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SCIENCE, RESEARCH AND INNOVATION PERFORMANCE OF THE EU 2022

Building
a sustainable future
in uncertain times

Executive summary

Research and
Innovation

Science, research and innovation performance of the EU 2022 – Building a sustainable future in uncertain times – Executive summary

European Commission
Directorate-General for Research and Innovation
Directorate G – Common Policy Centre
Unit G1 – Common R&I Strategy & Foresight Service

Contact Alexandr Hobza, Chief Economist and Head of Unit G1
 Julien Ravet, Coordinator of the Science, Research and Innovation Performance of the EU 2022 Report, Unit G1
Email RTD-ECONOMIC-ANALYSIS@ec.europa.eu Alexandr.HOBZA@ec.europa.eu Julien.RAVET@ec.europa.eu
 RTD-PUBLICATIONS@ec.europa.eu

European Commission
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EXECUTIVE SUMMARY

**BUILDING
A SUSTAINABLE
FUTURE IN
UNCERTAIN TIMES**

Europe is going through testing times. The past two years have been dominated by the COVID-19 pandemic, which has shaken our private and professional lives. The damage done by the Russian invasion of Ukraine is immense and the war is expected to have significant implications for the years to come. Moreover, these events come on top of long-term challenges facing Europe, such as accelerating climate change, the severe loss of biodiversity, progressively ageing populations, diminishing productivity growth, sluggish digitalisation, growing inequalities, internal security threats, terrorist attacks, increased migration and pressure at the EU's borders. The ongoing crises interact with these trends, often making them more pronounced. The COVID-19 pandemic has not only claimed many lives but also has had huge economic and social implications, which are concentrated on specific groups, such as the young persons with disabilities or the older population. At the same time, it created windows of opportunity to address some long-standing challenges, for example through the boost to digitalisation. The invasion of Ukraine has also magnified important dimensions, such as dependencies and vulnerabilities in a globally interconnected world. As a result of these developments, it is likely that Europeans will continue to live in a more uncertain and fragmented world.

Research and innovation (R&I) are an integral part of the response to these challenges. Bold transformative policies are needed to ensure the success of Europe's digital and green agenda, to strengthen resilience and preparedness, and to support Europe's competitive edge in the global race for knowledge and tech sovereignty. R&I have the potential to produce novel solutions in areas like health, digital technologies, industrial transformation, resilient societies, natural resources, energy,

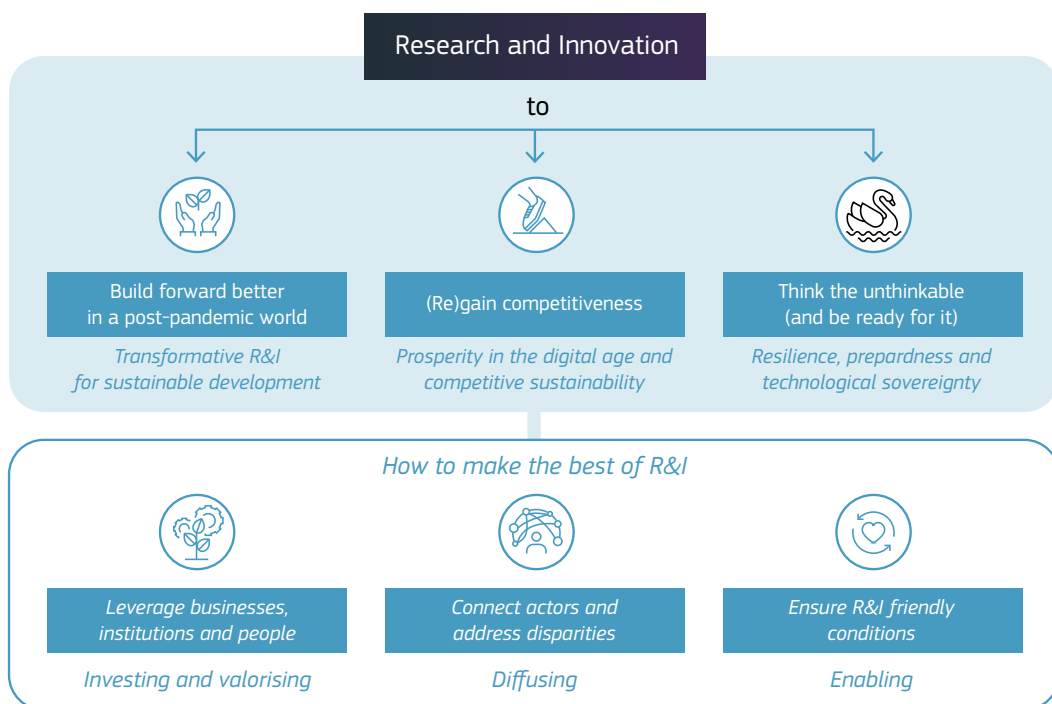
mobility, environment, food, a low-carbon economy and security. For example, the success of the EU ambition to reach the net-zero emission objective by 2050 crucially hinges on development and widespread use of new technologies. Moreover, R&I activities generate benefits for the economy as R&I are at the core of the productivity and competitiveness of our economy and support the creation of new and better jobs and the development of knowledge-intensive sectors. R&I, in particular frontier research, can also strengthen the resilience of our economy and society by building a reservoir of knowledge over the long term.

Against this backdrop, the 2022 edition of the *Science, Research and Innovation Performance of the EU* report provides **insights into how R&I policies can help build an inclusive, sustainable, competitive and resilient Europe by leveraging the essential role of R&I as a source of prosperity and catalyst for social, economic and environmental sustainability.** It emphasises the need to transform Europe to make it fit to deliver on the fundamental objective of providing inclusive wellbeing to citizens while respecting planetary boundaries, as embedded in the European Green Deal and the UN's Sustainable Development Goals (SDGs). Recent experiences document the challenge of staying on a trajectory towards this overarching long-term objective, whilst addressing new crises that may detract policy attention, resources or generate outright trade-offs among the policy objectives. Policy frameworks thus must stay focused on implementing the green and digital transformations, which must be fair and inclusive, while building up capacity to react in a flexible and agile way to new crises and changing conditions. As the challenges we face are shared, we need joint actions and a coordinated approach.

The evidence presented in this report leads to six main policy guidelines for the EU's R&I policy, and beyond that are essential for delivering on our ambitions and objectives. These are:

- ▶ Build forward better in a post-pandemic world
- ▶ (Re)gain competitiveness
- ▶ Think the unthinkable (and be ready for it)
- ▶ Leverage businesses, institutions and people
- ▶ Connect actors and address disparities
- ▶ Ensure R&I friendly conditions.

Figure 0-1: Six main policy guidelines



1. Build forward better in a post-pandemic world

R&I has played a key role throughout the **COVID-19 pandemic**. R&I exerted a strong influence on the development of the pandemic and its economic and social consequences. The pandemic also demonstrated the importance of data and digital technologies as support for policy actions to address the health risks. Measures to contain the pandemic have generated an important change in the way firms operate, acting as a catalyst for the digital transition. At the same time, R&D investment in the EU declined during the crisis, with significant differences between sectors. R&I activities increased in health and ICT while the automotive sector, for example, recorded drops.

In the context of the recovery, R&I policy has also become more prominent in reforms taken at the national level in the EU. R&I are acknowledged as indispensable components of the **Recovery and Resilience Facility (RRF)**. Plans developed by Member States include investments supporting the public science base, academia-business cooperation, business innovation and mobilising R&I capacities to accelerate the green and digital transitions and enhance resilience.

But more than ever, the pandemic has provided us with the opportunity to **'build forward better'** and aim for a more sustainable, more digital, more inclusive and, in particular, a more resilient Europe. Emerging technologies, and social and place-based innovations are essential parts of such a transformative change. In particular, the world will be exposed to an increasing frequency and intensity of extreme climatic events, which can lead to more and

harsher disasters, as well as huge losses of biodiversity. In this context, the **European Green Deal** proposes deeply transformative policies, with an important role for R&I. And Europe has important strengths to build upon: the EU is the global leader in scientific publications on topics related to sustainability and in patenting activity related to climate action, the environment and secure, clean and efficient energy, although not all trends are positive.

EU R&I policies have a role to play in coordinating the main actors of the transition: industry, universities, national and regional authorities and civil society at large. Given the complexity of the challenges ahead, the structures governing R&I policy processes should be designed to mobilise and support deep transformations across societal and economic systems. Foresight, experimentation and co-creation participatory exercises can bring novel ideas to policymaking and challenge dominant visions. They can also help equip our authorities with the relevant technologies needed, for instance when responding to security incidents, emergencies or addressing new forms of crime. Citizen engagement is critical for reinforcing trust in science and facilitating the innovation process and its uptake. In this regard, the engagement of civil society in science has been a key focus of the EU's R&I policies. The uptake of new and green technologies should also be accompanied by a just transition, where the workers in downscaling, polluting areas are supported in their transition to related fields of work through reskilling and other support measures.

A transformative R&I policy requires some degree of directionality to national and EU investments, i.e., to facilitate and coordinate the alignment of R&I investments with EU priorities. A key new feature of Horizon Europe, the EU's R&I Framework Programme, are **missions** that aim to tackle major societal challenges, based on trust in our ability to create a greener, more resilient, more inclusive and better society for future generations. These missions embrace a collaborative approach to catalyse ambitious R&I efforts for the long term, aiming to bring about real change on the ground. The five missions cover areas related to climate change, cancer, ocean and waters,

climate-neutral and smart cities, and healthy soils. They include clearly defined targets, timelines and procedures for tracking and evaluating the results obtained. Horizon Europe also builds on close **partnerships** between different public and private stakeholders with the objective of steering public and private co-investment in a more focused, ambitious and efficient way to ensure they deliver on the Commission's political objectives. Under Horizon Europe, European Partnerships are set up to contribute to EU-wide transitions towards sustainability and push the digital transformation.

What are the implications of COVID-19 for R&I?	More in Chapter 1
What is the role of R&I for sustainability?	More in Chapter 3
What are R&I missions?	More in Chapter 5
What is EU's R&I output in green-related areas?	More in Chapter 6
How do crises affect intangible assets?	More in Chapter 9
What policies can help foster a transition towards green technologies?	More in Chapter 10
How can artificial intelligence help to address the SDGs?	More in Chapter 11

2. (Re)gain competitiveness

In the current era of geopolitical tensions and regional economic rivalries, the quest to maintain or even boost competitiveness gets additional importance. It determines the nature of Europe's participation in global value chains as well as its ability to benefit from this participation and actively shape it. In this respect, our R&I performance is a main driving factor. In the global landscape, the EU remains an R&I **powerhouse**: as it produces about 20% of the world's scientific and technological output, while having just 7% of the world's population. However, this position has been eroding as the EU's major trading partners have been improving their innovation performance at a faster pace over the recent years. China is thus the global leader in terms of volume of scientific publications today and the USA has retained its lead in terms of quality and impact. This trend continued during the pandemic, which further skewed the global tech race in favour of the US and China, in particular in relation to digital technologies.

At the same time, **business dynamism has been declining in the EU**, fuelling concerns about the implications for innovation and economic growth. Despite some improvements, the EU keeps lagging behind its main international competitors in terms of number of start-up and scale-up firms. The number of EU unicorns is also increasing, but still is much below those located in the EU's main competitors. As young, fast-growing firms producing disruptive innovations are typically a key driver of the digital and green transition, efforts are still needed to improve the overall framework conditions for innovative companies to thrive.

Improving EU's business environment and innovation capacity requires addressing longstanding issues with a renewed vigour, such as shortcomings in access to finance, innovation-averse regulatory frameworks, the persistent divide between strongly performing firms and laggards, and difficulty in attracting and retaining talent. For the EU to ensure scientific excellence and remain a key scientific player on the global stage, there is a need to increase the effectiveness and performance of EU public research systems through stronger R&I investments and policy reforms. At the same time, it is crucial to continue reinforcing less developed national and regional research systems, aiming at narrowing the current knowledge gap within and between EU countries.

More generally, **R&I are key engines to foster Europe's productivity growth, competitiveness and socio-economic outcomes.** Human capital combined with R&D investments drives companies' ability to create, absorb and diffuse innovation. Enhanced productivity is also a means to achieve inclusive growth and desirable outcomes for society. At the same time, addressing the defining challenges of our time, in particular the climate and environmental crisis, is an opportunity to relaunch our economies in a sustainable manner, promoting **competitive sustainability**.

But despite the huge potential of the digital revolution, Europe has experienced **a secular decline in productivity growth**. This significant slowdown, affecting most advanced economies for over past decades, points to difficulties in generating, exploiting and diffusing new technologies and innovations that would allow for a more efficient use of resources. Moreover,

the digital divide between more productive and less productive firms has likely increased with the COVID-19 crisis. Efforts directed at easing the access to and adoption of productivity-enhancing technologies are important to increase competitiveness while reducing inequalities.

How does R&I link to productivity, business dynamism and competitiveness?	More in Chapter 4
How does EU R&I compare to global partners?	More in Chapters 2 and 6
How does COVID-19 affect productivity growth and what are mitigation measures?	More in Chapter 12

3. Think the unthinkable (and be prepared for it)

The experience with the COVID-19 pandemic and the military aggression of Russia against Ukraine show that Europe needs to reinforce its **preparedness** to effectively address new challenges. The rising environmental, geopolitical, economic and social instability in the world increases the likelihood of extreme events with disruptive effects. These events can come as a surprise (in the literature they are often called **black swans**, i.e., very rare and unpredictable events with very high impact), but they can also occur after a series of warning signs accompanied with visible evidence (these are likened to charging **grey rhinos** which can be seen from afar but difficult to stop once in motion). In the case of black swan events, there is a need for the R&I ecosystem to be agile and sufficiently flexible to quickly react to the new, unexpected challenges. Most crises can, however, be identified with some lead time if sufficient attention is paid to early warning signs – these are the grey rhinos. This emphasises the importance of foresight to identify and assess different crisis scenarios and start preparing for them. In this sense, experts had been pointing to a high likelihood of a global pandemic. However, these warnings had not generally been translated into an appropriate level of preparedness. On the positive side, previous investments in the development of new mRNA technologies then allowed a very quick production of efficient COVID-19 vaccines. Systematic foresight exercises, which help us reduce the space of unthinkable events, followed by appropriate adjustments in policies, can effectively increase preparedness and make EU R&I policy more agile to effectively respond to a crisis. Intensive foresight exercises have accompanied the strategic planning of Horizon Europe to ensure that strategic orientations are suitably informed by ongoing trends and take into account possible future contingencies (such as health or energy crises).

The Russian invasion of Ukraine has further emphasised the EU's dependencies. The globalisation of value chains had been a source of productivity gains in the past, but has also created vulnerabilities, including in the R&I domain. This experience calls for reinforcing resilience and strengthening the **EU's technological sovereignty**. As a case in point, the Russian invasion has clearly exposed the vulnerabilities of the EU energy sector. The new emphasis on the need to reduce EU dependency on Russian gas implies that R&I investments and efforts must be strengthened to accelerate the development and deployment of energy efficient and clean energy technologies. This will not only help reduce the dependency on Russia but also significantly contribute to the implementation of the European Green Deal. In this context, R&I policy can play a major role in shaping the direction of innovations and choices concerning the portfolio of energy technologies. The EU is well-positioned here and leads the international scene in terms of clean energy innovation. In addition, while the EU shows strengths in technological areas related to advanced manufacturing and advanced materials, its technological sovereignty is at risk in other fields, including in artificial intelligence (AI), big data, cloud computing, cybersecurity, robotics and micro-electronics. Finally, the Russian invasion of Ukraine has shown how important it is for the EU to invest in its own internal security, making sure its police, border guards and first responders can benefit from the latest technologies.

Hence, future R&I policies will have to be developed in a **complex triangle of transformation policies, competitiveness policies and technology sovereignty considerations**¹. Reducing strategic dependencies in key technological areas and value chains is necessary to strengthen EU resilience.

In doing so, the EU should not sacrifice the welfare gains stemming from an open and fair international division of labour by reverting to short-sighted protectionist policies driven by domestic interest groups under the pretext of technology sovereignty. In addition, a reinvigorated multilateral approach could help the EU reinforce its open strategic autonomy, strengthening its role as a leading actor in fostering international cooperation.

What is the position of EU R&I in the global stage?	More in Chapters 2, 5, 6
How does the global geopolitical context affect R&I?	More in Chapter 2

1 J., Edler, J., Blind, K., Kroll, H. and Schubert, T. (2021), *Technology Sovereignty as an Emerging Frame for Innovation Policy – Defining Rationales, Ends and Means*, Fraunhofer ISI Discussion Papers Innovation Systems and Policy Analysis No. 70.

4. Leverage businesses, institutions and people

Europe needs to invest in R&I and make the most out of this investment. R&D intensity stood at 2.3% of GDP in the EU in 2020, which is still far from the agreed 3% target². R&D intensity has actually increased since 2000 in most Member States, but significant heterogeneity persists across the EU. The EU accounts for almost 20% of global R&D expenditure, though its share has been on a declining trend. It is particularly important to boost private investments in R&D, which have been lower than for most competitors (1.5% of GDP in the EU compared to 1.7% in China and 2.3% in the US). During the COVID-19 pandemic, R&D business investments in the EU decreased from EUR 208 billion in 2019 to EUR 205 billion in 2020.

R&I performance heavily relies also on other assets such as ICT and human capital. The COVID-19 pandemic has accelerated the digitalisation process in the EU, but has also exacerbated the digital divide between EU firms, households, regions and countries. The boost to digitalisation after the pandemic has not been sufficient enough to reduce the gap between the EU and its international competitors. Against this backdrop, the EU will pursue a human-centric, sustainable vision for digital society throughout the Digital Decade to empower citizens and businesses. COVID-19 has also negatively impacted the formation of human capital. More than ever, inclusive human capital policies are crucial to increase Europe's innovation capacity.

Educational and training policies in combination with measures targeted at students from disadvantaged socio-economic backgrounds, as well as students with a disability or those with an ethnic minority background, will be fundamental in the post-pandemic era. Without a strong role for higher education institutions, we cannot achieve the necessary transformations in our society, and the **European Education Area** and **digital education** are key in this context.

More efforts are also needed to bridge the gap between research outputs and marketable innovations. The comparably low performance of the EU in patent applications and in the share of high-tech exports, stands in contrast with its large, qualified workforce and significant scientific production. This situation calls for addressing deficiencies by promoting a culture of knowledge valorisation in the EU's R&I system, ensuring that knowledge-based institutions know how to manage their intellectual capital, and by improving the links between academia, industry, citizens and policymakers.

2 COM/2020/628. A new ERA for Research and Innovation.

A major tool to foster R&I at the EU level is the **Framework Programme for R&I**. The budget of the Framework Programme for 2021-2027, Horizon Europe, is EUR 95.5 billion, accounting for almost 10% of public funding for research in Europe and representing the largest European research programme so far. **Cohesion Policy** will also invest in the 2021-2027 programming period more than EUR 56 billion in R&I by financing innovation in firms, bringing research results onto the market, supporting close business science cooperation with a particular emphasis on the less developed regions. The revitalised **European Research Area** (ERA) agenda also includes a set of ambitious

political objectives and R&D investment targets, which aim to spread excellence, enhance international collaboration, including the mobility of researchers, and better connect universities and companies. The objective is to encourage and support national authorities in implementing needed structural reforms of their R&I systems and to appropriately prioritise and align R&I investments and activities to maximise their impacts across Europe in line with our common political priorities. This also calls for enhanced national strategies tailored to the national context and specific needs, ensuring a timely delivery on those key objectives.

How much does the EU invest in R&I?	More in Chapter 5
How large is EU's scientific and technological output, and why do we need to valorise knowledge?	More in Chapter 6
What are the tools to leverage R&I?	More in Chapter 8
To what extent do scientific research findings reach the market?	More in Chapter 15

5. Connect actors and address disparities

Europe faces high levels of disparities in terms of income distribution, opportunities and regional development, which raise concerns about fairness as well as efficiency. Within its borders, Europe faces the divisions stirred by a sequence of crises, from the great financial crisis to the surge in migration, the COVID-19 pandemic and Russia's invasion of Ukraine.

R&I performance also exposes a deep geographic divide. R&D expenditures, scientific publications and patent applications are **concentrated in more developed regions.** The least innovative regions recorded a low and even declining growth of patent applications over the past decade. As a result, convergence across EU regions in terms of technological production has stalled. Productivity catching up, which has been experienced by many less-developed regions in Central and Eastern Europe, has been driving the rapid expansion of global supply chains and foreign direct investment, with only a limited role for innovation-driven productivity growth. Moreover, R&I ecosystems are very regionalised, which limits the scope for the geographical diffusion of innovation. For example, about 75% of collaborations on patents have been intra-regional in the EU and only 3-5% have been **inter-regional across national borders.**

To close the innovation divide, it is important to **connect different actors in R&I ecosystems.** This would facilitate innovation diffusion and transfer to less-performing regions and help trigger economic dynamism, which would benefit the competitiveness of the EU as a whole. Cross-border collaboration on research and innovation activities could optimise R&I efforts and generate scale economies in knowledge creation. Complementarities in R&I activities between EU regions in terms of industrial specialisation and

knowledge transfer could be also strengthened to ensure a smooth integration of the latest research findings and inventions across regions and countries. There is also a need to strengthen the capacity of the business sector to engage in R&I collaborations with academia and research centres, in particular, in high-tech sectors and in countries with less performing research systems. Continuing divergence between EU Member States on researchers' mobility patterns also calls for a better understanding of the drivers and barriers to international and intersectoral mobility as well as the implementation of policies to foster brain circulation.

At the same time **technological changes, including automation, machine learning and artificial intelligence, will pose challenges for workers and carry a risk of further contributing to increasing disparities.** The new technologies are progressively changing the skills requirements needed in labour markets. As a result, we have seen the shares of highly skilled jobs rising, middle-skilled jobs diminishing, while low-skilled jobs have remained relatively steady. In the digital era, job market requirements are shifting towards non-routine, abstract, analytical and social skills. In the EU, there is a strong heterogeneity of skills levels across countries, urban-rural areas and age groups. Hence, **reskilling policies for low- and middle-skilled workers** will be crucial for sustainable and inclusive economic growth. Lifelong learning and training have become increasingly important to keep workers' skills aligned with evolving job market demands and support longer working lives. Education and training policies should increase the emphasis on developing non-cognitive skills that complement digital skills, such as social intelligence, collaboration, creativity, and adaptability. Current trends in this respect are encouraging: adult participation in learning, R&D personnel and researchers, the

share of tertiary graduates among youth, and ICT graduates are rising across the EU, while NEETs (those not in employment, education or training) are decreasing.

Disparities also remain in terms of gender representation in R&I-related activities.

Women are significantly underrepresented in the EU's entrepreneurial landscape. Women represent the majority of tertiary graduates, yet they are underrepresented in ICT and engineering studies, as well as in the researchers' population.

With the COVID-19 pandemic, women researchers, particularly those with young children, experienced the highest decline in time devoted to research, with possibly adverse effects on their careers in the long term. These significant gender gaps are still to be tackled. The empowerment of women entrepreneurs and researchers remains a key policy objective so as to unleash the EU's untapped growth potential. Providing financial support to women in innovation and entrepreneurship is also essential to creating fair, inclusive and prosperous European R&I ecosystems.

How large are regional disparities in Europe?	More in Chapter 2
How does technological change affect the labour market?	More in Chapter 4
What is the gender representation share for entrepreneurs and researchers?	More in Chapters 4 and 5
Do firms in the EU's cohesion regions invest differently in digitalisation and in green measures compared to firms in non-cohesion regions?	More in Chapter 13
Are key technologies spatially concentrated in the EU's regional ecosystems and what are the implications?	More in Chapter 14

6. Ensure R&I friendly conditions

One of the main structural barriers faced by deep-tech and innovative companies is **limited access to finance**. The EU financial system continues to be strongly dependent on banks and equity investments still play a relatively minor role. While venture capital (VC) investments have only marginally been hit by the COVID-19 crisis, the EU still struggles to attract riskier and more patient investments, especially at the scale-up stage. Against this backdrop, promoting a transition to a green and digital economy requires a significant amount of financing resources. New financing tools need to be targeted towards more innovative EU businesses, while ensuring coherence with the already existing financial instruments available to EU firms. Integrating sustainability criteria into firms' financing is also essential to pursuing the objective of decarbonising the economy. The increasing financing opportunities coming from online finance can be expanded through policy actions aiming to reduce the fragmentation of the Digital Single Market and facilitate digital innovation, while ensuring consumers' protection.

In order to ensure well-functioning markets that incentivise competition and innovation, thereby maximising the impact of EU R&I investments, Europe needs a fit-for-purpose, forward-looking and overall **innovation-friendly institutional**

and regulatory framework. Good institutions are characterised by political stability, transparency and accountability, and show high degrees of rule of law with a low risk of expropriation and corruption. Regulation can be a powerful instrument to foster innovation in the EU. A stable and predictable regulatory environment encourages planning and investment, and enables firms to operate on safe legal grounds. Regulation can also create a strong stimulus for innovation through standard setting or regulatory stringency.

The emergence of new practices, technologies and business models, and the acceleration of innovation **call for more flexible and experimental approaches to regulation**, such as regulatory sandboxes. Access to efficient digital infrastructures and data is also essential to foster the EU's digital transition, but the ability of firms to invest in digitalisation varies significantly across the EU's regions.

Are framework conditions favourable for innovation in Europe?

More in Chapter 7

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The «Science, Research and Innovation Performance of the EU, 2022» report analyses Europe's performance in science, research and innovation and its drivers, amidst multiple crises. The report combines a thorough indicator-based analysis with deep dives into topical policy issues.

The aim of the report is to build a robust narrative that speaks to an audience of policymakers and analysts.

This is a flagship biennial publication by the European Commission's Directorate-General for Research & Innovation that draws on a long tradition of economic analysis. It is the fourth edition in this report series.

Research and Innovation policy

