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Quarterly R&I literature review 2021/Q2

# R&I and the green transition



R&I PAPER SERIES  
LITERATURE REVIEW



Research and  
Innovation

## **R&I and the green transition**

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# R&I and the green transition

*Quarterly R&I literature review 2021/Q2*



Literature review

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## INTRODUCTION

*This literature 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 for this edition: Ana Correia, Océane Peiffer-Smadja, Julien Ravet (team leader).*

In July 2021, the Commission adopted the 'Fit for 55' package, which includes proposals to make the EU's climate, energy, land use, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030. This package is crucial for making the European Green Deal a reality, with research and innovation (R&I) playing a central role. Against this backdrop, this edition covers papers that focus on the role of R&I for the green transition.

A new environmentally sustainable and inclusive approach to growth is urgently required, and investments in low-carbon innovation are central to this. Empirical evidence shows that demand-pull forces, such as general energy prices, carbon prices, targeted market-creating interventions, seem to boost R&I activities related to green technologies.

The selected papers underpin the importance of designing climate policies with innovation at the forefront. They also make a case for coordination of policies and designing them in a way to influence the volume, direction and pace

of R&I. In economies where fossil fuel technologies are initially prevalent, an optimal policy should include R&I subsidies specifically targeted at low-carbon and clean R&I.

This review also highlights the role of consumers and society in pushing innovation in the "clean direction". Changing social values can support structural change towards predominantly green technologies and politics can play a key role in this, empowering scientists and climate activists, and departing from brown lobbies.

Two recently published flagship reports are also presented in this edition. The European Innovation Scoreboard 2021 shows that EU innovation performance has continued to increase, with Sweden, Finland, Denmark and Belgium featuring as innovation leaders. The OECD SME and Entrepreneurship Outlook 2021 stresses how SMEs operations were affected by the pandemic, as well as the importance of government support in this context.



# DIRECTION IN INNOVATION AND ENVIRONMENT

Hémous, D. and Olsen, M. (2020). [Directed Technical Change in Labor and Environmental Economics](#). Forthcoming at the Annual Review of Economics

<b>Messages</b>	<b>1. A balanced growth path in an economy (all growth variables grow at an equal rate) allows to avoid slow development of green technologies in environmental economics and rising inequality in labor economics. 2. Climate policy should be designed with innovation at the forefront. 3. Directed technical change models should be further integrated in climate change and labor economics for better design of policy fostering innovation and predicting automation innovation effects.</b>
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The paper analyses the contribution of different types of Directed Technical Change (DTC) models in implementing optimal policy measures to foster green innovation. Contrary to endogenous growth theory models which included only one type of innovation, DTC models allow to integrate several types of innovation and to consequently refine policies according to different economic situations and the type of innovation targeted.

To study how to foster development of clean energy and clean technologies, DTC models which use clean energy as a substitute to dirty energy have been applied in environmental economics. Different applications of these models have led to the following conclusions: in economies where fossil fuel technologies are initially ahead, in addition to Pigovian carbon taxation, the optimal policy includes research subsidies specifically devoted to clean innovation and development of clean technologies.

Other DTC models have been used to focus on energy or resource-saving innovations. In these cases, while public intervention is crucial to the development of clean alternatives to fossil fuel energy, carbon pricing triggers the development of energy-saving technologies, and, research subsidies

may be necessary in the transition, but their importance is greatly reduced.

The two DTC frameworks have also been used in environmental economics to explain energy shocks, historic energy transitions, and carbon leakage and the authors conclude that they account well for historical trends.



Finally, the authors also investigate the contributions of “new” DTC models, applied in labour economics to study the effects of automation on markets. They find that labour market regulations are positively correlated with innovation in low-skill intensive sectors and that high-skill wages tend to reduce automation innovations. The authors call for further integration of DTC models in climate change and labour economics for better design of policy fostering innovation and predicts automation innovation effects.

# CONSUMER BEHAVIOUR AND CLEAN INNOVATION

Aghion, P., Bénabou, R., Martin, R. and Roulet A. (2021). [Environmental Preferences and Technological Choices: Is Market Competition Clean or Dirty?](#) National Bureau of Economic Research, No. w26921.

**Messages** 1. Greener consumer values push innovation in the clean direction. 2. Social concerns can alleviate polluting emissions, and even the effect is stronger the higher the competition. 3. Grassroots and public campaigns to promote citizens' environmental responsibility could be a viable alternative policy option to foster clean innovation.

The paper investigates the effects of consumers' environmental concerns and market competition on firms' decisions to innovate in clean technologies.

The authors use panel data on around 250,000 patents by 8,562 automobile-sector firms in 41 countries during 1998-2002 and 2008-2012.

They build a model integrating consumers' willingness to pay according to environmental friendliness of goods and estimates of market competition. Innovation is measured with patents that are classified as 'clean', 'dirty', 'grey' or 'other' using the International Patent Classification system (IPC).

The authors find a significant positive effect of pro-environment attitudes on the probability for a firm to patent relatively more in the clean direction, and this effect is stronger, the higher competition is.

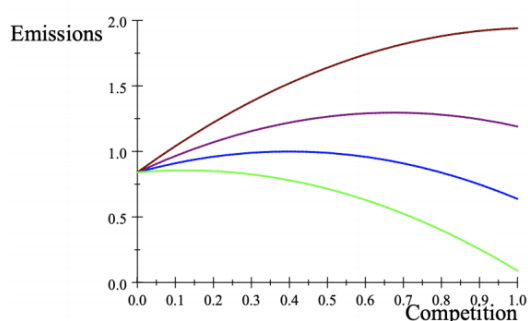
The paper demonstrates that greener consumer values push innovation in the clean direction, primarily by reducing the growth rate of dirty patents. Competition has a strong significant positive effect on all types of innovation. Furthermore, the authors also prove that

increase in fuel prices is associated with a higher growth rate of clean patents relative to dirty ones.

In addition, as illustrated in the figure below, the analysis demonstrates that social concerns can alleviate polluting emissions, and even more when competition is high.

With regard to policy implications, considering the often dramatic public reactions to increase fuel prices (e.g. the French "Gilet Jaunes"), the authors suggest that grassroots and public campaigns to promote citizens' environmental responsibility could be a viable alternative policy option, especially when combined with more competitive markets.

: Effect of competition and social values on pollution



Polluting emissions as a function of market competition, as prosocial attitudes vary from lowest to highest (top to bottom curves)

# CLIMATE TRAP, VALUES AND TECHNOLOGIES

Besley, T. and Persson T. (2020). [Escaping the Climate Trap? Values, Technologies, and Politics](#). November 2020, Working paper.

**Messages** 1. Changing social values can support structural change towards predominantly green technologies. 2. While green R&D subsidies and brown-goods taxes could hypothetically alter a society's trajectory, this will not happen without political implementation. 3. Politics can trigger transformative change via empowered climate activists and scientists, reduced influence of brown lobbies, or a higher weight on environmentalist views in the policy process.

This paper examines how changing environmental values, changing technologies, and the politics of environmental policy, can lead to creating sustainable societal change.

The authors create a dynamic model which integrates citizen behaviour (their preferences for green or brown goods and their voting), firms investments in innovation, and environmental taxes and subsidies to green innovation. They explore the path taken by society - either towards a state where brown goods are preferred to green goods (called 'climate trap') or towards a more environmentally friendly society.

They develop several versions of the model enriching it with different parameters and scenarios; equipping citizens to act not just as consumers but also as innovators (motivated environmental entrepreneurs running green-goods firms), and not just in public politics but also in private politics (boycott investments into brown-goods firms); allowing firms to act not only in the economic but also in the political sphere (by lobbying politicians); equipping politicians with additional

policy instruments such that they can influence firm-level decisions (and thus, indirectly, policies) not just in the present but also in the future.

The results suggest that changing social values can support structural change towards predominantly green technologies, but that this outcome is by no means guaranteed. Complementary technologies and values - as mediated by politics - create critical junctures that



make the future virtuous or vicious.

The authors conclude that while green R&D subsidies and brown-goods taxes could hypothetically

alter a society's trajectory, this will not happen without political implementation. They argue that politics can trigger transformative change via empowered climate activists and scientists, reduced influence of brown lobbies, or a higher weight on environmentalist views in the policy process.



# INNOVATION AND DIFFUSION OF CLEAN TECHS

Probst, B., Touboul, S., Glachant, M. and Dechezleprêtre A. (2021). [Global Trends in the Innovation and Diffusion of Climate Change Mitigation Technologies](#). Research square – preprint under review.

**Messages** 1. Low-carbon technologies patenting rates have increased at an annual average of 10% from 1995 to 2013, and then fell by around 6 percent annually from 2013 to 2017, likely due to historical decline in fossil fuel prices. 2. Technology transfer from high-income to middle-income countries is low despite the political instruments put in place. 3. Low carbon technologies still see a higher diffusion than the global average.

This paper provides an analysis of climate change mitigation technologies (CCMT) patenting rates over the 1995-2017 period. It also measures the transfer of patented technologies between countries to assess the efficiency of Technology Transfer Mechanism and other political instruments set up to increase the diffusion of CCMT.

The authors use the PATSTAT database, focusing on 286,997 patents classified as high-value international patents (i.e. patent families that were filed in at least two countries).

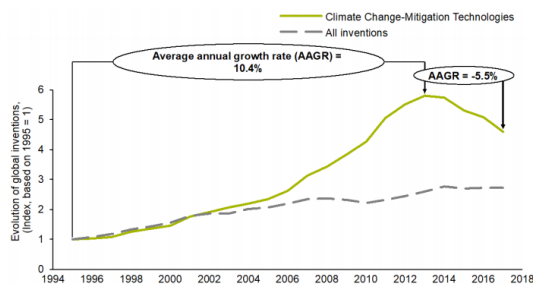
They demonstrate an average increase of 10% in annual patenting rates of low-carbon technologies from 1995 to 2013, followed by a fall of around 6 percent annually from 2013 to 2017. Inventions in energy generation (including renewable energy, nuclear energy, and biofuels) have seen the highest decline in 2013-2017. The authors conclude that the decline in low carbon patenting rates from 2013-2017 is likely to be related to the historical decline in fossil fuel prices.

When it comes to technology transfer, CCMT innovation remains highly concentrated in a few industrialised countries: Japan, US, and Germany account for 59% of global CMMT inventions, whereas the top-10

inventing countries account for 87%. Most industrialised countries are highly specialised in CCMT. For instance, in Denmark, around 20 percent of all patents are filled in CCMT. Conversely, emerging countries do not only innovate less, they are less specialised in CCMT than industrialised countries. Furthermore, while global transfers do not merely occur between industrialised countries, most of the transfers from high-income to middle-income countries go to China.

Still, besides demonstrating a low transfer to middle-income countries, authors find that CCMT technologies see a much higher diffusion than the global average. The level of CCMT transfer (23% of CCMT inventions) is higher than the average non-CCMT technology (17%).

The authors conclude that current transfer technologies mechanisms are insufficient to achieve technology transfer to emerging economies other than China.



# INDUCED INNOVATION IN ENERGY AND RELATED TECHNOLOGIES

Grubb, M., Drummond, P., Poncia et al. (2021). [Induced innovation in energy technologies and systems: a review of evidence and potential implications for CO2 mitigation.](#) *Environmental Research Letters*.

**Messages** 1. The review of econometric studies finds that demand-pull forces enhance innovation as measured by patents in most cases. 2. Technology costs decrease with cumulative investment for nearly all technologies in the analysis. 3. Innovation is cumulative, multi-faceted, and 'path-dependent' in the sense that it is self-reinforcing in its direction. 4. Policy should take into consideration the broad gains from innovation in large-scale models.

The paper conducts a systematic review of the empirical literature on induced innovation in low-carbon and energy-efficient technologies, focusing in particular on the extent to which 'demand-pull' forces encourage technological innovation. The papers analysed build on over 200 papers using original data analysis.

The authors highlight that the literature typically covers 'technology-push' policies (e.g. research grants to boost the supply of innovation) and 'demand-pull', market-creating, factors. Moreover, the impact of demand-pull on innovation may differ by sector and will mirror their 'push' and 'pull' characteristics. Indeed, the energy sector will be different from other sectors such as IT or pharmaceuticals. Energy-intensive sectors which include for example industry or transport generally have to compete on the basis of energy costs, rather than offering new and better functionality. As the authors note, "energy supply technologies tend to be big, complex, expensive and slow to develop." They are typically

subject to a 'technology valley of death', with big risks and lower incentives for private innovation.

The authors summarise their conclusions around three main points. First, demand-pull forces (general energy prices, carbon prices, targeted market-creating interventions) seem to boost patenting activity. Second, the costs of technology were found to go down as investment accumulates. Third, the innovation process is cumulative, multi-faceted, and self-reinforcing in its direction (path-dependent).



# AN INNOVATION-LED SUSTAINABLE GROWTH

Stern, N. and Valero, A. (2021). [Research policy, Chris Freeman special issue innovation, growth and the transition to net-zero emissions](#). *Research Policy*, 50(9).

**Messages**

- 1. A new environmentally sustainable and inclusive approach to growth is urgently required.**
- 2. Investments in low-carbon innovation are central to this.**
- 3. Coordinated policies should be constructed to influence the amount, direction and pace of innovation.**
- 4. Public action must build in a just transition for workers and consumers.**

This paper examines ideas and evidence on how policies and institutions can enable and foster private sector investment in sustainable and productive assets at the scale and pace required to tackle climate change and simultaneously achieve a strong economic recovery and growth into the future. The authors draw inspiration from Chris Freeman's work on the system-wide drivers of innovation, and his early vision of achieving environmental sustainability by reorienting growth.

The paper draws lessons for action and research related to path dependencies and clean innovation, clean growth, and the political economy dimensions of a transition to a net-zero growth model.

Conclusions for action include the following ideas. First, action at scale and across the economy, via a coordinated set of policies and institutions, is required in order to tackle the multiple market failures that coexist, and shift

the trajectory of economies so that path dependence favours clean innovation and investment.

Second, policies for a strong and sustainable recovery must include environmental and growth levers. A robust carbon price must be complemented by a suite of mutually reinforcing policies, regulations and investments in infrastructure, human capital and innovation.

Third, in order to enter a virtuous cycle where pro-environmental attitudes can facilitate and feed off the transition to net zero, a coherent and coordinated package of policies and investments must be both effectively implemented and communicated.

Conclusions for research include the need for tractable and quantifiable models, beyond traditional growth models, the need for more causal evidence of the effectiveness of policies and how they interact with other policies or institutional features, and the need to understand the political economy and behavioural dimensions that will foster the transition to net zero.



## IMPACT OF REGULATION ON INNOVATION

Aghion, P., Bergeaud, A., and Van Reenen, J. (2021). [\*The impact of regulation on innovation\*](#). National Bureau of Economic Research, No w28381.

### Messages

**1. The prospect of significant costs from labour regulations above a size threshold discourages firms just below this threshold from innovating. 2. On average, firms innovate more when they experience a positive shock, but this relationship significantly weakens when a firm is just below the regulatory threshold. 3. Baseline estimates show an aggregate innovation (and growth) loss of around 5.4%. 4. A more regulated economy may enable less innovation, but ‘when firms do innovate they tend to “swing for the fence” with more radical (and labour saving) breakthroughs.’**

The paper attempts to assess the impact of regulation on the pace and nature of innovation, and then to quantify it. It makes use of a ‘tractable and quantifiable endogenous growth model’ which includes size-contingent regulations. According to the authors, the latter allows them to depict how firm innovation and size change with stringier regulation.

The main dataset is composed by yearly balance sheets of all French firms between 1994 and 2007. The authors focus on private businesses and patenting information is derived from PATSTAT and matched with the database from the French tax authorities. The database is further restricted to only include firms with between 10 and 100 workers in 1994. By not including large firms in the sample, the authors manage to minimise the likely skewness of the distribution of innovation as measured by patents. All in all, this leads to a sample of 182,348 distinct firms and 1.66 million observations.

The results show that there are losses on aggregate innovation of around 5.4% in the baseline case, and between 1.4% and 9.8% when other parameters and values are considered. Most of the

identified losses result from less patenting activity across the sample of firms. The baseline analysis also shows a ‘fall in welfare of 2.2% from these dynamic losses’.

However, the authors raise the point that, while labour regulation discourages incremental innovation, there is actually only a small effect on what is considered more radical innovation. So overall the welfare loss is mitigated.

Finally, the paper’s primary focus was on the costs of labour regulation, which means that the benefits from that regulation to the employees e.g. in the form of greater involvement and trust in the firm were not considered. Future analyses should also bring those benefits to provide a more accurate picture of the impact of labour regulations on business innovation.



# MISSION-ORIENTED POLICY IN EMERGING COUNTRIES

Alves, A.C., Vonortas, N.S. and Zawislak P.A. (2021), [\*Mission-Oriented Policy for Innovation and the Fuzzy Boundary of Market Creation: the Brazilian Shipbuilding Case\*](#), *Science and Public Policy*, 48(1): 80-92.

**Messages** 1. The use of Mission-Oriented Policy can be extensive in developing countries for addressing the gap due to the lack of technological and institutional framework and for building the foundations of viable markets. 2. The fuzzy boundary between expectations and the concrete possibility of creating a market is full of uncertainty which generates costs not previously planned.

This paper analyses and discusses the main challenges of setting mission-oriented policies (MOPs) in the context of developing countries by looking at the recent development of the Brazilian shipbuilding sector.

This sector reemerged in Brazil in the 2000s following new offshore oil discoveries. To catch up quickly with a high demand for vessels, the Brazilian shipbuilding, and offshore industrial reemergence required a broad set of public policy interventions across many fronts, culminating into a full-fledged MOP.



Since it began in 2005, MOP in Brazilian shipbuilding triggered a set of changes in the industrial landscape of Brazil such as infrastructure, value chain, R&D, capital, and labour. It mobilised several resources and generated many jobs in the sector. When it reached its peak, shipbuilding became the second-largest job creating industry in the country losing only to the automobile.

Productivity, however, did not grow nearly as fast, with relatively low output and high costs of construction. Frequent project changes, inability to set and follow standards, high overheads,

external pressures from clients for deadlines, lacking engineering skills, as well as slow pace to deal with licensing and permits created several obstacles for capabilities to be built.

According to the authors, while MOPs may create high expectations for market creation and capability building, two aspects make the path from the current state to the new state of market creation fuzzy.

First, the length of the window of opportunity is hard to predict as competitive conditions change. In this case, the 2008 crisis directly impacted the demand

for cargo ships. Second, the speed of learning and the relative costs to transition from a set of available capabilities to new and more advanced one are also highly uncertain.

Hence the ‘capability transition’ required by MOP, that is, to build innovation capabilities to actually create markets, is not a trivial process. Incongruity between the intent and the real possibilities of market creation creates a fuzzy boundary, which can lead to the unsuccessful implementation of missions.

# INNOVATION PERFORMANCE KEEPS IMPROVING

European Commission (2021). [European Innovation Scoreboard 2021](#). Publications Office of the European Union, Luxembourg.

**Messages** **1. Innovation performance has continued to increase for the EU and all Member States. 2. Sweden, Finland, Denmark and Belgium are Innovation Leaders 3. An innovation divide persists despite the slow convergence within the EU. 4. At the global level, the EU is closing the performance gap to Australia and Canada. 5. Relative position towards China, Japan, South Korea and the USA is worsening.**

The 2021 edition of the European Innovation Scoreboard was released in June 2021. The Scoreboard provides a comparative analysis of innovation performance in EU countries, other European countries and selected third countries. It assesses relative strengths and weaknesses of national R&I systems and helps countries identify areas where they need to concentrate efforts.

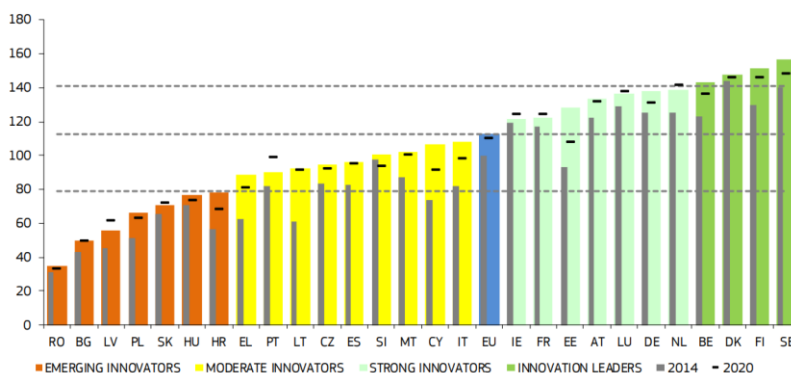
The Scoreboard shows that the average innovation performance of the EU has increased by 12.5 percentage points since 2014. Sweden continues to be the EU innovation leader, with Finland, Denmark and Belgium being the other three leaders in the ranking. Countries from Northern and Western Europe tend to show higher performance, but there were signs of convergence within the EU.

From the global perspective, the EU has a lead over Brazil, China, India, Russia, and South Africa, and a gap with Australia, Canada, Japan, South Korea and the United States.

Since 2014, the position of the EU relative to Australia, Canada, Brazil, India, Russia and South Africa has improved (either in terms of increased lead or reduced gap). However it has worsened relative to Japan, South Korea, the USA and China.

This edition uses a revised measurement framework that consists of methodological improvements to existing indicators, redefining country performance groups, and identifying additional innovation dimensions and indicators to be included in the EIS. The new framework also includes new indicators capturing digitalisation and sustainable innovation. Due to these revisions, the results in the 2021 edition are not comparable to those reported in previous editions of the EIS.

Figure 1: Performance of EU Member States' innovation systems



# OECD SME AND ENTREPRENEURSHIP OUTLOOK

OECD (2021), [\*OECD SME and Entrepreneurship Outlook 2021\*](#), OECD Publishing, Paris.

## Messages

**1. Small and medium-sized enterprises (SMEs) were particularly affected by the restrictions in mobility, international trade and other activities as a consequence of the global pandemic. 2. SMEs in the most affected sectors (e.g. food and accommodation) were either forced to close operations, or faced a contraction in their revenues and liquidity constraints. 3. Many SMEs have also been impacted by disruptions in global value chains. 4. In the first wave, governments rapidly mobilised unprecedented emergency packages. 5. At the same time, many SMEs showed a great capacity to reinvent their business models and increased the use of digital tools in their operations.**

The 2021 edition of the OECD SME and Entrepreneurship Outlook analyses the impact of the global pandemic in the operations of SMEs.

SMEs were significantly affected by the lockdowns and the restrictions in mobility and trade, with many of them closing doors, and other seeing their revenues decline substantially alongside acute liquidity constraints. Among those that remained open from May to December 2020, 55-70% saw their sales fall, and two thirds experienced declines of over 40%.

However, the report highlights the importance of government support packages quickly mobilized, namely subsidies, deferrals of payments, and loans and loan guarantees. In fact, the report finds that 20%-40% of SMEs received government support in one form or another in 2020 in OECD countries.

This edition also stresses the importance of digitalisation to the survival of SMEs, with many of them adapting their business models and increasing the uptake of digital tools in their operations.

Unsurprisingly, SMEs selling online had a better performance than their offline peers, with 50% of SMEs increasing the use of digital tools during the pandemic.

New business registrations also recorded a decrease following the great lockdown, but have more recently recovered - new firm creation in many countries reached or even surpassed pre-crisis levels, fuelled by the venture capital market. Social innovation also gained importance during 2020 both as a response to the socioeconomic challenges and through market-oriented social enterprises based on e.g. sustainable business and consumption models.

Going forward, if restrictions on mobility continue, there are concerns about the financial sustainability and indebtedness of SMEs which could lead to a wave of bankruptcies in OECD economies.

Finally, the Outlook also points to the importance of building resilience in value chains, to diversify sourcing and to production locations since many SMEs were affected during lockdowns by product shortages and price volatility.



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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 literature review covers papers that focus on the role of R&I for the green transition.

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*

