in the definition of essential activities and mandatory closures. Both government responses and their enforcement remain heterogeneous as for instance, in some cases national measures can be adjusted at the local level in any direction.

After analysis of the COVID confinement measures, the authors considered three criteria (essential sectors, *teleworkability* and forceful closure) to rank all the economic sectors and to classify them according to the impact of the COVID confinement decrees. These national specificities were projected on shares of sectoral employment (see table). Applied to the employment in the EU28, around 25% of employment is in sectors considered essential and operating more or less as normal even in a strict confinement regime. When widening to teleworking or partly active jobs, between 50 and 60% of EU employment would be active under the strict confinement. On the other hand, sectors that are marked as non-essential and explicitly closed because of the high contagion risk account for

less than 10% of overall EU employment (with significant cross-country variations).

The forcefully closed sectors are characterised through a prevalence of self-employment and almost one third of workers in these sectors are people less than 30 years old. Therefore, strict measures concerning those sectors are likely to have a particularly negative impact on younger workers. Furthermore, in the majority of countries workers in the forcefully closed sectors belong to the lowest average wage percentiles groups. These findings suggest that impact of the COVID crisis is likely to concentrate on the groups less equipped to deal with unemployment and sudden income losses. Technological progress and teleworking could help to milder the effects on employment, but there are enormous differences in the prevalence of telework across EU countries. Therefore, the recently forced transition to a much more generalised telework regime triggered by the COVID crisis is likely to have been much more difficult in some countries than others.

	Absolute number workers (thousands)		Employment share	
	In essential sectors	Total employment	In essential sectors	In non-essential
DE	23150.2	41914.5	55.2%	44.8%
ES	8490.2	19327.7	43.9%	56.1%
IT	14412.6	23214.9	62.1%	37.9%

Impact of confinement measures on employment

INTELLECTUAL PROPERTY IN TIMES OF CRITICAL PRODUCTION

Tietze, F., Vimalnath, P., Aristodemou, L. and Molloy, J. (2020). Crisis-Critical Intellectual Property: Findings from the COVID-19 Pandemic. University of Cambridge, Centre for Technology Management Working Paper Series No. 2.

Messages

1. In the time of emergency, innovation stakeholders and manufacturing firms engage themselves in new relationships. 2. Governmental decisions may prevent the occurrence of intellectual property related challenges among all actors. 3. Majority of coronavirus related patents are in the fields of organic chemistry and development of methodologies and drugs for prevention, diagnosis and treatment of viruses.

This paper aims at raising awareness that intellectual property (IP) considerations need to be addressed at an early stage of the pandemic and provide guidelines for policy makers and other stakeholders.

It focuses on the innovation perspective of the pandemic and provides analysis of the IP issues related to prevention,

diagnostics and treatment of COVID-19.

First weeks of the pandemic brought to the forefront five technology related challenges: treatment for acute respiratory pneumonia caused by COVID-19; diagnostic testing kits development and manufacturing in extremely large volumes, sharply rising need for intensive care units (ICU) in hospitals; improved digital capabilities for modelling and monitoring; high demand for skilled medical staff equipped with personal protective equipment (PPE).

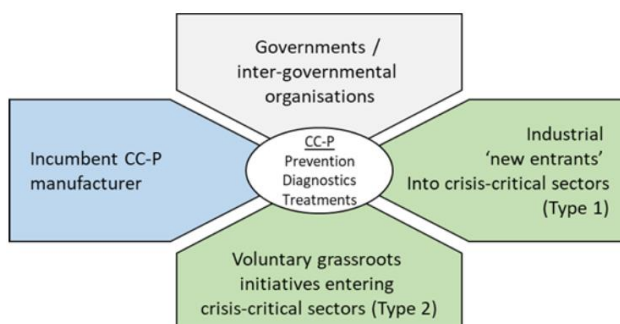
After defining crisis-critical (CC) IP as a set of intellectual property relevant for the research, development, manufacturing and distribution of critical

products, the paper develops scenarios with four main stakeholder groups. These scenarios distinct stakeholders depending if they operated in the crisis-critical sectors before pandemic or

reinforced these sectors later. New entrants may emerge from the industry, but also from voluntary grassroots initiatives, such as start-

ups or entrepreneurial scientists.

While industry entrants are likely to own IP before entering these sectors, grassroots initiatives typically form it only after the entrance. These new set-ups on the market lead to wide ranging innovation activities of all actors. At the same time, governments should consider ways to reduce IP related risk for all. Different approaches require active governmental involvement to facilitate options such as voluntary based lending of non-exclusive licences to new entrant for the time of pandemic, facilitation of patent pools that have already been used in the industry or, as a last resort, the governments have the opportunity to use compulsory licensing in the time of pandemic.



COVID-19 INSIGHTS FROM INNOVATION ECONOMISTS

Younes, G. A., Ayoubi, C., Ballester, O., Cristelli, G., de Rassenfosse, G., Foray, D., Gaule, P., Pellegrino, G. & van den Heuvel, M. and Webster, B, (2020). [COVID-19 Insights from Innovation Economists](#).

Messages

1. Failures on the market for vaccine research are important cause of the crisis. 2. There is a remarkable shift of funds to cope with the new virus, however, the authors argue that in the long run, more support is needed. 3. The current response to the pandemic, characterised by intellectual freedom, scientific openness and decentralized competition, is more suitable than the mission-oriented (command-and-control) approach.

The authors identify the following general reasons for underinvestment in vaccine R&D: an insufficient demand for vaccines in normal times; vaccine is subject to a time consistency problem; it is characterized by high fixed costs for research but relatively low cost of manufacturing. In the current situation, most of the mentioned market failures have however been solved due to the large public investment in the research.

The case for investing in research to prevent pandemic outbreaks may have been strong, however the authors argues that the discrepancy between the needs and the current level of support is enormous. In the short run, only a subset of researchers have the right human capital to advance the knowledge frontier in any specific area. This may be mitigated by the fact that a wide range of innovations could be useful to fight COVID-19, from vaccines, drugs and medical equipment to innovation in testing. Even minor innovations could be useful and the upside of a breakthrough is massive. In the longer run, policy should aim at increasing the total quantity of inputs that go into the research, and in particular in human capital at the right level of skills and knowledge.

The authors claim that the mission-oriented approach delivers best results when there is a specific and well-defined

technology target. Despite the fact that the current crisis, identified by the clear goal of finding a vaccine very quickly and at any cost, seems to represent a case for mission-oriented approach, the authors oppose it. They argue that the current response, characterized by the intellectual freedom, scientific openness and decentralized competition is indeed the right one.

Patents may be a barrier in the fight against COVID-19. The best would be if private companies would act responsibly by providing a broad and affordable access to tests, drugs, and vaccines. Also, a 'patent pool' (a collection of patents from different patent holders available in bulk) would provide an incentive in the search for a solution. Such patents in a pool are available in one place, under clear terms, and at a reasonable price. If voluntary contributions fail, governments can force patent holders to share their inventions.



COVID-19 RECOVERY PACKAGES AND CLIMATE CHANGE

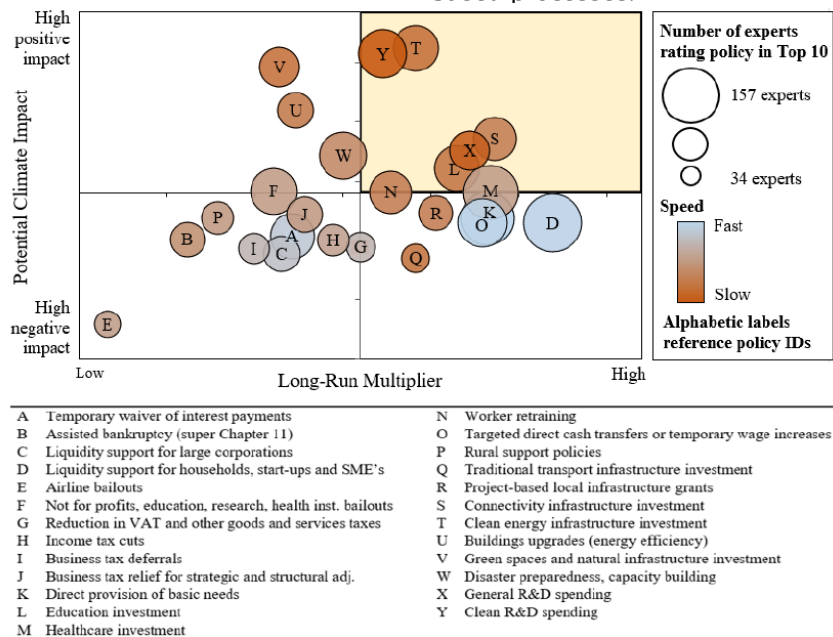
Hepburn, C., O’Callaghan, B., Stern, N., Stiglitz, J. and Zenghelis, D. (2020). Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change? Forthcoming in the Oxford Review of Economic Policy.

Messages

1. The paper identifies five policy actions that can make COVID-19 fiscal recovery packages climate-positive: clean infrastructure investment, buildings efficiency, investment in education and training, natural capital investment and clean R&D investment. 2. The identified policies are perceived as both highly desirable for climate targets and characterised by high multipliers in the long term, because of strong returns on public investment.

The COVID-19 crisis brought a decline in economic activity. The restrictions in mobility have reduced global energy demand and pollutant emissions. However, these trends are likely to be reversed and the magnitude will depend on the nature of the economic recovery and the type of recovery policies that will be implemented. The paper exploits data from a survey on 264 officials from policy institutions, think-tanks, and academia to gather perspectives on COVID-19 recovery packages. Experts are asked to assess 25 policy archetypes based on three metrics, i.e. speed of implementation, climate impact potential and long-run economic multiplier.

Survey results together with an analysis of existing literature on expansionary fiscal policy suggest that clean infrastructure investment, buildings efficiency, investment in education and (re)training, natural capital investment and clean R&D spending are highly desirable policies, as they have favourable impacts on climate and high long-run multipliers. Furthermore, non-economic and non-climate benefits can increase the desirability of such policies, e.g. in terms of social outcomes, particularly in low-income countries. The policy design is also found to be crucial, most notably by prioritising investment based on consultative and evidence-based processes.



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