Europe and the need to *Align, Act and Accelerate* Research and Innovation:
new challenges and opportunities for "research intensive" doctoral education

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Abstract
The need for continuously modernizing doctoral education in Europe in close articulation with research and innovation is discussed in terms of emerging requirements to accelerate our collective response to geopolitical threats, boost innovation in defence and security, and rethink our understanding of "science for policy" in times of knowledge abundance. Over three years into the war in Ukraine and with a new US administration in place, it is critically important to emphasize that Europe is the world's most reliable partner – and the most efficient in terms of outputs per resources, thanks to our diversity. Building on the *Letta*, *Draghi*, *Heitor* and *Niinisto* reports of 2024, while investment capacities still lag behind, we now have a unique opportunity to **advance doctoral education in very close articulation with research and innovation** towards Europe´s *strategic autonomy* on a world level. But we must strengthen and reform our funding systems to promote greater risk-taking, faster decisions, and institutional tolerance for failure. Doctoral education, together with the *Choose Europe* initiative to foster research careers, should be promoted without any hesitation and with adequate investment levels to turn the *European brain drain* of last decades to the US into a *brain gain*. The *Union Strategy on Preparedness* mark key steps in this direction, but requires to better *Align, Act and Accelerate* Research and Innovation.

1. The context: *a new complex of uncertainty*

Europe is facing an unique opportunity to better foster knowledge towards its strategic autonomy at a world level. In a context of knowledge abundance, we all face new challenges for "scientific activism" to face uncertainty, together with the fragmentation of multilateralism and the polarization of our societies.

Doctoral education plays an critical role in this context. But its analysis and continuous evolution must take into account the work of the German sociologist Klaus Eder[2], together with that of Josef Henrich (2016), for whom learning is not the same as cultural evolution. **Social learning does not change the world, but it provides the elements to change it**. It promotes an increase in the evolution of behaviors, expanding the scope of possibilities for evolution. In other words, doctoral education and research, together with collaborative research and innovation, must be understood as a "cultural movement" involving *institutional innovations* to address processes of stimulating ***generational change*.**

Over three years into the war in Ukraine and with a new US administration in place, we clearly know that Europe is the most reliable partner at a world level, the most efficient by outputs per resources thanks to our diversity. Our values and democracies are a world reference, to be preserved and strengthened, at any cost. Obviously, Europe is lagging behind in terms of Research and Innovation

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2 Eder, K. (1993), "The New Politics of Class: Social Movements and Cultural Dynamics in Advanced Societies", SAGE Publications.

(R&I) investment and a lot of improvements and even changes are necessary. But we all are facing an unique opportunity to make it happen, and Align, Act and Accelerate our policies[3] to evolve from the current situation:

- As measured by the **top 1% most cited scientific publications worldwide, the EU ranks third, behind China and the USA**, with its share of the total declining from 20.7% in 2000 to 17.8% in 2020. The European Union ranked second globally for the total number of scientific publications, behind China and ahead of the USA, and accounted for 18.1% of the global total in 2022, amounting to approximately 650 000 publications. Over the past two decades, the EU's contribution to global scientific publications has dropped from 25.5% in 2000 to 18.1% in 2022;[4]
- From 2005 until 2015, the EU was leading the world in terms of scientific AI publications (37%), followed by China (34%) and the US (29%). However, by 2021 China had surpassed both the EU (30%) and the US (28%), accounting for 42% of publications[5]. Looking at the breakdown per sector, the EU ranks second in all of the four main sectors (i.e. health, environment, transport and agriculture), while the US leads in health and China in the other three. As China steadily enhances the quality of its publications (measured as top 10 % most-cited scientific publications), the **EU has descended to the third position globally**, closely trailing the United States.
- The **EU's share in total patent applications has been declining in recent decades**. Accounting for around 30% of the world's patent applications in 2000, the EU's share declined to 17.3% in 2021. Between 2014 and 2020, the EU led in global high-value patent filings related to renewables (29%) and energy efficiency (24%), but lost ground in smart systems (17%) ranking fourth after the US, China and Japan;
- **EU´s technology base is more diversified than that of other major economies**, but the EU is disproportionally more specialized in less complex technologies than its counterparts. Although the EU is a technological leader in certain high-tech industries (e.g. EUV and High-NA lithography machines by ASML, among many other examples), China has been leveraging its status of *factory of the world* to establish new standarts globally and helping downstream industries (e.g. EVs) to vertically integrate with high tech industries (e.g. semiconductors, advanced materials) and has been successful at reshuffling the level global playing field in general. The main point here is that **EU has lost technological leadership** in some domains that it had before (e.g. software services) and has not kept up with other new areas. In general, analysis shows that: i) The EU shows a higher specialization in food chemistry, climate and environmental technologies; while ii) The US and China are leading in areas related to digital technologies such as semiconductors, computer technologies, optics, digital communications and audio-visual technologies, which are the expected to be key drivers of growth in the near future[6];
- **Europe has kept civilian and military research and innovation systems apart**. In contrast, the US has successfully linked disruptive science, innovation and technology development to US defense policy, allowing it to meet national security needs and simultaneously benefiting US economic growth and competitiveness through commercial applications. Similarly, China has pursued civil-military fusion for many years.

[3] https://op.europa.eu/en/publication-detail/-/publication/2f9fc221-86bb-11ef-a67d-01aa75ed71a1/language-en
[4] EC (2024) Science, research and innovation performance of the EU - Publications Office of the EU (europa.eu)
[5] EC (2023).
[6] EC (2024) Science, research and innovation performance of the EU - Publications Office of the EU (europa.eu)

The 'Align, Act, Accelerate' report of October 2024[7] should be understood as a comprehensive analysis of European R&D programs often mentioned alongside the "Letta Report" (April 2024[8]), the 'Draghi Report' (September 2024[9]) and the "Niinisto Report" (October 2024[10]), respectively on European internal market, competitiveness and security— they all clearly note an urgent need for Europe to unite its forces: i) Our collective response to escalating geopolitical threats must accelerate; ii) We must expedite our research and innovation in Defense and Security, together with *Prevention, Preparedness and Readiness; and iii)* These should be associated with evolving understanding of "science for policy" in times of deep transformation[11].

This paper thus focuses on the prospective analysis of the conditions for **promoting knowledge through doctoral education** as a critical factor for competitiveness and for facing emerging societal challenges at a global level in the growing "uncertainty complex" that we are witnessing at an international level[12]. It includes four volatile and interactive aspects:

i) the **fast rate of technological change** in which we live, in a context of increasing abundance of knowledge and, above all, information, with the exponential growth of scientific publications on a global scale, including a new relevance of science produced and disseminated in China[13]. This has stimulated new initiatives of "technology monitoring", "data analytics" and "search" for "reliable knowledge", together with the need for new evaluation and financing mechanisms, as well as more public and private investment in many regions of the world (including Europe), naturally, for frontier research, disruptive innovation and collaborative science/innovation;

ii) the **growing fragmentation of multilateralism** (i.e., the change of direction from globalization to regionalization), reinforced recently by recent North American policies, together with the defense and security of populations being considered notably and for the first time at political level in Europe as the priority factor for the competitiveness of its regions. It includes the discussion on the concept of *strategic autonomy*[14], with the growing relevance of space and information systems for defense and security, including, of course, energy and environmental security, public health, civil protection and the security of populations, as well as autonomy in the production of industrial and agri-food goods. But it also includes an in-depth discussion on "science and global geopolitics" and how Europe, among others (i.e., Latin America and Africa) will relate to the USA and China in the coming years;

iii) the **accelerated social and political polarization of societies**, together with a relative weakening of democracies and the emergence of "*me first*" behaviours in a demographic context that is growing and changing[15]. This includes the need to prioritize young adults and better understand their ambitions, together with the challenges of attracting and retaining talented young people for science and innovation activities and the complexity of guaranteeing better jobs and research careers; and

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[7] The so-called Heitor Report, as available in https://op.europa.eu/en/publication-detail/-/publication/2f9fc221-86bb-11ef-a67d-01aa75ed71a1/language-en.

[8] https://single-market-economy.ec.europa.eu/news/enrico-lettas-report-future-single-market-2024-04-10_en.

[9] https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en.

[10] https://commission.europa.eu/topics/defence/safer-together-path-towards-fully-prepared-union_en.

[11] See European Commission: Joint Research Centre, SCHWAAG-SERGER, S., SOETE, L. and STIERNA, J., Scientific Report - For an Innovative, Sustainable and Fair Economy in Europe, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/0336180, JRC140513 https://publications.jrc.ec.europa.eu/repository/handle/JRC140513

[12] See, for example, CEPS Ideas Lab (2025), March 2025, https://www.ceps.eu/ceps-publications/2025-ideas-lab-report/. Também, https://www.ceps.eu/ceps-publications/unpredictable-tariffs-by-the-us-implications-for-the-euro-area-and-its-monetary-policy/

[13] See, for example, Marginson and Yang (2001) and Schwaag Serger et al. (2021). See also Qian (2024) for an analysis of China's research funding system and the effects of AI.

[14] See, for example, https://www.europeanpapers.eu/europeanforum/strategic-autonomy-new-identity-eu-global-actor.

[15] https://population.un.org/wpp/.

iv) the **emerging societal challenges** associated with mental health, inequality in access to innovative biomedical treatments (especially for "non-curable diseases"[16]), as well as the destabilizing planetary pressures and inequalities of the Anthropocene, together with emerging environmental health challenges and the One-Health concept, as well as the search for comprehensive social transformations to alleviate these pressures in a demographic scenario that is growing on a global scale[17].

It is particularly noted that Ursula von der Leyen, President of the EU Commission, announced recently, a comprehensive proposal, "ReARM EU", enabling EU countries to increase their defense spending. In addition, the European Commission launched the concepts for a new "Union Strategy on Prepadeness", as a political attempt to foster and unite European leaders towards an common secure strategy. Nevertheless, it remains to collectively understand how to translate the recommendations of Letta(2024), Draghi (2024) and Heitor (2024), mentioned above, for enhancing Europe's research impact into action.

The analysis in this paper is, therefore, geared towards discussing the conditions for stimulating "scientific activism" through doctoral education in close articulation with research and innovation. It will include considering the emergence of new positions on "Research Security" in the US[18] and Europe[19], as well as the analysis of the latest Human Development Report, which includes the slowdown in the promotion of greater equality between and within national states, as well as the unequal impact of Artificial Intelligence on a global scale[20].

The text aims to deepen the debate on the conditions for promoting new ideas on how doctoral education together with the defense and security of populations can be considered together with an inclusive and green transition in the emerging digital era, as well as contributing to eradicating poverty and reducing inequalities at local and global levels. It will necessarily include the debate on energy and environmental security, together with civil protection and public health.

Next section briefly describes main foreseen changes in Europe and section 3 discusses the challenge and the context for a new public financial framework at European level to better promoting doctoral education. Section 4 includes a final summary.

2. A proposal: *Align, Act and Accelerate* Research and Innovation

To address the emerging new complex of uncertainty, we all must consider three main foreseen changes in Europe, all of them strongly influencing doctoral education and research: i) the priority been given to **defense as the main driver of EU competitiveness**; ii) the need to **better engage young generations**, providing better jobs to guarantee a better future for them, together with *Choose Europe* to foster research careers in Europe; and iii) the need to take much more risks by **accepting failures as steps to success**. The following paragraphs briefly describe main implications of each of them.

2.1. The trend in the political debate at EU level is for **giving priority for "Defense as the main driver of EU competitiveness"** and this requires a continuous modernization of doctoral education

This **should be associated with a better articulation of Research and Innovation (R&I) and doctoral education with the challenges Europe is facing**, with increased investments in R&I in a way to foster an increased growth layer of innovative companies.

[16] Ringborg, U. et al. (2024), "Strategies to decrease inequalities in cancer therapeutics/care and prevention - A Conference organized by the Pontifical Academy of Sciences (PAS) and the European Academy of Cancer Sciences (EACS)", Molecular Oncol., doi:10.1002/1878-0261.13575.

[17] https://population.un.org/wpp/.

[18] See Jason (2024) "Safeguarding the Research Enterprise", Jason, May 2024.

[19] https://home-affairs.ec.europa.eu/policies/internal-security/innovation-and-security-research_en#related-documents

[20] https://hdr.undp.org/content/human-development-report-2025.

Doctoral education and R&I are critical to strengthen EU *defense and security*, together with *Prevention, Preparedness and Readiness*, as well as *new solutions to society's climate, nature and biodiversity crisis*. But Europeans, at large, need coherent policies to strengthen supply chains across Europe focusing on high added value product and systems to "**escape the mid tech trap**" identified by the French Nobel laureate Jean Tirole and coworkers[21].

Our analysis suggests six main efforts to accomplish with this vision, as follows:

i. A revised and **strong Framework Program for Research and Innovation** (i.e., FP10 for 2028-2034), with a portfolio of incentives, better articulated with all European Member States and Associated countries (i.e., UK, Nor, Swiss, Canada). It may be included in an overall "Competitiveness fund", but should be governed as a ***self-standing programme*** comprising a "**transformative agenda**" to address **four critical core "spheres" of action**, because of their structural interdependencies and interrelations: i) **Competitive excelence; ii) industrial competitiveness; iii) societal challenges; and iv) EU R&I ecosystem**. The "transformative agenda" should be launched in the short term, through specific actions in the last two years of Horizon Europe, 2025-2027, and embedded in the next EU framework Programme, 2028-2034. Articulation with Member States and Associated countries should be established through a better usage of "**Seals of Excellence**" and this requires radical changes in the operation of national funding agencies of research and innovation;

ii. Focus the Framework Program for Research and Innovation, together with doctoral education, on **high added value product and systems to "escape the mid tech trap"** of Jean Tirole and coworkers. This includes advanced space and IT systems, among others, but it requires a **totally revisited governance model** for the Framework Program, making use of the experience of ERC and EIC through independent governance councils;

iii. Launch and strengthen **public procurement at EU level[22]**, providing a critical vehicle for Europe and Member States to stimulate demand for societally desirable solutions and at the same time promote competitiveness. This must complement and be effectively implemented in parallel to the Framework Program for Research and Innovation to foster "European public purchases" of high added value product and systems (including those oriented for defense industries and security of European populations). Both the Letta Report[23] and the Political Guidelines for the Next Commission[24] point to the importance of making better use of public procurement as a driver of innovation;

iv. A revised **cohesion policy**, together with suport schemes throuhout entire Europe for doctoral education, in complement and in parallel to the Framework Program for Research and Innovation, oriented to build supply chains of the defense and security industries throughout Europe. Requires radical changes in most European regional frameworks, which require continuous monitoring, assessment and review efforts throughout all Europe;

v. Consider doctoral education, together with research and innovation in the Framework Program for Research and Innovation, as well as at national and regional levels, through a **nuanced, granular and revised global cooperation in science and technology**, with specific global partnerships and including actions with US and Chinese institutions, but also India, Brazil, Africa, and the Emirates, oriented to foster R&I strategic partnerships through Europe. It should be clear that the approach of the European Commission over the last decade is leading to an **excessive and costly deterioration in European scientific relations** with countries that are not fully or formally aligned with the European Union's interests or values. When such countries are becoming scientific and strategic markets, Europe cannot afford to adopt a simplistic or black- and white approach. Comparisons between EU-China and EU-US S&T cooperation illustrate our point. While

[21] https://www.econpol.eu/publications/policy_report/eu-innovation-policy-how-to-escape-the-middle-technology-trap.
[22] See, for example, Edler (2019; 2023).
[23] Letta (2024).
[24] Ursula Von der Leyen (2024), "Europe´s Choice".

formal relations between the US and China are fraught with conflict and the rivalry between them, ideologically, militarily and technologically, defines our current era, the two countries continue to cooperate closely academically, and are each other's largest partners in internationally co-authored papers. Thus, **the share of US publications in science and engineering involving a co-author with a Chinese affiliation has grown from 7% in 2004 to 24% in 2022**. In comparison, in the same time period, the share of US publications involving a co-author with a UK affiliation has grown from 13% to 14% (NSF)[25]. Anyway, it is also important to keep in mind the work of Phillip Aghion showing the negative impact of US and CN researchers after the the first Trump administration implemented the "China Shock Initiative", which was meant to "protect US intellectual property and technologies against Chinese Economic Espionage". Their research finds that "Chinese researchers with prior US collaborations reallocated away from US coauthors after the shock and also towards more basic research"[26];

vi. Consider doctoral education, together with the Framework Program for Research and Innovation a **revisited approach to research security**, making use of a "project by project scheme", avoiding "blind" measures and overalll top-down procedures.

In the discussion of these recommendations, it should be clear that "**dual use occurs naturally given the ubiquitous nature of modern technology** (e.g., AI, material science, the internet, drones) and the broad needs of a modern military (e.g., health, fitness)[27]. Instead, the European Commission and national agencies should administer programmes as "military RD&I" and "everything else" (i.e., civilian, dual use) and **optimize the innovation dividend** arising from the need for increased national security and defense expenditure by **exploiting dual use both ways"[28]**. See, for example, the recent EC´s Joint Research Council report o**n effective "Defense Research and Innovation Ecosystem"** (i.e., EDRA – European Defense and Research Area[29]).

Following the Nobel laureate Richard Feynman[30], the radical difference between "body of knowledge" derived from science, and the "application of that body of knowledge" requires an better undertsaniong by European citizens, at alrge, and this clearly requires the continuous effort to **foster scienctific culture** throuhghout Europe.

2.2. **Engage young generations**, modernizing doctoral education and providing **better jobs to guarantee a better future for them**.

This is critically relevant at a generational and political levels with impact for all Europeans to face the rise of "populist" movements in Europe (and the world, as particularly stimulated by the new US administration and the Russian autocrats), including the support of many young adults. In addition, there is an opportunity for Europe to invest more on young generations, including for doctoral education, and **to turn the current "European Brain drain to the US" into an "European Brain gain".** Figure 1 shows that during the period from 2001 to 2010, some member states including Germany, France, Sweden, the Netherlands, Belgium, and Finland experienced significant brain drain, mostly to

[25] https://www.nsf.gov/nsb/publications/2024/changedlandscape.pdf.

[26] See details at https://www.college-de-france.fr/sites/default/files/media/document/2024-03/Does%20Chinese%20Research%20Hinge%20on%20US%20Coauthors.%20Evidence%20from%20the%20China%20Initiative.pdf.

[27] See the Align, Act, Accelerate Report, Recommendation 12, https://op.europa.eu/en/publication-detail/-/publication/2f9fc221-86bb-11ef-a67d-01aa75ed71a1/language-en

[28] For example, US DARPA have and continue to fund significant health research, including in breast cancer, regenerative medicine ,vaccines and diagnostic tests, among many other areas.

[29] See European Commission: Joint Research Centre, SCHWAAG-SERGER, S., SOETE, L. and STIERNA, J., Scientific Report - For an Innovative, Sustainable and Fair Economy in Europe, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/0336180, JRC140513 https://publications.jrc.ec.europa.eu/repository/handle/JRC140513

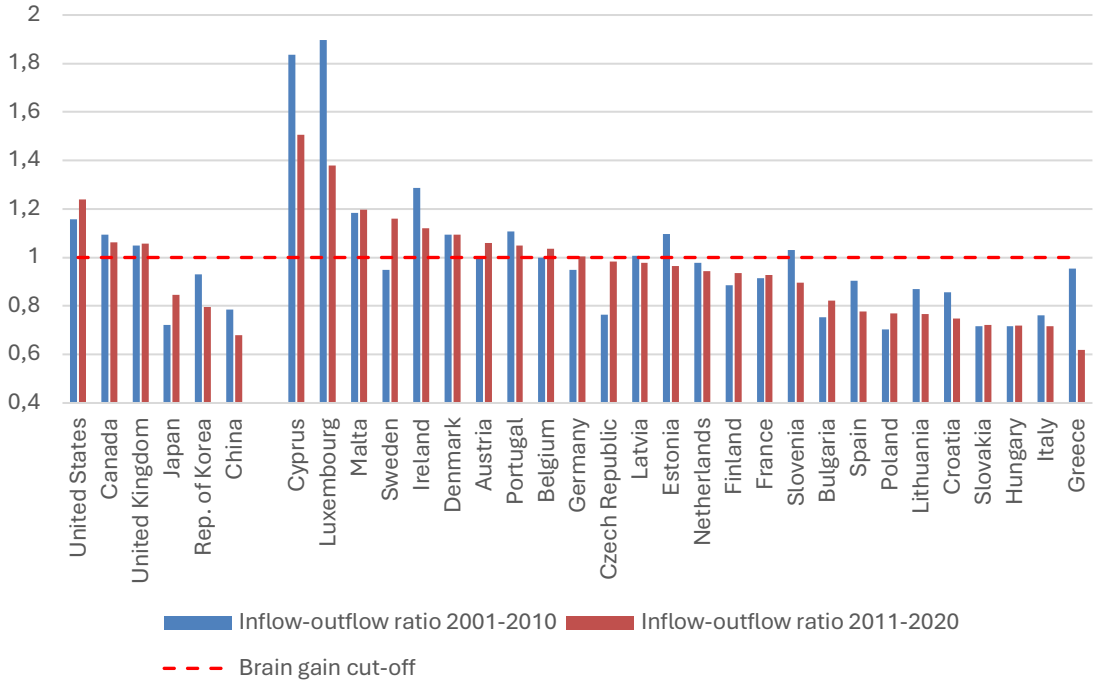
[30] See Feynman , R. (1998), "The Meaning of it All: Thoughts of a Citizen-Scientist".

the USA or UK. In the subsequent decade from 2011 to 2020, Sweden, Belgium and Germany have improved.

It requires continuously modernizing doctoral education and increasing significantly the interaction between Academia, Research and Technology Organizations (i.e., RTOs) and enterprises, stimulating the exchanges among successive generations. It should consider launching **"Choose Europe",** as a "pilot program" already in 2025-27, making use of the existing MSCA- Marie Skolowsky Curie Actions cofund mechanisms to attract young talent researchers for European public and private institutions, through **better research careers**. The recent CESAER survey on Research Careers is very clear in this regard[31]. There is an urgent need to more intensively involve younger generations in research and innovation through better research careers. Educational institutions can play a significant role in educating them at all levels about the history and importance of democratic norms and values.

Figure 1: Brain drain trends for EU member states and across the world, 2001-2020

Note: The figure below documents **European brain drain**, through countries' brain drain in relative terms. A value below 1 implies that more researchers are leaving the country than entering it. While a value above 1 implies that the country has more researchers entering than leaving



Source: DG Research and Innovation – Common R&I Strategy and Foresight Service – Chief Economist Unit based on Science Metrix using Scopus database

It should be noted that the ***European brain drain*** quantified in the figure is **occurring at the same time as an increase of the number of researchers in Europe**. There were 2.08 million researchers (in Full Time Equivalents - FTE) employed in the EU in 2022, which marked an increase of 648 000 when compared with 2012. They represent **about 2 % of the European labour force**. The number of researchers (FTE) significantly increased in Portugal and more than doubled in Poland, Sweden and Greece between 2012 and 2022. Most researchers (57%) are employed in the business sector, about one third of them (32%) in the academic sector, and 10% in the government sector. For comparison,

[31] See https://www.cesaer.org/news/research-careers-a-critical-choice-for-europe-1850/.

in 2021, South Korea had the largest number of scientists and researchers per 1,000 FTE's, with 17.3 people working in research or science field per 1,000 employees. Sweden was second , with 16.6. The European average was 9.4 .

However, the growth in the number of researchers in Europe has **not** been matched by an increase in the **quality of research jobs** and this has also **driven brain drain**. The need to address the **precarity many researchers now face** was explicitly addressed in the European Council conclusions of May 2021[32] on research careers and in the 'Pact for Research and Innovation' agreed in November 2021. The **Manifesto on early research careers**, published in September 2022 by the *Initiative for Science in Europe*, calls for urgent action[33].

Analysis shows the need "to add to the current portfolio of excellent MSCA and ERC programmes by establishing a new ***Choose Europe*** instrument specifically focused on **outstanding young researchers** in, or following, their first postdoctoral position to enable them to rapidly become independent researchers. We believe that by **giving outstanding young researchers an early opportunity** to pursue their creative ideas, Europe will be internationally attractive and benefit from their presence and results".

Two research projects and consortia funded by the European Commission provide evidence on the evolving situation in Europe[34], underlining the **need for better data and for monitoring the quality of research careers**. Analysis has shown that the EU relies on an **unacceptable coupling between "project funding" and "contractual schemes"**, exacerbating precarity for young researchers and leading to diffuse (or even lack of) responsibility, at individual and institutional levels[35].

2.3. **Take much more risks by accepting failures as steps to success in doctoral education and research**.

We are facing a fast rate of technical change that requires **MUCH more disruptive innovation together with frontier research**. And this is absolutely **critical at the level of doctoral education**.

We certainly need to build on the experience of the European Research Council (ERC, since 2007) and the European Innovation Council (EIC, since 2021), together with strong "mission oriented collaborative research", BUT **experiment new ways to assess and fund R&D, with decreased time to funding, decreased transaction costs, and increased risks**.

And the action should start by creating an "**Experimental Unit**" under EIC[36]. **This must include:**

i. **assess, compare, experient and foster new initiatives**, including for doctoral education and research, such as SPRIND in Germany and ARIA in UK, use advanced information systems and test new methods as those being experimented by many private foundations[37];
ii. **increase public expenditure on biomedical research and innovation, together with doctoral education,** to counter balance the large increase in private expenditure and the resulting very high price of pharmaceutical;

[32] https://www.consilium.europa.eu/en/press/press-releases/2021/05/28/improving-conditions-for-research-careers-in-europe-council-adopts-conclusions/

[33] https://initiative-se.eu/2022/09/25/press-release-a-manifesto-for-early-career-researchers/

[34] See details in RISIS, https://www.risis2.eu/2023/05/22/monitoring-and-analyzing-research-careers-for-informed-policy-making-in-the-era/; and SECURE, https://secureproject.eu/.

[35] See details in Science Europe (2016).

[36] https://op.europa.eu/en/publication-detail/-/publication/2f9fc221-86bb-11ef-a67d-01aa75ed71a1/language-en

[37] See details in the Align, Act, Accelerate Report, Recommendation 4, https://op.europa.eu/en/publication-detail/-/publication/2f9fc221-86bb-11ef-a67d-01aa75ed71a1/language-en.

iii. guarantee **more private expenditure with cofund mechanisms** in many other areas , including for greening of industry, together with new ways to guarantee food security at global level;
iv. **promote technology monitoring**, by promoting related **new tools and actors**, as well as strongly engaging the private sector in doctoral education.

3. The challenge: *the context for a new public financial framework*

The three foreseen changes described above require a better understanding that EU can effectively act under threats, as demonstrated during the COVID-19 crisis, and use lessons learned from that period to develop again major financial instruments.

Still, and despite efforts and incremental improvements, **Europe exhibits an innovation deficit** when compared to the US and China, especially in critical and complex technologies. Turning research outcomes into business opportunities and the scaling up of innovative companies remains a challenge, with radical impact on doctoral education and research in Europe.

Our analysis clearly suggest that the need to spur public investment Europe will requires a new and revisited approach to ***need new European own resources***. To better understand the significance for Europeans, at large, to increase the research, development and innovation (RD&I) expenditure in Europe, analysis must follows OECD and Eurostat well established methodologies over the last 60 years, under which **research expenditure is mainly characterized by human resources related expenditures**, which account for about 90% of total expenditure[38]. Therefore, increasing the expenditure in RD&I in most European Member States and regions in the next decade is associated with attracting and retaining adequate concentrations of doctorate researchers, together with **three other critical issues**: i) Adequacy of **salary levels** throughout the labour force; ii) Modernizing **research careers**; and iii) Considerable expansion, structuring and modernization of **technical careers supporting RD&I activities** (i.e., S&T technicians and programme managers).

The **growth in the number of researchers** in many European Member States in recent decades occurs associated with a **relatively low expenditure per researcher** in many European Member States. For example, Slovenia and Portugal exhibit some of the highest growth rates in the number of researchers, reaching about 11 per thousand inhabitants in 2021 and similar to the concentration of researchers in Germany and Austria. But the disparity in salary levels and support staff leads to large differences in the levels of funding per researcher among those Member States.

European Member States with the lowest RD&I expenditure per researcher are characterized by only one technician for every 4 to 5 researchers in 2022, Figure 2. This ratio is particularly low compared with the 1 technician for every 1.7 researchers in Germany and around 1 technician for every researcher in the US. The **lack of technical careers** over the last few decades in many MS and, above all, the **relative absence of research management careers** in many widening countries, has resulted in a growing inequality in professional support for research and innovation activities, with important consequences in terms of the intensity of expenditure per researcher.

It should be noted that, unlike in the US, where debt and procurement have been managed more flexibly over last decades, **European investments in research and innovation have been hindered by stringent financial regulations**. Moreover, **funding is fragmented**; about 90% is nationally sourced, with only 10% coming from European sources. In addition, while the US mobilizes 2.4% of its GDP for private financing of research and innovation initiatives, the EU manages only 1.2%. This had given a significant advantage to *American Ivy League universities* and tech companies. However, there is the

[38] See details in the OECD's Frascati Manual, the internationally recognised methodology for collecting and using R&D statistics since 1964, with its sixth revision in 2015, as in https://www.oecd.org/en/publications/2015/10/frascati-manual-2015_g1g57dcb.html.

need to carefully assess the situation across different knowledge areas and, for example, we all need to better understand notable exceptions and the need to better balance private and public expenditure in R&D. For example, the situation in biomedical research (e.g., in "cancer pharmaceuticals" and other "non-curable diseases"), where the dominance of business expenditure in R&D have been implemented with unacceptable high prices for cancer pharmaceuticals, together with and increasingly high inequalities in the access to those pharma.

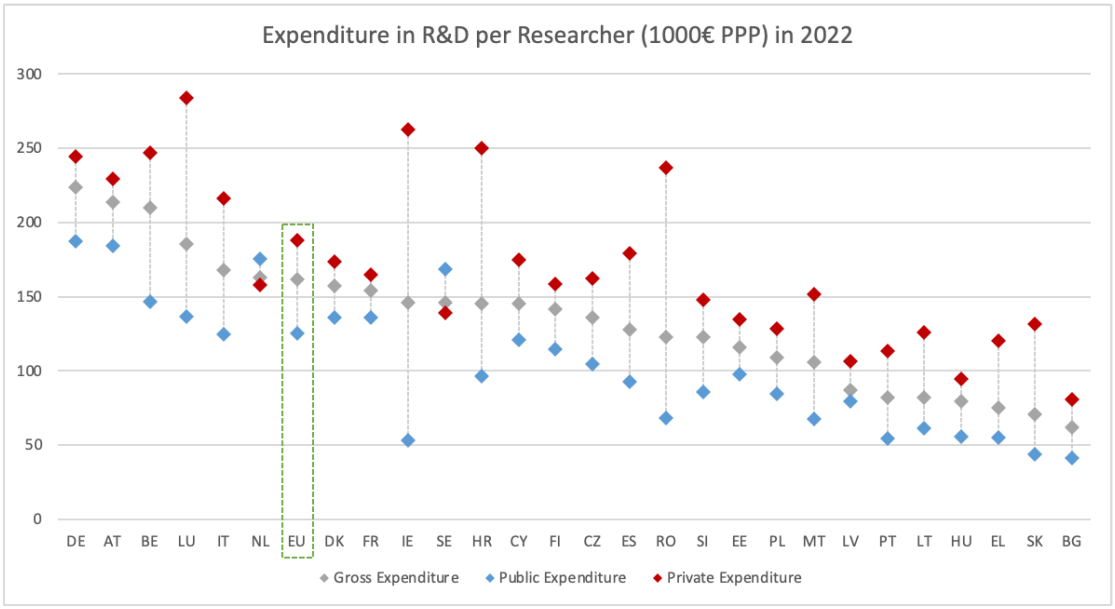


Figure 2. **R&D expenditure per Researcher** in European member states in 2022 (PPP per researcher, corrected to 2005 prices); Source: Eurostat (Data available in December 29, 2023)

4. Summary

Doctoral education in Europe must evolve in close articulation with research and innovation and in terms of emerging requirements to accelerate our collective response to geopolitical threats, boost innovation in defence and security, and rethink our understanding of "science for policy" in times of knowledge abundance.

Europeans, at large, are facing a fast *pace of technological change*, in times of *abundance of knowledge* at a global level, together with the rise of Chinese science. New and enlarged funding schemes, together with an continuously evolving doctoral education and research and new funding instruments are essential, inspired by models such as Germany's SPRIN-D and the UK's ARIA. Strengthening the *European Research Council* and establishing an Experimental Unit under the *European Innovation Council* could assess and test novel funding mechanisms, many already piloted by private foundations. It could also help attract more private investment through co-funding, especially in areas like industrial greening and food security. Additionally, it should develop effective tools for technology monitoring – a crucial capacity in times of rapid transformation – with strong private sector involvement. The aim is not to replace existing structures, but to complement them with agile, risk-tolerant approaches.

Doctoral education in Europe, together with research and innovation, must facilitate to escape the "mid-tech trap" by prioritizing collaborative research and innovation towards **high added-value technologies** such as AI, space systems, advanced materials, quantum and robotics.

Strengthening and continuolsly modernizing doctoral education in close articulation with *Research and Innovation* is absolutely required for a **stronger Europe.** It must consider an increased growth

layer of innovative companies and RTOs making use of advanced ideas to strengthen EU defense and security, together with *Prevention, Preparedness and Readiness,* as well as new solutions to society's climate, nature and biodiversity crisis. This requires considering doctoral education together with an *European Research Alliance on Civilian Prevention, Preparedness and Readiness through Citizen Engagement*. But, above all, this needs new sources of financing and it is clear that "national budgets alone cannot bear the brunt of it. Therefore we must build on the experience of *NextGenerationEU* and **guarantee new European *own resources*** by taking debt and accessing to capital markets.

Overall **opportunities are enormous for *"research intensive" doctoral education.***

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