BRIEFING

European Parliament

Scientific integrity: Handling knowledge as a public good

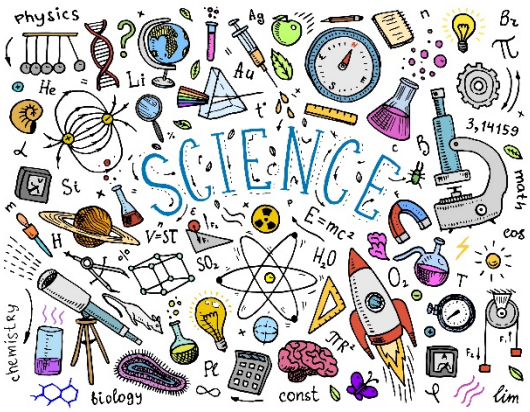
SUMMARY

In September 2021, the special Eurobarometer 516 survey on European citizens' knowledge and attitudes towards science and technology[1] found that 86 % of citizens think that science and technology exert an overall positive influence on society. Whilst the coronavirus pandemic has highlighted the importance of scientific research as a provider of solutions to global challenges, it has also exemplified the capacity of scientific communities to accelerate scientific research cooperation, including through the uptake of the open science movement, characterised by increased free access to scientific publications and underlying data.

The capacity to create such knowledge is founded on scientific integrity, which is defined as the scientific communities' and professionals' adherence to the highest standards of ethics and rigor in their research activities. The digitalisation of science is fostering both the availability of scientific outcomes (such as scientific publications), and their scrutiny.

To facilitate global cooperation on research and innovation, multilateral efforts have been made since the early 2000s to forge a common definition of scientific integrity and provide scientific communities with tools that will enable them to promote research integrity.

Through its competence for research and technological development, the EU is supporting the academic communities' commitment to ensuring the highest standards on integrity, in full compliance with the principle of academic freedom enshrined in Article 13 of the Charter of Fundamental Rights of the European Union.



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Introduction

Research integrity is understood as the compliance of scientific endeavours with the highest standards of ethics and rigor, which allows for the verification of all steps undertaken. Its scope includes how scientific research is designed and conducted, and how scientific results are disseminated and exploited beyond laboratories. Integrity is a corollary of the key normative principles[2] underpinning science, such as universality.

Research integrity is about handling scientific knowledge as a public good that is free from any scientific misconduct that would either contribute to the dissemination of false results or raise doubts about the soundness of scientific outcomes.

Traditionally, efforts to ensure integrity have focused on three main kinds of scientific misconduct:

- plagiarism (unacknowledged copying or attempted misappropriation of authorship, whether of ideas, text or results);
- falsification of results (manipulation of research materials, equipment, or processes, or modification or omission of data or results to establish a research record not corresponding to the experiment);
- fabrication of results (creation or making up of data or results, and subsequent use in any science-creation or dissemination-related activity).

Whilst curbing scientific misconduct remains key to facilitating the creation of knowledge, new trends, such as the digitalisation of science, are enlarging the scope of integrity from a matter of individual behaviour to one that also includes institutional responsibility. For instance, other questionable scientific research practices, such as conflict of interest, are attracting more political attention owing to the magnitude of their potential adverse political and socio-economic impacts.

An extended approach to integrity: From the lab to the world

Research integrity is a key tenet of the scientific community

Research integrity, understood as ensuring the scientific soundness of a scientific endeavour, has two main complementary dimensions. First, scientific research involves the observation and discussion of an established set of knowledge. As conceptualised by different prominent epistemologists, such as Gaston Bachelard and Karl Popper,[3] 'the scientific status of a theory is its falsifiability, or refutability, or testability', which implies that scientific research relies on a critical mind to validate and extend the body of available knowledge. Second, research activities are subject to collective scrutiny by the scientific communities, composed of researchers affiliated to, or recognised by, academic institutions. The soundness of research objects, methods and outcomes is based on peer-review scrutiny. This global standard is enshrined in a 2017 recommendation on science and scientific researchers made by the United Nations Educational, Scientific and Culture Organisation (UNESCO), according to which researchers should conduct scientific activities on the basis of 'utmost respect for [their] autonomy and freedom of research indispensable to scientific progress', based on the 'questions, criticisms and suggestions addressed to them by their colleagues throughout the world'.

Evolution of science renews the relevance of integrity

Digitalisation of science increases the availability of scientific outputs

Technological change is shifting the modalities of scientific creation and dissemination across the discipline fields: digitalisation, and information and communication technologies, facilitate the online availability of scientific knowledge, thereby increasing its findability, accessibility and reusability. This technological evolution has shaped the Open Science movement and enabled it to launch new pathways for conducting the main scientific activities, notably through an increase in collaborative practices and a proliferation of online journals and scientific publications. During the

past two decades, there has been a global increase in the number of scientific journals (with up to 25 600 active journals counted by Scopus in October 2020 and more than 4 million scientific peer reviewed articles available[4]). The inflow of available scientific knowledge and the associated data (with a trend towards providing ever-increasing free access to both authors and readers through the 'open-access diamond'[5] model) have the combined effect of facilitating the accessibility of research creations, and hence of increasing the scientific communities' capacity to exchange information about and scrutinise developments in the scientific field.

At the same time, there are growing concerns about the quality of scientific publications. For instance, a number of online publishers have been prioritising their self-interest at the expense of knowledge understood as a public good. Their editorial content features deviations from the best editorial and publication practices, by including, among other things, false data and misleading information. Yet, whilst being difficult to categorise, the publications they produce – known as predatory scientific journals – are scrutinised by peer-reviewed methodologies. Overall, the impact of digitalisation on the effectiveness of the peer-review scrutiny appears significant: whereas in 2000 an average of only 40 scientific papers were retracted annually, in 2021 their number had grown to 3 300. While this figure can be explained by the stronger linkages within the scientific communities, it cannot be interpreted as an indicator of poor quality in science (see below).

Growing scientific employment in a more competitive context

Beyond technological change, the volume of employment in the scientific sector is growing worldwide, contributing among other things to the increase in scientific publications. This trend is particularly pronounced among doctoral students, whose number is on the rise including within the EU. According to Eurostat data, from 2013 to 2020 the number of doctoral students enrolled in institutions established in the 27 Member States increased by 8.8 %; in 2020, there were more than 18 million doctoral students in the EU.

Another significant trend in the evolution of scientific activity patterns relates to the increase in competitive research funding among the national science policy mixes. In a 2018 policy paper, the OECD concluded that competitive funding is a key feature of research and innovation funding and that there is a general trend towards introducing competitive elements. This is relevant for research integrity in several ways: in principle, the allocation of such funding is based on a peer-review process, to ensure a merit-based ranking. On the one hand, this is an additional opportunity for scrutiny, relevant also in consideration of the intensification of transnational and inter-sectorial collaborative research, which requires specific skills from scientific communities to agree on common standards to ensure integrity, as well as their capacity to ensure that non-academic partners comply with the desired levels of integrity. In this respect, EU academia seem especially proficient, given the rate of co-published articles. On the other hand, several prominent researchers, such as a former chair of the French Académie des sciences, stress the presence of risks, including that of scientific misconduct, associated with an intensified funding competition in a context of budget cuts or stagnation.

Assessing scientific misconduct and questionable research conduct

Compliance with research integrity is not easy to measure. Importantly, in line with the academic freedom tradition and the 2017 UNESCO recommendation on science and scientific researchers, the scrutiny of research integrity is to be conducted autonomously, only by members of academia, scientific communities and institutions. This is explained most notably by the fact that the peer-review principle cannot ensure the full scrutiny and replication of the research outcomes examined (i.e. repeating a study's procedure and observing whether the prior findings recur). Beyond cases of plagiarism, fabrication and falsification of data and/or results, other individual questionable research practices, such as relying on a non-rigorous statistical framework, can undermine integrity. The available academic works on quantifying research integrity highlight two main consequences.

On the one hand, the rate at which scientific misconduct occurs seems low. For instance, both assessments conducted on researchers' declarations about their own track record and a review of inappropriate image duplications by biomedical researchers point to a very low prevalence of misconduct: for instance, less than 2 % of the biomedical papers examined out of a sample of more than 20 000 articles published in 40 publications, contained features of deliberate manipulation.

On the other hand, experimental sciences face a reproducibility challenge across the disciplines (i.e. difficulties in obtaining consistent results using the same input data, as well as computational steps, methods, and code and conditions of analysis). In 2016, *Nature* published the results of a survey in which 1 576 researchers took part. More than 50 % of them flagged their failure to reproduce one of their own experiments. The Royal Netherlands Academy of Arts and Sciences (KNAW) disclosed the state of play of reproducibility across the eight fields of empirical sciences in 2018,[6] with reproducibility rates ranging from 11 % in pre-clinical studies in oncology to 77 % in experimental psychology. Complementary facts provide an explanation. According to Daniele Fanelli, natural sciences expert specialising in scientific misconduct, this can be explained by several causes: questionable research practices, such as the use of samples with limited statistical power (representativeness), can produce false negative or false positive results. Another relevant cause of non-reproducibility stems from the prevalence of manuscripts and articles published without the appropriate set of raw data underpinning the observations contained in them. In 2022, *Nature* presented the findings of a study coordinated by a researcher from the Catholic University of Croatia, which tested the state of play of the availability of the underlying data of scientific publications. The authors of 1 792 manuscripts published in January 2019 by 300 journals published by BioMed Central (a UK open-access publisher) were asked to provide their raw data. Less than 50 % of the authors who responded shared their data, even though their manuscripts had mentioned that such data was available on request.

The emergence of multilateral cooperation on research integrity

The need to ensure the integrity of science through a common understanding among the scientific communities at global level led to the launch of the first world conference on research integrity in Lisbon in 2007, with 275 participants from 47 countries.

The second edition of the conference, held in Singapore in 2010, ended with the adoption of the Singapore Statement. It was based on four principles – honesty, accountability, professionalism and good stewardship – and 14 corresponding responsibilities in the conduct of research (integrity, data sharing, record keeping, authorship, publication, peer review, conflict of interest, reporting of misconduct and irresponsible research, communication with the public, compliance with regulations, education, and social responsibilities).

All editions of the world conference on research integrity have been informed by the proceedings of the OECD global science forum, included in a set of best practices for ensuring scientific integrity and preventing misconduct, as well as developing and sharing further expertise.

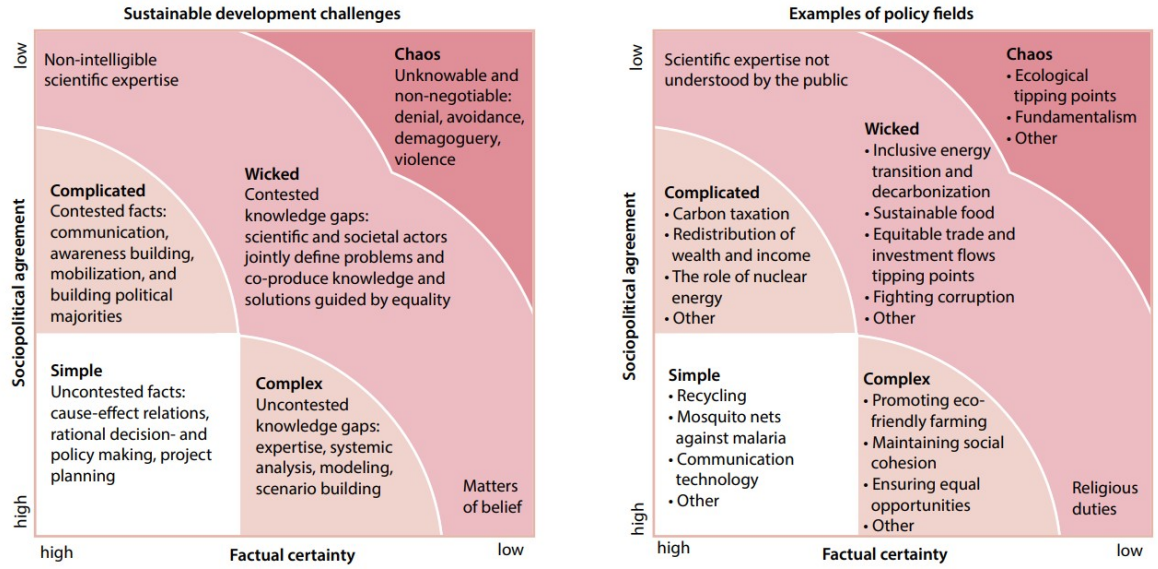
Research and integrity is also a point on the G7 agenda. In 2022, the ministers responsible for science welcomed the adoption of a paper on common values and principles on research security and research integrity. This paper defines research integrity as 'the adherence to the professional values, principles, and best practices that ensure and uphold the validity, social relevance, responsibility, and quality of research'. It then notes that, while such 'principles may vary from country to country, they are key to upholding academic freedom as a universal right and public good'.

The sensitive role of scientific knowledge in the context of global challenges

Science-based policymaking and public institutions' role in achieving integrity

The coronavirus pandemic has highlighted the key role of science in providing the factual basis needed to understand a phenomenon and contribute to a policy response (design –implementation – monitoring). In the context of the EU's overarching political priorities of accelerating the twin digital and green transition, the need for technological development and for non-technological innovation (such as a governance scheme for the new technologies) features in a 2022 strategic foresight report by the European Commission, more specifically in the chapter on the critical technologies for the twinning. In this chapter, the authors argue that the growing political relevance of a sound interface between science, public institutions, industry and society at large calls for a framework to ensure integrity across a wide range of cooperative initiatives. This framework would include a safeguard against scientific misconducts but would also provide solutions for other kinds of questionable research practices. This is notably the case of the risk of conflict of interest, and/or conflicts of commitment, that can arise when having to reconcile the differences that exist between the activities of a researcher and a laboratory. According to the European Commission's 2022 report 'Science, research and innovation performance of the EU', this is especially relevant in the EU, which ranks second after Japan worldwide in terms of its share of public-private co-publications.

Figure 1 – Challenges arising from the interplay between science-based facts and socio-political preferences



Source: Global sustainable development report 2019, United Nations, 2019.

The policy responses unfold at individual and institutional level. The most obvious framework to ensure the integrity of science through partnership endeavours lies in the legal basis of the employment relationship. The European Charter for Researchers adopted in 2005 noted that 'researchers need to be aware that they are accountable towards their employers, funders or other related public or private bodies'. Interestingly, in the past decade, the public institutions employing and/or funding researchers and research activities have reinforced their safeguards against conflicts of interest. For instance, the EU has mainstreamed research integrity through the grant cycle of the EU research and innovation framework programmes. The evaluation of the proposals submitted under Horizon Europe calls is performed by independent experts whose selection rules currently rely on eight complementary causes for exclusion, to ensure the integrity of the evaluation process.

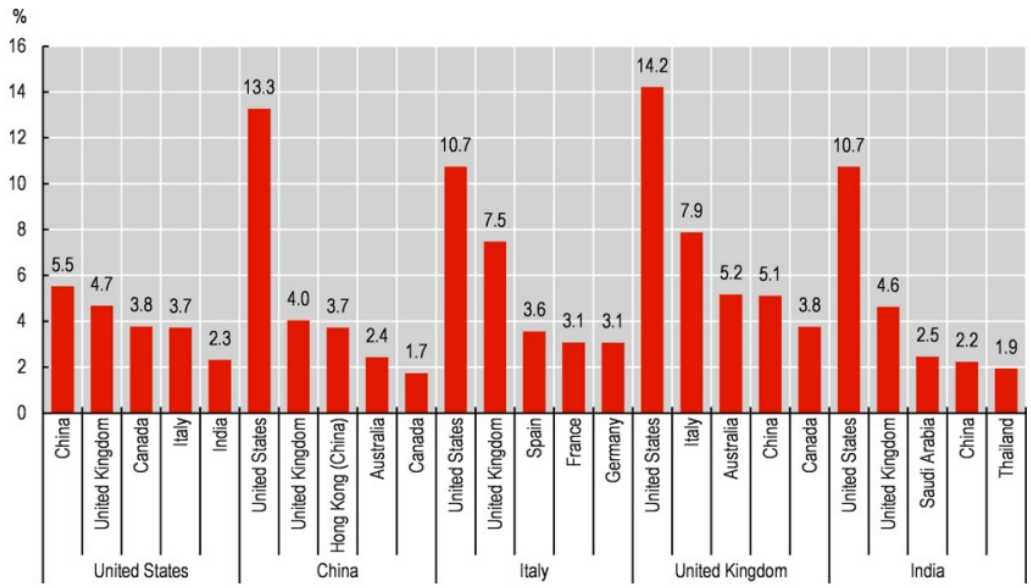
Subsequent project implementation is also underpinned by specific legal obligations of the beneficiaries, to reduce the misuse of research results.

Throughout and beyond the research project cycle, the pandemic also highlighted the role of integrity in scientific communication, both within the scientific community and to society at large. A 2021 opinion by the ethics committee of the French Centre national de la recherche scientifique (CNRS), while noting the need to differentiate validated knowledge from working hypothesis or debated issues (Figure 1), invited research and academic institutions to encourage scientists to disseminate their knowledge in the media, and offer them training on scientific mediation.

Integrity as an enabler of the openness of EU scientific excellence to the world

A 2022 OECD policy paper on integrity and security in the global research ecosystem explores the dilemma between the value of global cooperation in advancing knowledge and the need to safeguard against the risk of foreign interference. While highlighting the significant share of transnational research cooperation (Figure 2), the report outlines a threefold taxonomy of potential foreign interference in the field of scientific activities, at institutional level. A first set of detrimental practices refers to any misappropriation or misuse of any knowledge, data, sample or know-how. Misuse of data can include breaches of the relevant EU legislation, such as the EU General Data Protection Regulation. The second set of interference constitutes deceptive practices, including conflicts of interest or conflicts of commitment among the academic institution's staff, students and partners. The third set of interference practices involves any coercion exerted in order to restrict the academic freedom of an academic or an academic institution. Article 13 of the EU Charter of Fundamental Rights stipulates that 'the arts and scientific research shall be free of constraint. Academic freedom shall be respected'. The EU's global approach to research and innovation seeks to help the EU become a leader in knowledge creation (measured as a share of excellent publications), and ensure that science and innovation contribute to the EU's open strategic autonomy in the context of the twin digital and green transition. Whilst responsibility for tackling foreign interference lies chiefly with the Member States, the EU also provides safeguards against the risks associated with Horizon's openness to the world, along with legislative solutions to protect the use of EU-funded results.

Figure 2 – Selected countries and their top five partner countries in terms of percentage share of total number of co-authored medical research publications (1 January – 30 November 2020)



Source: Integrity and security in the global research ecosystem, OECD, 2022.

How research integrity is handled in Horizon Europe

Regulation (EU) 2021/695 establishing Horizon Europe has several provisions to ensure the promotion of research integrity across its funded activities. These are listed below

Article 19(2) creates an obligation for all legal entities participating in any Horizon Europe funded action to confirm that their activities will comply with the European code of conduct for research integrity published by all European academies. This obligation is therefore included in Article 14 of the Horizon model grant agreement. The European Research Council Executive Agency publishes a summary of the cases of suspected scientific misconduct linked to the proposals submitted in reply to its calls for funding, including their evaluation and implementation. Between 2012 and 2018, the annual number of cases of misconduct varied from 10 to 17.

Article 22(5) allows restrictions on the participation of third-country legal entities in actions relating to EU strategic assets, interests, autonomy or security. In the Commission's 2021-2022work programme, this provision has been activated in relation to roughly 30 topics in the digital-industry-space cluster alone. In addition, Article 40 of the Horizon Europe Regulation allows the Commission to object to transfers of ownership of results, when such transfers to a legal entity established in a non-associated third country would not be in line with EU interests. This provides the Commission with a further remit in addition to Article 8 of Regulation (EU) 2019/452 on the screening of foreign direct investment into the Union, which allows the Commission to issue an opinion to Member States, whenever such investment would affect projects or programmes of Union interest on grounds of security or public order.

How policy can promote research integrity

The landscape of EU and international initiatives

Whilst the EU has taken steps to complement and support Member States' initiatives to promote scientific integrity, Member States and the academic actors (universities, research performing organisations, research funding organisations) continue to be at the centre of initiatives to introduce safeguards against foreign interference in research.

- On 1 December 2015, the Council of the EU adopted a set of conclusions on research integrity. Considering that research integrity, together with academic freedom, is a precondition for high-quality research and its socio-economical uptake, the Council calls on the institutions to foster an institutional culture of research integrity in order to create a climate in which responsible behaviour is expected at individual and institutional level. Academic players and Member States have taken several measures in this regard.
- One of the main achievements of transnational cooperation among stakeholders is the 2017 update of the European code of conduct for research integrity by All European Academies (ALLEA), available in 21 official languages. The updated code highlights four principles (reliability, honesty, respect, accountability) that are to be applied to the continuum of research creation, training and dissemination.
- Following the December 2015 Council conclusions, the European Network of Research Integrity Offices (ENRIO), established as a follow-up to the 2007 Lisbon conference mentioned above, welcomed new members from six Member States (Czechia, France, Luxembourg, the Netherlands, Poland and Slovakia).
  21 Member States, Norway and the United Kingdom belong to the network. Beyond their transnational cooperation, research stakeholders have also updated their internal policies to promote researchers' integrity-related skills. For instance, in 2019, the University of Lund (Sweden) created the post of scientific integrity officer for all its faculties. Since 2021, a compulsory course of research ethics is followed by all PhD students of this university.

Member States' legislative and non-legislative initiatives

A number of Member States have followed up on the 2015 conclusions, in line with their responsibility as legislators and research funders.

Examples of legislative initiatives include Denmark's 2017 Act on research misconduct, which established an investigative body,[7] the Danish Committee on Research Misconduct, in charge of assessing the (scientific) materiality of alleged cases of misconduct; the academic institutions remain competent as regards other questionable research practices. Another example is Spain's 2022 Law 17/2022 on science, technology and innovation, which created the Spanish Committee on Research Ethics as a collegial consultative independent body in charge of issuing guidelines, conducting specific assessments, and representing Spanish authorities internationally on matters associated with scientific integrity (Article 6(10)). Yet another is France's 2020 Law 2020/1074 on research programming for the 2021-2030 period, which introduced a general legislative framework for research integrity (Article 16(V)),[8] whereby research organisations must ensure scientific integrity and its scrutiny across all their activities.

As regards funding initiatives, since 2019, the German research funding organisation Deutsche Forschungsgemeinschaft has been enforcing a set of 19 guidelines on safeguarding good research practices, in a legally binding manner. A transition period in this regard expires in 2023.

As regards providing safeguards against foreign interference, Member States have adopted several initiatives to reduce and mitigate the risks associated with detrimental, deceptive and coercive practices. In particular, in 2011, France launched a holistic overhaul of the regulation framework applying to the protection of the nation's scientific and technological assets. By identifying scientific infrastructure, such as laboratories, the framework allows the competent authorities to scrutinise the right of access to physical and digital premises, as well as monitoring the risks associated with international scientific activities. A 2019 report published by the Office parlementaire d'évaluation des choix scientifiques et technologiques (parliamentary observatory on scientific and technological choices) concluded that such monitoring had not resulted in a systemic impediment to the academic freedom of the researchers active in the identified laboratories. For 2018, it is estimated that more than 95 % of the 9 400 requests for access were granted without further scrutiny. However, the report stressed the risks of the steady increase in the number of identified structures, which might undermine the capacity to ensure timely overall monitoring.

Recent policy initiatives on research integrity beyond the EU

In 2022, the US White House Office of Science and Technology Policy published a report on protecting the integrity of government science. According to the report, protecting scientific integrity throughout its creation and dissemination results in better decisions, which translate into better policies that help people and communities of all backgrounds thrive. The approach taken by the office has similarities with the EU and the OECD approaches, notably in its holistic definition of the notion of interference in the domain of science.

Canada adopted a research and scientific integrity policy in 2018, under the coordination of the National Research Council of Canada. Japan meanwhile provided legislative backing for research integrity with the adoption in 2008 of an act on activation of the creation of science and technology innovation.

In addition to the Member States, academic stakeholders play a key role in preventing and mitigating risks relating to research integrity. In the Netherlands, at the government's request, the association of Netherlands universities have adopted a framework for knowledge security relevant to both the staff of academic institutions and their governance bodies. At university level, it recommends the establishment of a knowledge security advisory team composed of the relevant experts (e.g. the information security officers). The authors expect more than 80 % of potential cooperation to be below the level of risk that would require the team's involvement.

Positions of the European Parliament and of the Council

Parliament

Parliament has addressed the relevance of scientific integrity in its legislative proceedings through various resolutions. In its resolution of 9 March 2022 on foreign interference in all democratic processes in the European Union, including disinformation, Parliament makes several references to the risks to scientific integrity associated with established cases of foreign interference directed at EU academic players. Such risks refer to detrimental practices at individual and institutional level (in particular, the resolution invites Member States to 'adopt effective rules on foreign funding for higher education institutions, including strict ceilings and reporting requirements'). The risks also relate to theft of knowledge. In its resolution of 6 April 2022 on a global approach to research and innovation, Parliament states that its international research and innovation cooperation, the EU should assume a leading role and set high ethical standards and apply a high degree of research integrity in the provision of world-class science. It also expresses its wish that Horizon Europe 'will work towards a common understanding and implementation of principles such as research ethics and integrity'.

As for legislative initiatives, Parliament's position of 25 March 2021 on the proposal for a regulation setting up a Union regime for the control of exports, brokering, technical assistance, transit and transfer of dual-use items, includes a reference to the specificities of academic cooperation. In particular, 'academic and research institutions face distinct challenges in export control due, inter alia, to their general commitment to the free exchange of ideas, the fact that their research work often involves cutting edge technologies, their organisational structures and the international nature of their scientific exchanges'. It calls then on Member States and the Commission to raise awareness among the academic communities and to provide for a common understanding of the relevant standards, such as the one on 'basic scientific research' (Article 13 of Regulation (EU) 2021/821 setting up a Union regime for the control of exports).

Council

In 2020 and 2022, the competitiveness Council adopted two sets of conclusions directly relevant to the aim of strengthening EU scientific integrity. In its conclusions of 1 December 2020 on the new European research area (ERA), in line with the multi-stakeholder landscape of the EU science policies, the Council calls on the Commission, Member States and academic institutions to work together or further reinforcing freedom of scientific research within the ERA. The Council welcomes the Bonn Declaration on the freedom of scientific research, prepared and endorsed on 20 October 2020 under the German Presidency of the Council. The declaration, whilst incorporating research integrity into the scope of the freedom of scientific research, acknowledges the prominent role of academic institutions, which should 'encourage and support high standards of good scientific practice, guidelines and advisory structures for safeguarding integrity'.

In its conclusions of 28 September 2021 on a global approach to research and innovation, the Council 'invites the Commission and the Member States to apply the European Code of Conduct for Research Integrity'. It also placed scientific integrity on the list of topics to be addressed in continuing the EU's negotiations on a joint roadmap with China. With its conclusions of 10 June 2022 on research assessment and implementation of Open Science, the Council states that currently, research assessment is to a great extent too focused on quantitative indicators, and considers that this may lead to negative bias in terms of research reproducibility and integrity. It therefore highlights the value of designing an EU initiative to facilitate the coordination of changes to research assessment systems.

Views of EU academics and scientific players on integrity

European academic players are dedicating substantial attention to the issue of scientific integrity as part of the established framework of academic freedoms, and to modalities for improving it. The advice and opinions shared focus on aspects such as exploring ways to improve research practices, designing governance and institutional settings to frame an integrity culture, providing training for academic communities across the generations and scientific fields, and reflecting on how to harness research evaluation to reduce the risk of scientific misconduct.

Curating research integrity at EU level: review of EU initiatives and options

Whilst the above policy guidance adopted by EU institutions relies chiefly on national legislative and non-legislative initiatives, there is an increasing number of initiatives to harness the European research area in order to promote research integrity at the transnational level. This is done directly, by promoting a pan-European coordinated approach on research integrity, or indirectly, by targeting framework conditions such as the individual assessment of scientists and researchers.

In 2020, the European Molecular Biology Organization explored options for a coordinated approach in Europe on the governance of research integrity. It considered the creation of a European body whose missions could include an investigative remit on scientific misconduct (in line with the Danish Committee on Research Misconduct presented above), as well as the power to oversee the implementation of academic institutions' research integrity policies). Such a body would contribute to forging a common set of practices across the European research area. The report mentions different possible governance models that include the hosting of such a European body either in an existing transnational European research performing or funding organisation within EU governance (for instance, a Commission executive agency, such as the European Research Council (ERC), which has already established a Standing Committee on Conflict of Interests, Scientific Misconduct and Ethical Issues), or outside the EU's institutional structure (for instance CERN). The creation of such a body might also facilitate the monitoring of the compliance of the legal entities involved in Horizon Europe activities on research integrity (see box above on Horizon Europe). In 2022, the EU invested €5 million through Horizon Europe to establish a transnational network on research integrity, one of whose expected outcomes is the creation of a methodology to address research misconduct.

EU initiatives on the European research area also provide new opportunities to strengthen integrity at transnational level. With the adoption of an agreement on reforming research assessment, concluded between the Commission and 350 academic institutions established in more than 40 countries, the EU is set to accelerate the shift of the peer review of research assessment towards a more qualitative approach, which should also hamper the business model of predatory journals significantly.

In 2020, the League of European Research Universities (LERU) published a full set of recommendations on a research integrity culture at universities. LERU identifies several measures that universities could adopt to improve research practices, such as improving the understanding and use of state-of-the-art statistical tools and methodologies, as well as supporting major replication studies and giving more importance to negative results (which can be defined as scientifically obtained data that invalidate a hypothesis or render an experiment inconclusive) by increasing their publication rate and findability. This raises the need to encourage publication of the raw data obtained, not least by investing in an appropriate digital infrastructure, able to curate the availability and security of data over time, while ensuring lawful use of such data. As for the governance of academic institutions, LERU encourages universities to enhance their transparency and accountability also by creating new institutional roles in relation to integrity, such as ombudsman positions. As regards training, LERU insists specifically on reaching the widest audience among university communities, targeting PhD students but also undergraduate students and experienced researchers, whilst adapting to the different needs of the scientific disciplines.

In 2022, through an opinion of its secretary-general, the Guild of European Research-Intensive Universities provided options to advance on the reform of research assessment, with the aim of lowering the adverse effects on and risks associated with scientific integrity. Three options are considered, covering all the advantages and drawbacks: substituting metrics-driven assessment

with a comprehensive qualitative review of research performance; switching the distribution of base funding to universities from research performance to other allocation keys such as the number of students; and increasing the share of research funded through competitive calls based on quality assessment. The opinion highlights the EU's multilingual dimension and insists on the need for a balance between facilitating the publication of scientific literature in all languages and preserving the capacity of European researchers to convey their findings globally by publishing in the 'major European languages'.

Following the abovementioned 2022 Council conclusions on research assessment and open science, ALLEA published a welcoming opinion, highlighting in particular the trade-offs associated with the current scientific journals and publications landscape in the ongoing transition to open science. Similarly, in 2022, the Italian National Research Council (CNR) published a set of recommendations to researchers, to help them identify potential predatory journals (based on criteria such as the rejection rate of the proposed articles, which may be up to 90-95 % in the leading scientific journals, whereas a rejection rate below 10 % might indicate an editorial policy qualifying as predatory). The CNR encourages researchers to monitor their peers as a way to reduce the influence of such predatory journals; it also highlights the drawbacks of a highly concentrated market of scientific publications, with publishing groups being able to redirect rejected manuscripts from their prestigious journals to other journals of theirs that have significantly lower rejection rates.

On the question of the interplay between research integrity and security, a 2020 report 'Towards sustainable Europe-China collaboration in higher education in research', the Leiden Asia Centre provides a set of recommendations for European academic players and individuals. Based on an assessment of China's relevant policy initiatives, including on research integrity, the report builds on similar advice adopted by other European academic institutions, such as the German Rectors' conference 2020 resolution on key questions on university cooperation with the People's Republic of China, or the 2020 guidelines for reflection on international academic collaboration produced by the Swedish Foundation for International Cooperation in Research and Higher Education.[9] All these recommendations converge in upholding research integrity. Academic institutions in particular must consider designing measures to safeguard academic integrity, not least academic freedom.

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ENDNOTES

[1] European citizens' knowledge and attitudes towards science and technology, Special Eurobarometer 516, 2021.

[2] R. K., Merton, *The sociology of science – theoretical and empirical investigations*, Chicago University Press, 1973.

[3] G. B. Bachelard, Le nouvel esprit scientifique, 1938; K. Popper, Conjectures and refutations, 1963.

[4] EU-based researchers are assumed to have authored 24 % of all scientific and engineering articles in 2019.

[5] The number of Open Access diamond journals is high (estimated at 29 000). Such journals generally publish fewer articles (356 000) than APC-based ones (approximately 453 000) per year. The OA diamond sector is diverse in terms of regions (45 % in Europe, 25 % in Latin America, 16 % in Asia, 5 % in the US/Canada) and disciplines (60 % social sciences and humanities, 22 % science-engineering-technologies, 17 % medicine). In Europe, more than half of these journals are based in one of the eastern European countries (source: plan S).

[6] See Table 1 'Occurrence of non-reproducibility', in Royal Netherlands Academy of Arts and Sciences (KNAW), Replication studies, improving reproducibility in the empirical sciences, 2018, p. 22.

[7] Austria also established an investigative body, the Committee for Research Integrity, whose mission is to investigate allegations of research misconduct and to propose follow-up measures to the academic institutions employing the researcher(s) involved. Interestingly, this committee is composed of non-Austrian residents only, to lower the probability of a conflict of interest.

[8] A subsequent regulation (Decree 2021/1572) defines the scope of the legislative provision and the modalities of the due dilligence to be conducted to ensure compliance.

[9] The report also considers three other reports: a) Checklist for collaboration with Chinese universities and other research institutions, The Hague Centre for Security Studies, 2019; b) Managing risks in internationalisation: security-related issues, Universities UK, 2019, c) Guidelines to counter foreign interference in the Australian university sector, Australian Department of Education, 2019.

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