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Commission

Quarterly R&I literature review 2021/Q1

R&I in times of crisis



R&I PAPER SERIES
LITERATURE REVIEW



Research and
Innovation

R&I in times of crisis

European Commission
Directorate-General for Research and Innovation
Directorate G — Common Policy Centre
Unit G.1 — Common R&I Strategy & Foresight Service

Contact Jessica Larsson, Deputy Head of Unit G1, Deputy Chief Economist
Ruzica Rakic, Coordinator of the Literature Review, Unit G1

Email Jessica.LARSSON@ec.europa.eu
Ruzica.RAKIC@ec.europa.eu
RTD-ECONOMIC-ANALYSIS@ec.europa.eu

European Commission
B-1049 Brussels

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EUROPEAN COMMISSION

R&I in times of crisis

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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, Ruzica Rakic (coordinator for the review), Julien Ravet (team leader).

This edition of the review covers papers and reports that emphasize: (i) the R&I response in times of crisis, and (ii) specific digital issues related to R&I.

Crises create unique opportunities and demand on research and innovation systems. The current pandemic has created economic and financial pressure that could compromise the ambitions of R&I systems. The latest EIB investment report estimates that 45% of EU firms can be expected to reduce their investments with the current crisis. On the other hand, the recent OECD STI Outlook highlights how R&I have played a central role in the response to the COVID-19 crisis. To this respect, R&I can be seen as a key strategic investment in times of crisis, and there is a critical role for public institutions and government-led incentives to play today.

Digital technologies have been main enablers for business continuation during the pandemic. However, EU companies are less present than the US and Chinese ones in fast-growing digital sectors (although the EU registers much more patents in both green and digital technologies than its global competitors). Digital capital has accumulated over time to a point where it corresponds to at least a quarter of the assets of firms today (based on US data), with concentration in ‘superstars’ companies. At the same time, with the expansion of new data and methods, and the development of initiatives such as the European Open Science Cloud, we may be at a turning point in various scientific fields. Against this backdrop, skills, in particular digital skills, remain an essential asset for Europe.



COVID-19, MARKET SIZE AND R&D RESPONSE

Agarwal, R. and Gaule, P. (2021), [What Drives Innovation? Lessons from COVID-19. Working Paper, IZA Discussion Paper Series, No 14079.](#)

Messages 1. With the COVID-19 crisis, the R&D response in terms of trials has been significantly larger than what would be implied by market size. 2. The aggregate short-term elasticity of science and innovation can be very large. 3. Public institutions and government-led incentives were a key driver of the COVID-19 R&D effort.

What lessons can we draw from the response to COVID-19 about the drivers of innovation? With the COVID-19 pandemic, we can observe a rare instance of a large discrete shift in global medical needs and in the market size for the pharmaceutical industry. In this paper, the authors examine how the landscape of clinical trials changed in response to the COVID-19 shift.

Based on publicly available data on pharmaceutical clinical trials around the world, they find that:

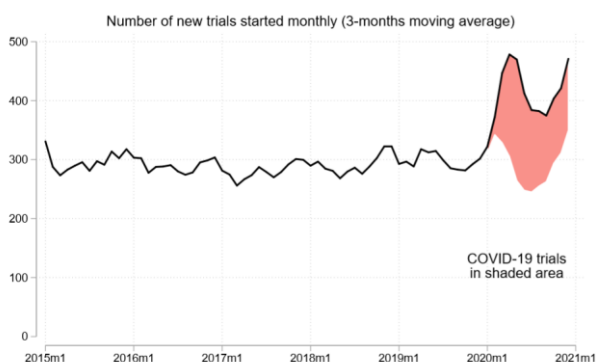
1. Typically, global pharmaceutical industry follows the ‘law of diminishing efforts’, with an elasticity of R&D effort with respect to market size of about 1/2.

2. However, the number of COVID-19 trials has been 7 to 20 times greater than that implied by the historical relationship between market size and R&D effort.

3. In the initial months of the pandemic, up to 50% of newly started trials were directed towards COVID-19. New clinical trials increased by 38% in 2020 with little crowding out of R&D effort for other diseases.

4. Public research institutions and government-led incentives were a key driver of the COVID-19 R&D effort, accounting for 70% of all COVID-19 clinical trials globally, and being 10 percentage points more likely to conduct a COVID-19 trial relative to private firms. In addition, concerning the speed of COVID-19 vaccine development, U.S. and Chinese candidates were on average 2 months faster than candidates from other countries.

Hence, boosting market size by itself may not be an effective tool to scale up innovation to fight large diseases. The authors suggest taking a broader perspective on what drives innovation, with a key role for policymakers and philanthropists to complement the market size effect in order to scale up global innovation to promote the greater good.



Notes: Based on clinicaltrials.gov data, the figure displays the total of new clinical trials worldwide (across all diseases) on a monthly basis. COVID-19 trials are shown in the shaded area. COVID-19 trials are tagged as such by clinicaltrials.gov based upon a set of keywords related to COVID-19.

OPTIMAL INNOVATION POLICY IN CRISIS TIMES

Gross, D. P. and Sampat B. N. (2021), [The Economics of Crisis Innovation Policy: A Historical Perspective](#). Working Paper, NBER Working Paper Series

Messages 1. Crises put unique demands on the innovation system. 2. Optimal crisis innovation policy is likely different from optimal innovation policy in normal times. 3. Overinvesting in R&D during disease, environmental catastrophe, or even war crises can be less costly than undershooting.

The authors define crisis as “an immediate, extreme threat to human life, prosperity, or freedom” and argue that crises, such as disease, environmental catastrophe, and even war, can be tackled with science, technology and innovation. Overinvesting in R&D during such crises can be less costly than underinvestment.

There have been many comparisons between the COVID-19 crisis and the World War II. In terms of R&I, the authors analyse how the U.S. Office of Scientific Research and Development¹ (OSRD) approached World War II crisis innovation and use that example to shape a discussion of the specific features of crisis innovation problems.

The paper describes five main features of the OSRD organization useful to consider in designing a theory of crisis

innovation: **1. Emphasis on applied research**, where the priorities are defined with end users; **2. Prioritizing results**, where OSRD favored R&D contractors “with the facilities and the manpower which promised the best results in the shortest possible time”; **3. Coordination**: end users can often give valuable guidance to crisis R&D efforts; **4. Redundancy**: the need for fast solutions may rationalize funding of overlapping research efforts and collaboration amongst R&D performers; and **5. Diffusion**: during the crisis, it is important to ensure that finished technology can be produced at scale and deployed as soon as the R&D is complete.

The table below summarizes some of the implications of crisis for R&D in regular times.

IMPLICATIONS FOR R&D IN REGULAR TIMES

It is important to invest in basic research and in additional technological and scientific capabilities, including growing the stock of scientific human, physical, and institutional capital across a range of fields.

It is important to be able to design R&D-funding and R&D-performing institutions that can pivot quickly in a crisis.

Crises can also have effects on innovation that outlive the crisis itself. It seems possible that the COVID-19 research effort could have positive impacts on biomedical innovation, potentially unleashing a new era of vaccine innovation, similarly as the World War II penicillin program did for antibiotics, among others.

¹ OERD was designed to coordinate World War II crisis research effort.

OECD STI OUTLOOK

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

Messages 1. Science and innovation have played a central role in the immediate response to the COVID-19 crisis. 2. Public and private funding were mobilised and research was targeted towards diagnostics, treatments and the development of vaccines. 3. The COVID-19 pandemic has also put immense economic and financial pressure that could compromise the ambitions of research and innovation systems to generate the solutions needed to fulfil the green and digital transitions.

The 2021 edition of the OECD Science, Technology and Innovation Outlook takes a close look to the main changes provoked by COVID-19 in science and innovation systems. In many ways, research and innovation were the “exit strategy” out of COVID-19 and have reinforced the importance of R&I in crisis preparedness and response. At the same time, the current crisis also exposed existing vulnerabilities and inequalities in R&I capacities and systems which should be addressed in order to meet the twin challenge of the green and digital transitions. Some of the main takeaways from the report include:

1. R&I systems have enabled a quick and significant COVID-19 response thanks to both public and private efforts. The report found that “in the first few months of the pandemic, national research funding bodies worldwide spent around USD 5 billion on emergency funding for COVID-19 R&D”.
2. The research community was also quickly mobilised to contribute to a better

understanding of the virus, where “around 75 000 scientific publications on COVID-19 were published between January and November 2020”. Open access and open data also played an important role to enable quicker sharing of COVID-19 data and publications.

3. There was strong innovative potential of business to respond to the crisis. For example, during the first months of the pandemic we witnessed the development of “frugal innovations” in response to shortages of medical equipment and other emergency supplies. Also, the biopharmaceutical industry, often in partnership with academia, has launched hundreds of clinical trials targeting COVID-19 drugs and vaccines.”

4. The crisis has impacted sectors differently. Indeed, digital- and health-related sectors have been less affected than other sectors such as automotive.

5. Global collaboration in R&I on COVID-19 biomedical research has been unprecedented.



EIB INVESTMENT REPORT

European Investment Bank (2021), [Investment report 2020/2021: Building a smart and green Europe in the COVID-19 era](#). EIB, Luxembourg

Messages 1. 45% of (the surveyed) EU firms expect to reduce investment in the coming year, while only 6% expect to increase it. 2. EU companies are among global R&D leaders in various traditional industries, but are less present in fast-growing digital sectors. 3. EU registered 76% more patents that combined both green and digital technologies than the United States, and four times more than China.

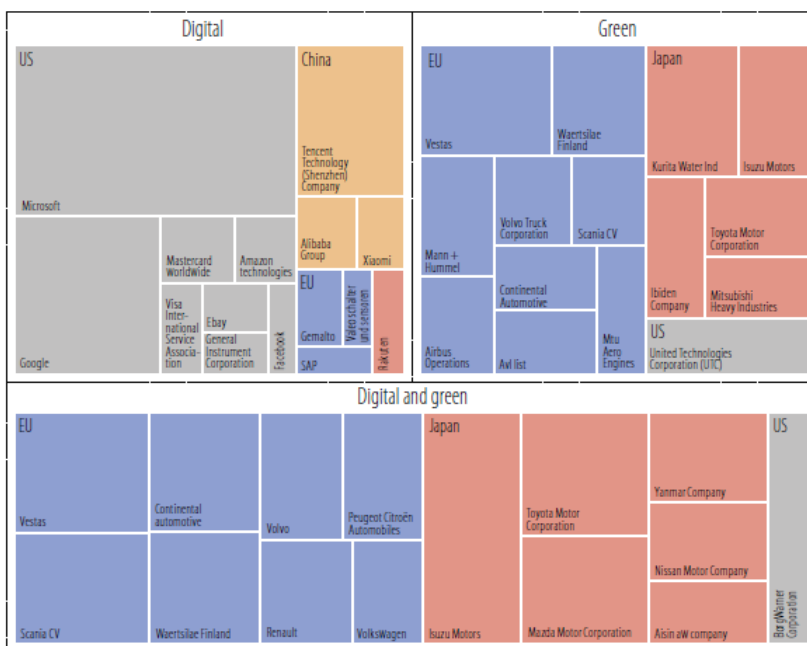
EIB Investment report provides a comprehensive overview and analysis of investment and the financing of investment in the European Union. This year’s focus was on the impact of COVID-19 on investments and the green and digital transitions.

Regarding the impact of COVID-19 pandemic on business, according to the annual survey of 12 500 firms in Europe, the report suggests that 45% of firms expect to reduce investment in the coming year, while only 6% expect to increase it.

When it comes to the digital transition, the EU does not appear to be generating much new innovation in the digital sector, which could weigh on its long-term competitiveness. By 2020, 37% of European firms had still not adopted any new digital technologies, compared with 27% in the US.

On the other hand, the EU is a global leader in green innovation, and even more so in innovation that is both green and digital. To stay ahead, however, the EU must continue to invest and innovate.

The US companies Google, Amazon, Facebook, Apple and Microsoft (also known as GAFAM) dominate patenting activities in digital technologies. However, none of these top companies in the digital sector end up at the top of the “green” or “green and digital” categories. The top companies in green and digital-green technologies are instead from Europe and Japan.



MEASURING CHANGES IN DIGITAL CAPITAL

Tambe, P., Hitt, L., Rock, D. and Brynjolfsson, E. (2020), [*Digital Capital and Superstar Firms*](#). National Bureau of Economic Research, No. w28285

Messages

1. Digital (intangible) capital enables more value to be created from the adoption of general purpose technologies. 2. Digital capital has accumulated over time and by the end of 2016 it corresponded to at least a quarter of the assets of firms, with concentration in a small group of 'superstars'. 3. The prediction of future firm productivity can be done by looking at today's digital capital accumulation.

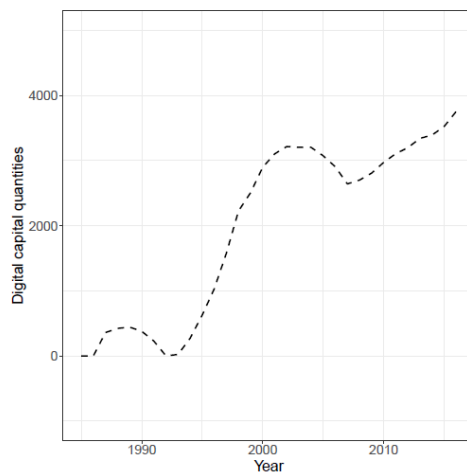
The authors point to the economic differences and similarities between tangible (or physical) and intangible assets. Both types of capital are used by a firm so as to boost future productive capacity. Additionally, both types of assets are subject to depreciation and may require further investments. A significant difference between the two lies on the sensitiveness of the valuation due to external factors, with the value of intangible capital in principle fluctuating more than physical capital. The paper also stresses that it is more difficult to measure the stock of digital capital than the stock of physical assets.

The paper proposes a methodological approach to compute "measures of changes in the prices and quantities of digital capital" using US firm-level data between 1990 and 2016. LinkedIn data were used to get information on IT employment. As a result, the authors could combine this improved measure on IT labour with financial information and thence estimate digital capital quantities and prices.

The central contribution of the paper is that it aims at directly linking the flow of services "that firms derive from their digital intangible capital to economic outcomes". Moreover, another novelty of the analysis is that it enables the measurement of the quantity of intangible capital instead of making inferences and using correlations.

The main findings of the paper are: 1. There was a sharp rise of digital capital in the late 1990s which was then interrupted by a decrease around the time of the dotcom bubble. 2. Digital capital returned to an upward trend after 2010 which coincided with the emergence of technologies such as the cloud, big data, and AI, just to name a few. 3. There is considerable heterogeneity among firms regarding the quantities of digital capital. In particular, there was a concentration in a small group of superstar firms, defined by the paper as those firms at "the top decile of the sample in terms of market value". Finally, the paper finds that 'the contribution of digital capital to growth during 1990-2016 was approximately double that of IT capital stock'.

Figure VIII: Digital capital quantities



DIGITAL TECHNOLOGIES CHANGING ECONOMIC SCIENCE

Currie, J., Kleven, H. and Zwieters, E. (2020), [Technology and Big Data Are Changing Economics: Mining Text to Track Methods](#). *AEA Papers and Proceedings*, 110: 42-48.

Messages

1. With an expansion of new data and methods, we may be at a turning point in the field of economic science. 2. Machine learning and text analysis are among the most popular novel empirical methods in the field of applied microeconomics.

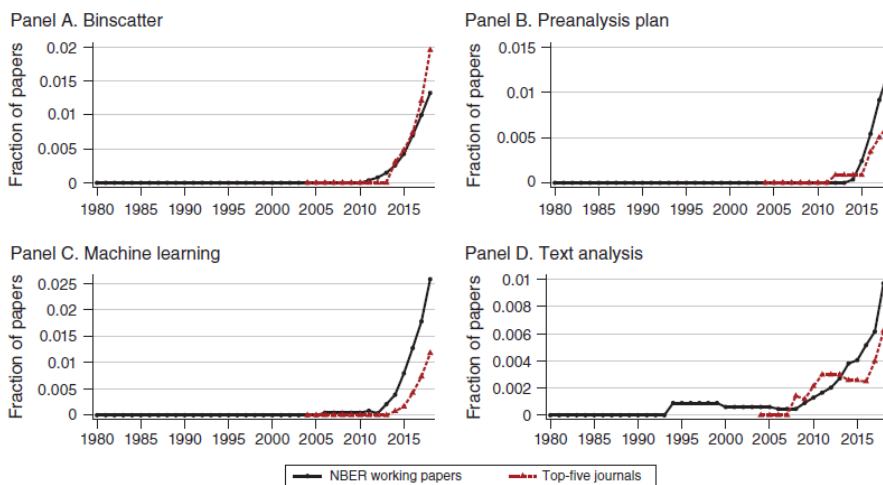
The paper analyses how new data and methods are changing economic science by looking at the scientific publications in applied microeconomics. The data they analyse come from two sources, all publications in applied microeconomics in the National Bureau of Economic Research (NBER) working paper series between 1980 and 2018, and in the “top five” economics journals (American Economic Review, Econometrica, Journal of Political Economy, Quarterly Journal of Economics, and Review of Economic Studies) between 2004 and 2019.

The paper identifies different novel empirical methods in the field of economics. Machine learning is the most popular among these new methods, with

referrals in 2.5% of NBER working papers. Text analysis has also become more common, with referrals in about 1% of NBER working papers in 2019. Binscatter plots have become a popular way of visualizing big data since 2010.

Even though these new methods increased in popularity, the paper suggests that they have not grown at the expense of older empirical methods, such as instrumental variables and fixed effects. The old and new methods appear to be complements rather than substitutes, given the rise of the “collage” approach to empirical work. Namely, authors attempt to make a case based on a more multipronged approach, instead of a single method or dataset.

Recent empirical methods in the field of economic



HUMAN CAPITAL CONTRIBUTING TO PRODUCTIVITY

Cammeraat, E., Samek, L. and Squicciarini, M. (2021), *Management, skills and productivity*. OECD Science, Technology and Industry Policy Papers, No. 101.

Messages 1. Higher skills intensity (educational attainment) is significantly related to productivity. 2. Skills endowments appear much dispersed across countries and industries. 3. A positive relationship exists between STEM skills and productivity.

This paper focuses on the complex relationship between organisational capital (OC), workforce skills and labour productivity. It examines how numeracy and task-based skills in areas of information and communication technology (ICT) and science, technology, engineering and mathematics (STEM) influence productivity. Authors examine the data at the industry level, and also look to what degree skills of workers relate to overall industry performance. Such a broad approach allows to analyse the relationship between workforce and management skills, but also maps the skills dispersion in relation to productivity levels.

The analysis builds on previous OECD work constructing indicators for cognitive and task-based skills indicators relying on data from international assessment of adult competencies (PIAAC). Furthermore, the analysis exploits industry-level output information from the OECD Structural Analysis (STAN).

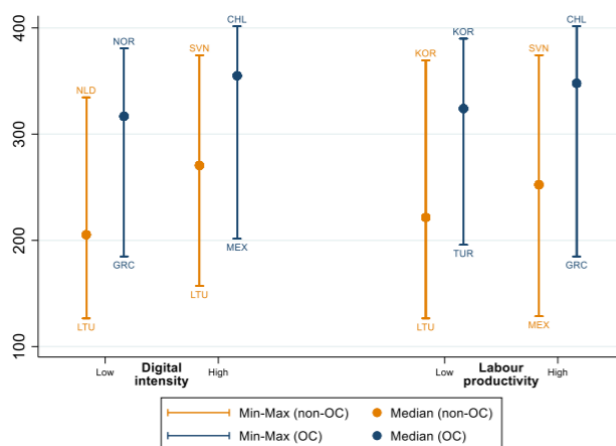
The findings emphasise the need to endow all workers with good STEM skills, and even more so for staff critical to organisational capital.

Among others, the analysis highlighted the fact that both, ICT and STEM skills, are higher for both, workers with and without organisational capital

in industries that are more digitally intensive or more productive. And regardless of the type of skill considered (graph below shows ICT task-based) or the dimension over which the skill endowment studied, occupations relevant to organisational capital perform better on average.

Even with a broad set of conclusions provided by the paper, our knowledge remains limited as concerns the extent to which industries invest in managerial and organisational capital and how workers' skills relate to productivity. Based on the results, further research could shed more light on the role of training policies in upgrading STEM and ICT skills and on mechanisms through which the skills of workers affect productivity.

Figure: Median skill scores by digital intensity and labour productivity



GENDER AND FUNDING DECISIONS

Kolev, J., Fuentes-Medel, Y. and Murray, F. (2020), [Gender Differences in Scientific Communication and Their Impact on Grant Funding Decisions](#). *AEA Papers and Proceedings*, 110():245-49.

Messages **1. While women are nearly half of the US labor force and represent the majority of recent tertiary graduates in the US, a gender gap remains in STEM fields. 2. Scientific communication in grant-awarding institutions shows different approaches by gender. 3. Updating institutional processes/design would enable more inclusive funding decisions.**

The paper looks into scientific communication by gender at two grant-awarding institutions, namely the Bill and Melinda Gates Foundation and the National Institutes of Health (NIH). The sample covers 6,931 Gates applicants affiliated with US-based academic institutions and 12,589 NIH grant applications. Since these two institutions have different institutional goals and application processes, this allows the authors to check for persistent gender differences in applications and how that may potentially influence funding decisions. For the text analysis, the authors use abstracts of the applications.

The first result confirms that there are significant differences between NIH abstracts and Gates' which shows that this empirical strategy is robust to test for persistent gender differences. Second, the results show differences in the scientific language used by gender, with female applicants found to appear less likely to submit their research application with positive language, and more likely to write their applications with *high readability*, and with a preference for *concrete language* when doing so. Third, even if female researchers in the applications make less use of broader language, their research is

actually covering a *wider range of medical subjects*.

Finally, results suggest that funding outcomes are dependent on the institutional setting, and that grant application text characteristics can influence funding decisions. Hence, the most suitable approach for gender inclusiveness in application processes is to update the institutional design, so that institutional processes are "not negatively predisposed toward female scientific language".

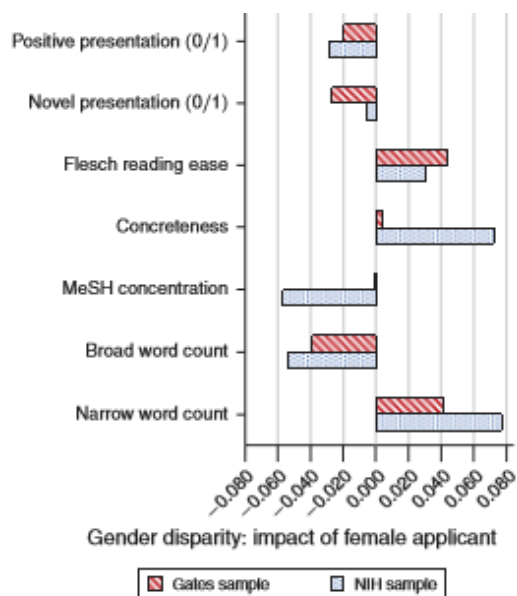


FIGURE 1. GENDER DIFFERENCES IN ABSTRACT TEXT CHARACTERISTICS

THE STORY OF EUROPEAN OPEN SCIENCE CLOUD

Burgelman, J.-C. (2021), [Politics and Open Science: How the European Open Science Cloud Became Reality \(the Untold Story\)](#). *Data Intelligence* 2021; 3 (1): 5–19

Messages

1. European Open Science Cloud (EOSC) is a key policy initiative to support Open Science (OS) in Europe. 2. The EU is committed to make data resulting from its research and deployment programmes available in line with the principle ‘as open as possible, as closed as necessary’. 3. The only way Europe can take care of its research data in a way that fits the European specificities fully, is by supporting EOSC.

The paper provides an overview of how the [European Open Science Cloud](#) (EOSC) became a key policy initiative to support Open Science (OS) in Europe.

The idea of EOSC emerged in 2014/15 in the European Commission, DG Research and Innovation, as a response to the impact of digital technologies on science and in order not to “miss the boat” in data-driven science as it was the case with the Web 2.0 revolution. Some of the main premises were to ensure “the nondiscriminatory access to the data, the interoperability across disciplines and making sure these data are managed in respect of European sensitivities like what will later become the European General Data Protection Regulation (GDPR)”. Another important reason was, the EU to master the results of its publicly funded research itself.

The proposed science cloud guarantee GDPR compliance and at the same time

offer all the advantages of data science to all without giving premium usage rights to non-European commercial third parties. It would feature a federated but distributed architecture focussing on services and software. The author explained the idea behind science cloud using “air traffic control” metaphor. “Most countries have airports (data infrastructures), air companies (data handling services), pilots (data producers and handlers), but once a plane wants to take off (data traffic), we need to put in place standard procedures (FAIR) for take-off, being in the air and landing, certify staff to do it, etc.”

The EOSC was launched in 2018, however it is still a huge challenge to put it in place and make it a reality. It is encouraging that the new president of the European Commission, Von der Leyen, and her Commission put EOSC and data sovereignty among the key policy goals of her mandate.



EOSC pilot

The European Open Science
Cloud for Research Pilot Project

EXPERIMENTATION, INNOVATION, AND ECONOMICS

Kremer, M. (2020), *Experimentation, Innovation, and Economics*. American Economic Review, 110 (7): 1974-94.

Messages	1. Experimental approach can be a powerful tool for advancing economic science, informing policymakers and stimulating innovation. 2. Institutions can be designed to accelerate innovation and direct it toward the world’s most pressing needs.
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The paper argues that field experiments in addition to isolating causal impact of policies from potential confounding factors, can also:

1. provide the researcher with a richer sense of context;
2. address specific, practical problems;
3. promote broader collaboration;
4. allow more rapid iteration.

The author presents different examples, spanning from education in developing country schools, or pricing of preventive health products, to behavioral development economics, showing how aforementioned features make the experimental approach an effective instrument for advancing scientific

understanding, informing policy, and promoting innovation.

Moreover, the paper discusses three types of institutions that support innovation: 1. Institutions that facilitate experimentation; 2. Institutions through which governments and philanthropists can directly support innovation (see table below), and 3. Institutions which incentivize the private sector to create specific new technologies.

Finally, the paper presents how institutions can be designed to accelerate innovation and direct it toward the world’s most pressing needs. In particular, mechanisms such as patent buyouts and advance market commitments have been discussed.

Examples of institutions for supporting innovation and experimental research

	Institutions to facilitate experiments	Institutions to fund innovation
Government	At Universities: EPOD/CID at Harvard, CEGA at Berkeley, and IGC at the LSE and Oxford	World Bank (through programmes SIEF , DIME and GIL), UK’s Department for International Development (through programmes PEDL , ATAI)
NGOs and philanthropic organisations	NGOs have supported solutions, such as: Evidence Action , Precision Agriculture for Development , and TARL Africa	Bill and Melinda Gates Foundation, the Hewlett Foundation, the Wellspring Philanthropic Fund, the Douglas B. Marshall Jr. Family Foundation

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The “Quarterly R&I Literature Review” provides a brief summary of a selection of recent publications on R&I economics and policy.

The aim of the Review is to inform policymakers on the latest findings from the literature that links R&I economics to R&I policy.

This edition of the review covers papers and reports that emphasize: (i) the R&I response in times of crisis, and (ii) specific digital issues related to R&I.

The Literature Review, together with the Working Papers and the Policy Briefs, is part of the “R&I Paper Series” which serves as a repository of analytical papers that supports an evidence-based EU policy, for R&I and beyond.

Studies and reports

